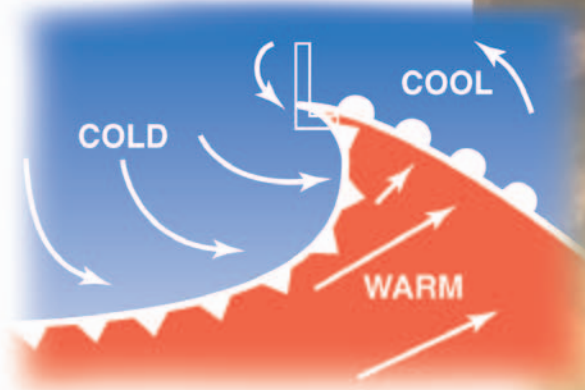


## Chapter 10



# Weather Theory

Whether preparing for a local flight or a long cross-country, flight-planning decisions based on weather can dramatically affect the safety of the flight. A solid understanding of weather theory provides the tools necessary to understand the reports and forecasts obtained from a Flight Service Station weather specialist and other aviation weather services.

This chapter is designed to help pilots acquire the background knowledge of weather principles necessary to develop sound decision making skills relating to weather. It is important to note, however, that there is no substitute for experience.

### NATURE OF THE ATMOSPHERE

The atmosphere is a mixture of gases that surround the Earth. This blanket of gases provides protection from ultraviolet rays as well as supporting human, animal, and plant life on the planet. Nitrogen accounts for 78 percent of the gases that comprise the atmosphere, while oxygen makes up 21 percent. Argon, carbon dioxide, and traces of other gases make up the remaining 1 percent. [Figure 10-1]

Within this envelope of gases, there are several recognizable layers of the atmosphere that are defined not only by altitude, but also by the specific characteristics of that level. [Figure 10-2]

The first layer, known as the **troposphere**, extends from sea level up to 20,000 feet (8 km) over the northern and southern poles and up to 48,000 feet (14.5 km) over the equatorial regions. The vast majority of weather, clouds, storms, and temperature variances

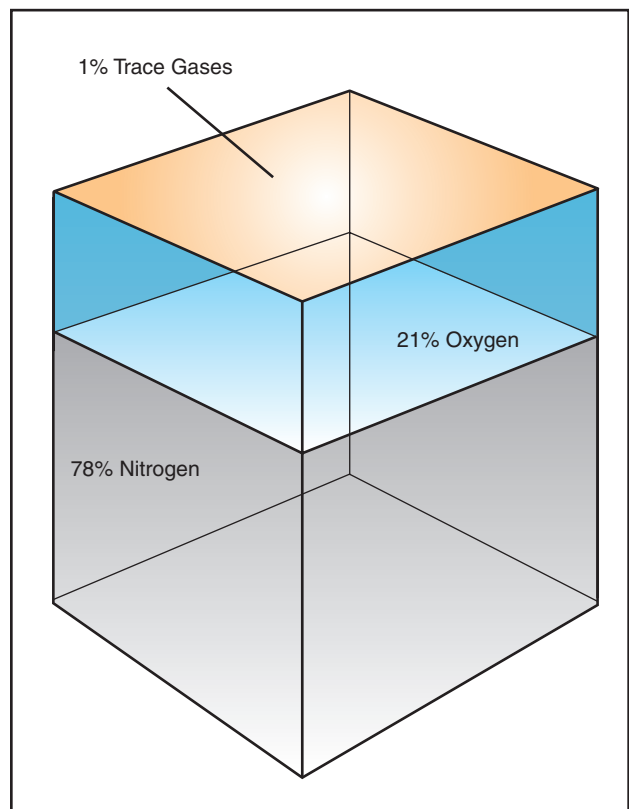


Figure 10-1. Composition of the atmosphere.

**Troposphere**—The layer of the atmosphere extending from the surface to a height of 20,000 to 60,000 feet depending on latitude.

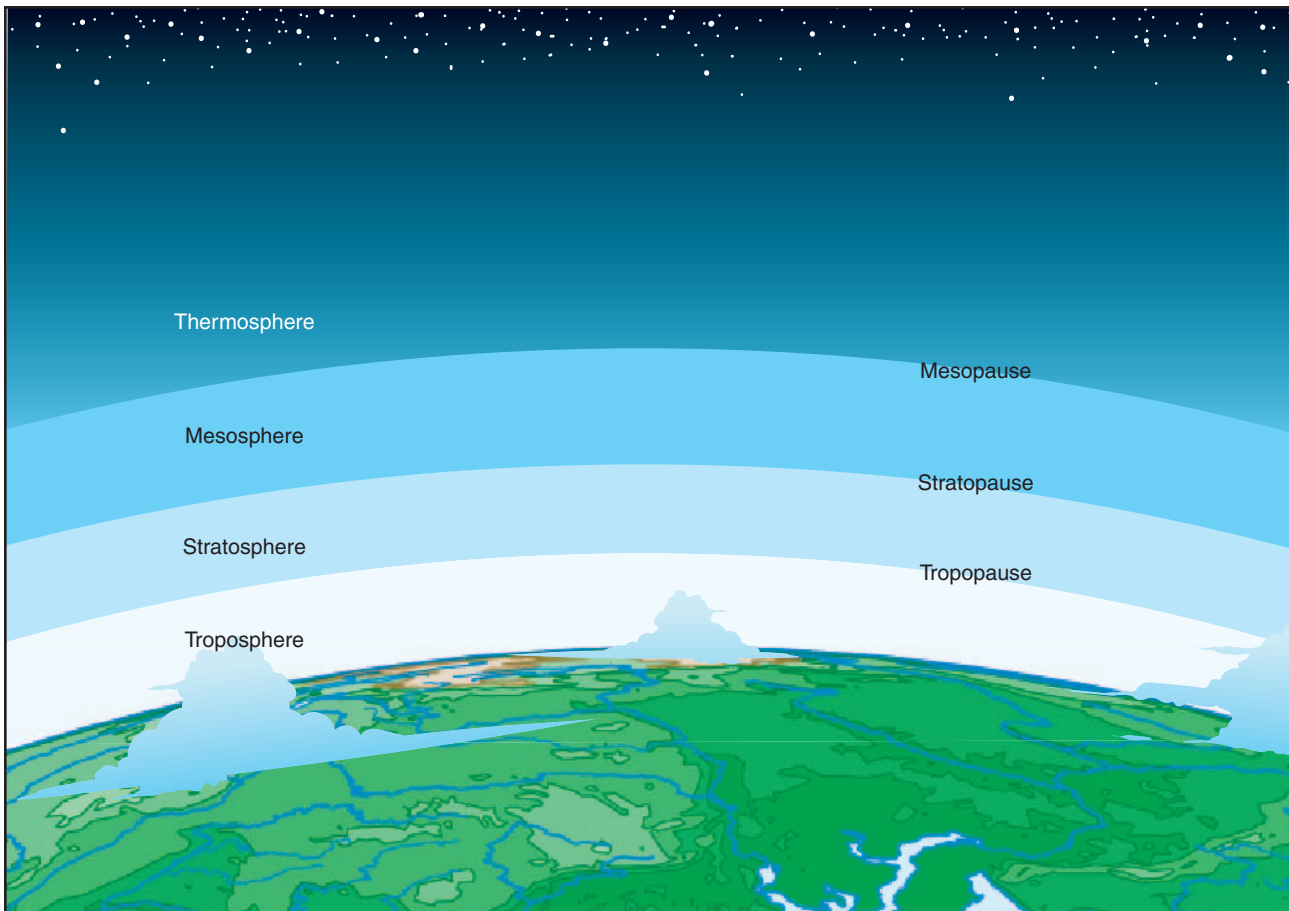


Figure 10-2. Layers of the atmosphere.

occur within this first layer of the atmosphere. Inside the troposphere, the temperature decreases at a rate of about  $2^{\circ}$  Celsius every 1,000 feet of altitude gain, and the pressure decreases at a rate of about 1 inch per 1,000 feet of altitude gain. At the top of the troposphere is a boundary known as the **tropopause**, which traps moisture, and the associated weather, in the troposphere. The altitude of the tropopause varies with latitude and with the season of the year; therefore, it takes on an elliptical shape, as opposed to round. Location of the tropopause is important because it is commonly associated with the location of the **jetstream** and possible clear air turbulence.

The atmospheric level above the tropopause is the **stratosphere**, which extends from the tropopause to a height of about 160,000 feet (50 km). Little weather exists in this layer and the air remains stable. At the top of the stratosphere is another boundary known as the stratopause, which exists at approximately 160,000 feet. Directly above this is the **mesosphere**, which extends to the mesopause boundary at about 280,000 feet (85 km). The temperature in the mesosphere decreases rapidly with an increase in altitude and can be as cold as  $-90^{\circ}\text{C}$ . The last layer of the atmosphere is the **thermosphere**. It starts above the mesosphere and gradually fades into outer space.

## OXYGEN AND THE HUMAN BODY

As discussed earlier, nitrogen and other trace gases make up 79 percent of the atmosphere, while the remaining 21 percent is life sustaining, atmospheric oxygen. At sea level, atmospheric pressure is great enough to support normal growth, activity, and life. At 18,000 feet, however, the partial pressure of oxygen is significantly reduced to the point that it adversely affects the normal activities and functioning of the human body. In fact, the reactions of the average person begin to be impaired at an altitude of about 10,000 feet and for some people as low as 5,000 feet. The physiological reactions to oxygen deprivation are insidious and affect people in different ways. These symptoms range from mild disorientation to total incapacitation, depending on body tolerance and altitude.

**Tropopause**—The boundary between the troposphere and the stratosphere which acts as a lid to confine most of the water vapor, and the associated weather, to the troposphere.

**Jetstream**—A narrow band of wind with speeds of 100 to 200 m.p.h. usually associated with the tropopause.

**Stratosphere**—A layer of the atmosphere above the tropopause extending to a height of approximately 160,000 feet.

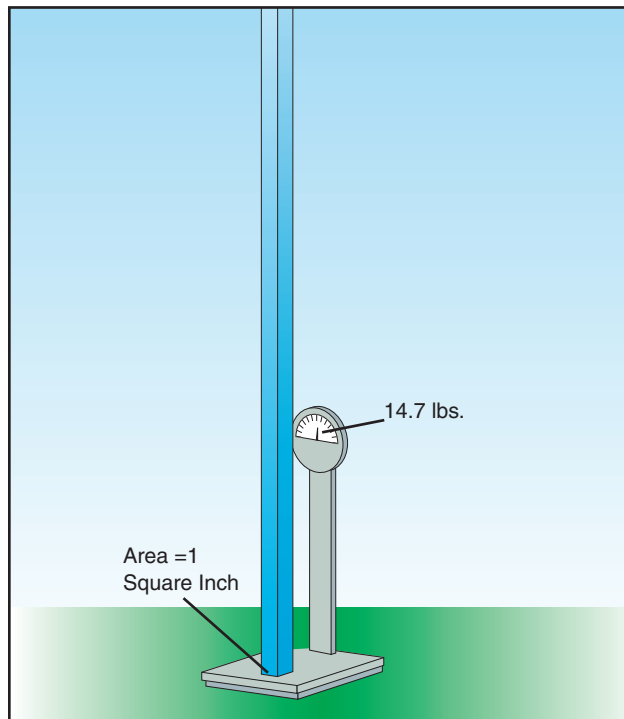
**Mesosphere**—A layer of the atmosphere directly above the stratosphere.

**Thermosphere**—The last layer of the atmosphere that begins above the mesosphere and gradually fades away into space.

By using supplemental oxygen or cabin pressurization systems, pilots can fly at higher altitudes and overcome the ill effects of oxygen deprivation.

### SIGNIFICANCE OF ATMOSPHERIC PRESSURE

At sea level, the atmosphere exerts pressure on the Earth at a force of 14.7 pounds per square inch. This means a column of air 1-inch square, extending from the surface up to the upper atmospheric limit, weighs about 14.7 pounds. [Figure 10-3] A person standing at sea level also experiences the pressure of the atmosphere; however, the pressure is not a downward force, but rather a force of pressure over the entire surface of the skin.

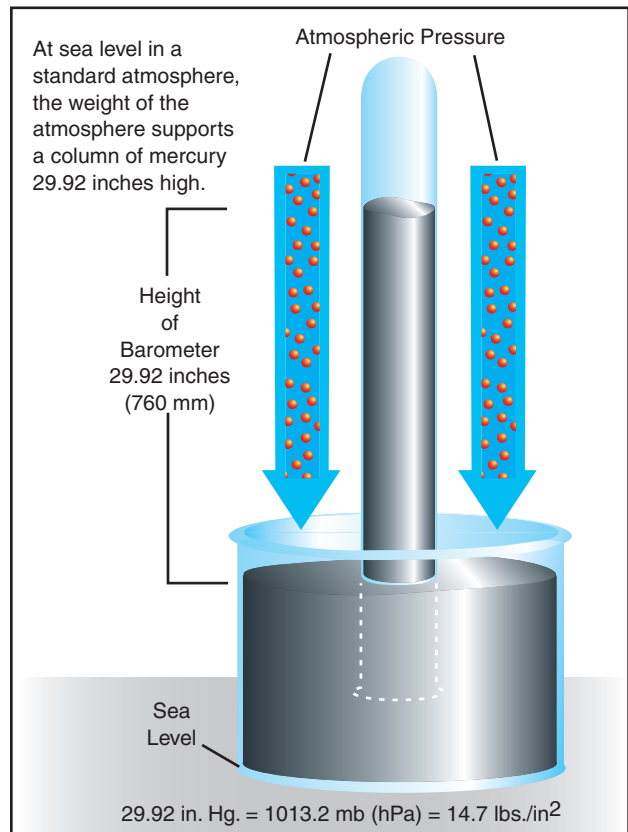


**Figure 10-3. One square inch of atmosphere weighs approximately 14.7 pounds.**

The actual pressure at a given place and time will differ with altitude, temperature, and density of the air. These conditions also affect aircraft performance, especially with regard to takeoff, rate of climb, and landings.

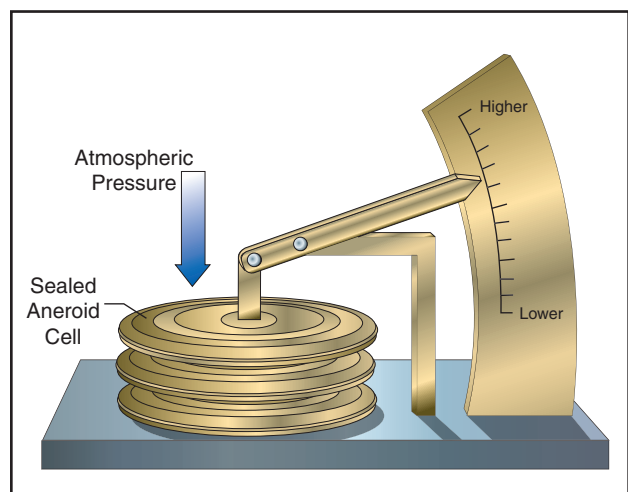
### MEASUREMENT OF ATMOSPHERIC PRESSURE

Atmospheric pressure is typically measured in inches of mercury (in. Hg.) by a mercurial barometer. [Figure 10-4] The barometer measures the height of a column of mercury inside a glass tube. A section of the mercury is exposed to the pressure of the atmosphere, which exerts a force on the mercury. An increase in pressure forces the mercury to rise inside the tube; as pressure drops, mercury drains out of the tube, decreasing the height of the column. This type of barometer is typically used in a lab or weather observation station, is not easily transported, and is a bit difficult to read.

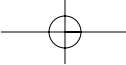


**Figure 10-4. Mercurial barometer.**

An aneroid barometer is an alternative to a mercurial barometer; it is easier to read and transport. [Figure 10-5] The aneroid barometer contains a closed vessel, called an aneroid cell, that contracts or expands with changes in pressure. The aneroid cell attaches to a pressure indicator with a mechanical linkage to provide pressure readings. The pressure sensing part of an aircraft altimeter is essentially an aneroid barometer. It is important to note that due to the linkage mechanism of an aneroid barometer, it is not as accurate as a mercurial barometer.



**Figure 10-5. Aneroid barometer.**



To provide a common reference for temperature and pressure the International Standard Atmosphere (ISA) has been established. These standard conditions are the basis for certain flight instruments and most airplane performance data. Standard sea level pressure is defined as 29.92 in. Hg. at 59°F (15°C). Atmospheric pressure is also reported in millibars, with 1 inch of mercury equaling approximately 34 millibars and standard sea level equaling 1013.2 millibars. Typical millibar pressure readings range from 950.0 to 1040.0 millibars. Constant pressure charts and hurricane pressure reports are written using millibars.

Since weather stations are located around the globe, all local barometric pressure readings are converted to a sea level pressure to provide a standard for records and reports. To achieve this, each station converts its barometric pressure by adding approximately 1 inch of mercury for every 1,000 feet of elevation gain. For example, a station at 5,000 feet above sea level, with a reading of 24.92 inches of mercury, reports a sea level pressure reading of 29.92 inches. [Figure 10-6] Using common sea level pressure readings helps ensure aircraft altimeters are set correctly, based on the current pressure readings.

By tracking barometric pressure trends across a large area, weather forecasters can more accurately predict movement of pressure systems and the associated weather. For example, tracking a pattern of rising pressure at a single weather station generally indicates the approach of fair weather. Conversely, decreasing or rapidly falling pressure usually indicates approaching bad weather and possibly, severe storms.

## EFFECT OF ALTITUDE ON ATMOSPHERIC PRESSURE

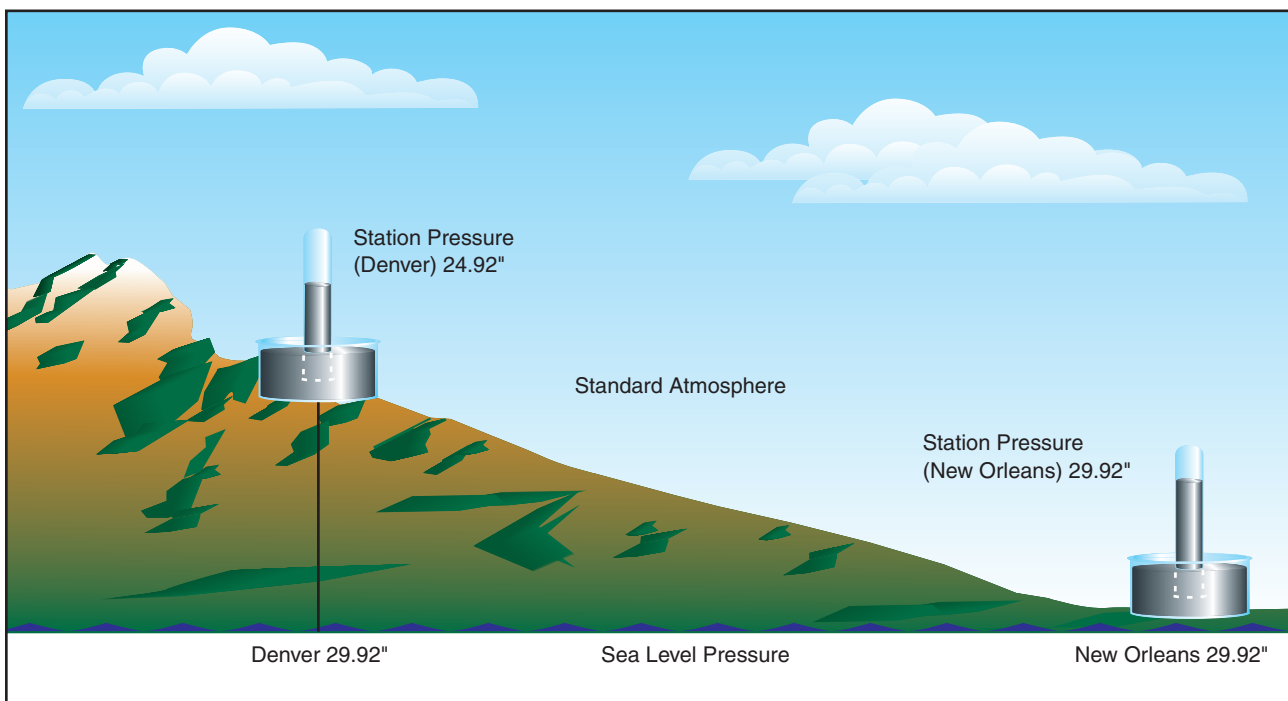
As altitude increases, pressure diminishes, as the weight of the air column decreases. On average, with every 1,000 feet of altitude increase, the atmospheric pressure decreases 1 inch of mercury. This decrease in pressure (increase in density altitude) has a pronounced effect on aircraft performance.

## EFFECT OF ALTITUDE ON FLIGHT

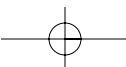
Altitude affects every aspect of flight from aircraft performance to human performance. At higher altitudes, with a decreased atmospheric pressure, takeoff and landing distances are increased, as are climb rates.

When an aircraft takes off, lift must be developed by the flow of air around the wings. If the air is thin, more speed is required to obtain enough lift for takeoff; therefore, the ground run is longer. An aircraft that requires a 1,000-foot ground run at sea level will require almost double that at an airport 5,000 feet above sea level [Figure 10-7]. It is also true that at higher altitudes, due to the decreased density of the air, aircraft engines and propellers are less efficient. This leads to reduced rates of climb and a greater ground run for obstacle clearance.

**ISA—International Standard Atmosphere: Standard atmospheric conditions consisting of a temperature of 59°F (15°C), and a barometric pressure of 29.92 in. Hg. (1013.2 mb) at sea level. ISA values can be calculated for various altitudes using standard lapse rate.**



**Figure 10-6.** Station pressure is converted to, and reported in, sea level pressure.



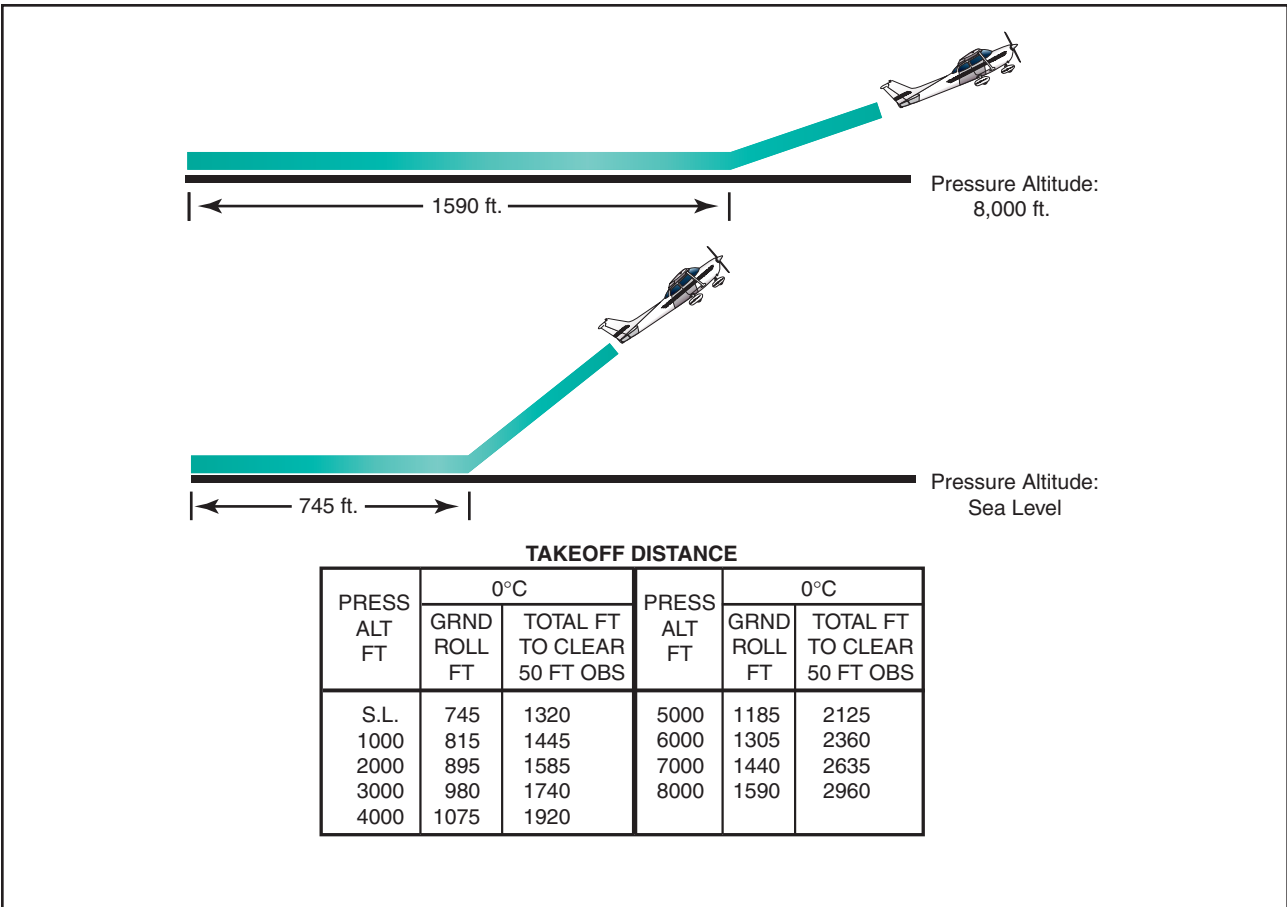
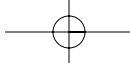


Figure 10-7. Takeoff distance increases with increased altitude.

**EFFECT OF DIFFERENCES IN AIR DENSITY**

Differences in air density caused by changes in temperature result in changes in pressure. This, in turn, creates motion in the atmosphere, both vertically and horizontally, in the form of currents and wind. Motion in the atmosphere, combined with moisture, produces clouds and precipitation otherwise known as weather.

**WIND**

Pressure and temperature changes produce two kinds of motion in the atmosphere—vertical movement of ascending and descending currents, and horizontal movement in the form of wind. Both types of motion in the atmosphere are important as they affect the takeoff, landing, and cruise flight operations. More important, however, is that these motions in the atmosphere, otherwise called atmospheric circulation, cause weather changes.

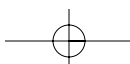
**THE CAUSE OF ATMOSPHERIC CIRCULATION**

Atmospheric circulation is the movement of air around the surface of the Earth. It is caused by uneven heating of the Earth’s surface and upsets the equilibrium of the atmosphere, creating changes in air movement and atmospheric pressure. Because the Earth has a curved

surface that rotates on a tilted axis while orbiting the sun, the equatorial regions of the Earth receive a greater amount of heat from the sun than the polar regions. The amount of sun that heats the Earth depends upon the time of day, time of year, and the latitude of the specific region. All of these factors affect the length of time and the angle at which sunlight strikes the surface.

In general circulation theory, areas of low pressure exist over the equatorial regions, and areas of high pressure exist over the polar regions due to a difference in temperature. Solar heating causes air to become less dense and rise in equatorial areas. The resulting low pressure allows the high-pressure air at the poles to flow along the planet’s surface toward the equator. As the warm air flows toward the poles, it cools, becoming more dense, and sinks back toward the surface. [Figure 10-8] This pattern of air circulation is correct in theory; however, the circulation of air is modified by several forces, most importantly the rotation of the Earth.

The force created by the rotation of the Earth is known as Coriolis force. This force is not perceptible to us as we walk around because we move so slowly and travel relatively short distances compared to the size and rotation rate of the Earth. However, it does significantly affect bodies that move over great distances, such as an





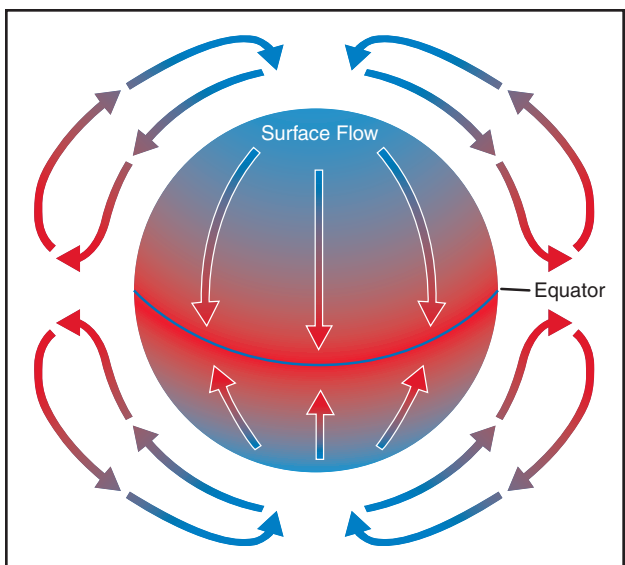


Figure 10-8. Circulation pattern in a static environment.

air mass or body of water. The Coriolis force deflects air to the right in the Northern Hemisphere, causing it to follow a curved path instead of a straight line. The amount of deflection differs depending on the latitude. It is greatest at the poles, and diminishes to zero at the equator. The magnitude of Coriolis force also differs with the speed of the moving body—the faster the speed, the greater the deviation. In the Northern Hemisphere, the rotation of the Earth deflects moving air to the right and changes the general circulation pattern of the air.

The speed of the Earth's rotation causes the general flow to break up into three distinct cells in each hemisphere. [Figure 10-9] In the Northern Hemisphere, the warm air at the equator rises upward from the surface, travels northward, and is deflected eastward by the rotation of the Earth. By the time it has traveled one-third of the distance from the equator to the North Pole, it is no longer moving northward, but eastward. This air cools and sinks in a belt-like area at about 30° latitude, creating an area of high pressure as it sinks toward the surface. Then it flows southward along the surface back toward the equator. Coriolis force bends the flow to the right, thus creating the northeasterly trade winds that prevail from 30° latitude to the equator. Similar forces create circulation cells that encircle the Earth between 30° and 60° latitude, and between 60° and the poles. This circulation pattern results in the prevailing westerly winds in the conterminous United States.

Circulation patterns are further complicated by seasonal changes, differences between the surfaces of continents and oceans, and other factors.

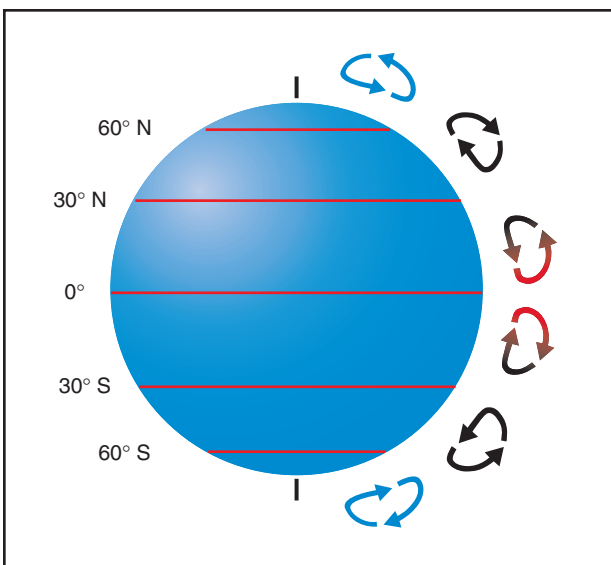


Figure 10-9. Three-cell circulation pattern due to the rotation of the Earth.

Frictional forces caused by the topography of the Earth's surface modify the movement of the air in the atmosphere. Within 2,000 feet of the ground, the friction between the surface and the atmosphere slows the moving air. The wind is diverted from its path because the frictional force reduces the Coriolis force. This is why the wind direction at the surface varies somewhat from the wind direction just a few thousand feet above the Earth.

## WIND PATTERNS

Air flows from areas of high pressure into those of low pressure because air always seeks out lower pressure. In the Northern Hemisphere, this flow of air from areas of high to low pressure is deflected to the right; producing a clockwise circulation around an area of high pressure. This is also known as anti-cyclonic circulation. The opposite is true of low-pressure areas; the air flows toward a low and is deflected to create a counter-clockwise or cyclonic circulation. [Figure 10-10]

High-pressure systems are generally areas of dry, stable, descending air. Good weather is typically associated with high-pressure systems for this reason. Conversely, air flows into a low-pressure area to replace rising air. This air tends to be unstable, and usually brings increasing cloudiness and precipitation. Thus, bad weather is commonly associated with areas of low pressure.

A good understanding of high- and low-pressure wind patterns can be of great help when planning a flight, because a pilot can take advantage of beneficial tailwinds. [Figure 10-11] When planning a flight from west to east, favorable winds would be encountered

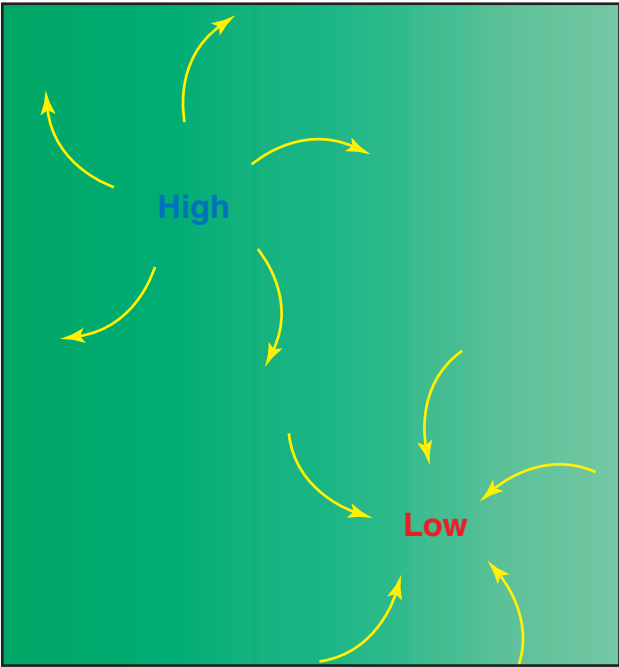


Figure 10-10. Circulation pattern about areas of high and low pressure.

along the northern side of a high-pressure system or the southern side of a low-pressure system. On the return flight, the most favorable winds would be along the southern side of the same high-pressure system or the northern side of a low-pressure system. An added advantage is a better understanding of what type of weather to expect in a given area along a route of flight based on the prevailing areas of highs and lows.

The theory of circulation and wind patterns is accurate for large-scale atmospheric circulation; however, it does not take into account changes to the circulation on a local scale. Local conditions, geological features, and other anomalies can change the wind direction and speed close to the Earth's surface.

## CONVECTIVE CURRENTS

Different surfaces radiate heat in varying amounts. Plowed ground, rocks, sand, and barren land give off a large amount of heat; water, trees, and other areas of vegetation tend to absorb and retain heat. The resulting uneven heating of the air creates small areas of local circulation called convective currents.

Convective currents cause the bumpy, turbulent air sometimes experienced when flying at lower altitudes during warmer weather. On a low altitude flight over varying surfaces, updrafts are likely to occur over pavement or barren places, and downdrafts often occur over water or expansive areas of vegetation like a group of trees. Typically, these turbulent conditions can be avoided by flying at higher altitudes, even above cumulus cloud layers. [Figure 10-12]

Convective currents are particularly noticeable in areas with a landmass directly adjacent to a large body of water, such as an ocean, large lake, or other appreciable area of water. During the day, land heats faster than water, so the air over the land becomes warmer and less dense. It rises and is replaced by cooler, denser air flowing in from over the water. This causes an onshore wind, called a **sea breeze**. Conversely, at night land cools faster than water, as does the corresponding air. In this case, the warmer air over the water rises and is replaced by the cooler, denser air from the land, creating an offshore wind called a **land breeze**. This reverses the local wind circulation pattern. Convective currents can occur anywhere there is an uneven heating of the Earth's surface. [Figure 10-13]

**Sea Breeze**—A coastal breeze blowing from sea to land caused by the temperature difference when the land surface is warmer than the sea surface. The sea breeze usually occurs during the day.

**Land Breeze**—A coastal breeze flowing from land to sea caused by the temperature difference when the sea surface is warmer than the adjacent land. The land breeze usually occurs at night.

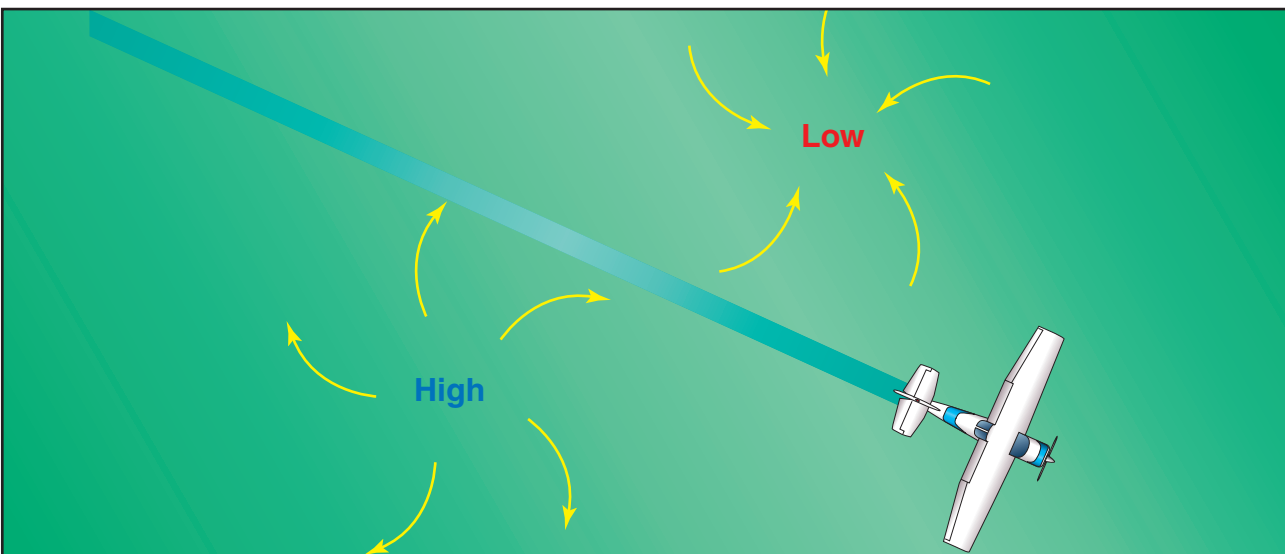


Figure 10-11. Favorable winds near a high-pressure system.

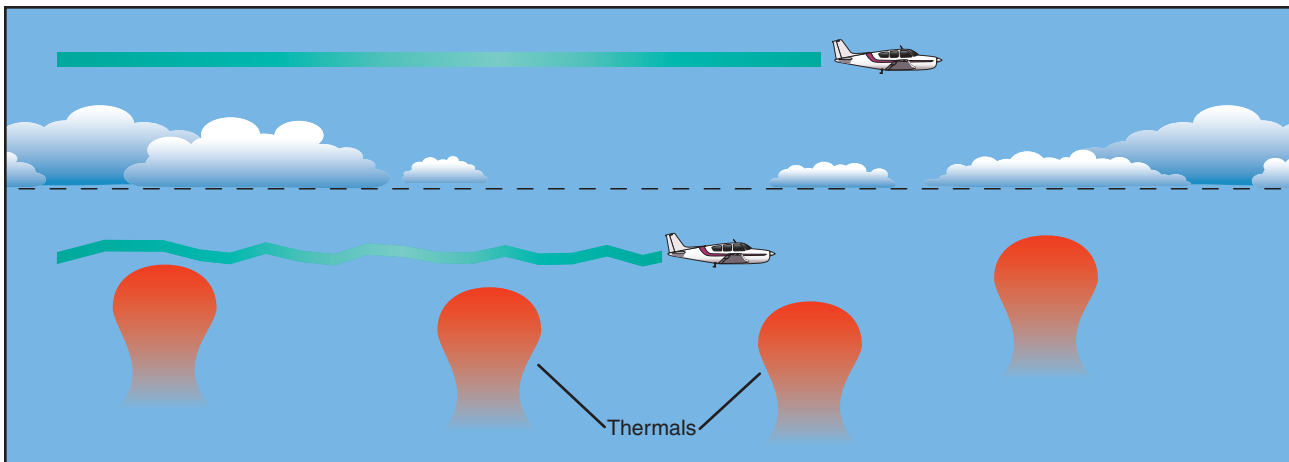
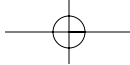


Figure 10-12. Convective turbulence avoidance.

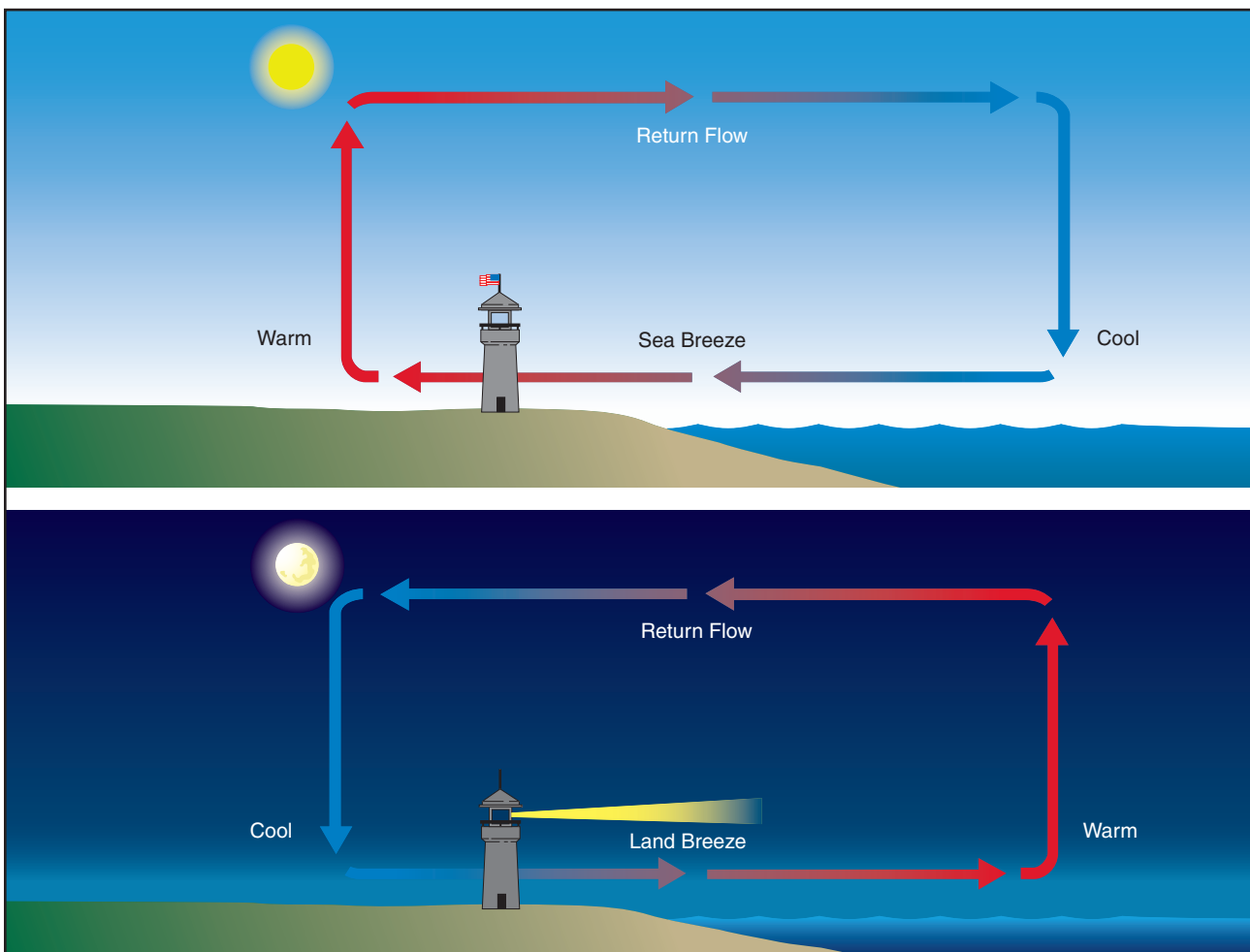
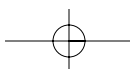


Figure 10-13. Sea breeze and land breeze wind circulation patterns.

Convection currents close to the ground can affect a pilot's ability to control the aircraft. On final approach, for example, the rising air from terrain devoid of vegetation sometimes produces a ballooning effect that can cause a pilot to overshoot the intended landing spot. On the other hand, an approach over a large body of water or an area of thick vegetation tends to create a sinking effect that can cause an unwary pilot to land short of the intended landing spot. [Figure 10-14]

### EFFECT OF OBSTRUCTIONS ON WIND

Another atmospheric hazard exists that can create problems for pilots. Obstructions on the ground affect the flow of wind and can be an unseen danger. Ground topography and large buildings can break up the flow of the wind and create wind gusts that change rapidly in direction and speed. These obstructions range from manmade structures like hangars to large natural obstructions, such as mountains, bluffs, or canyons. It





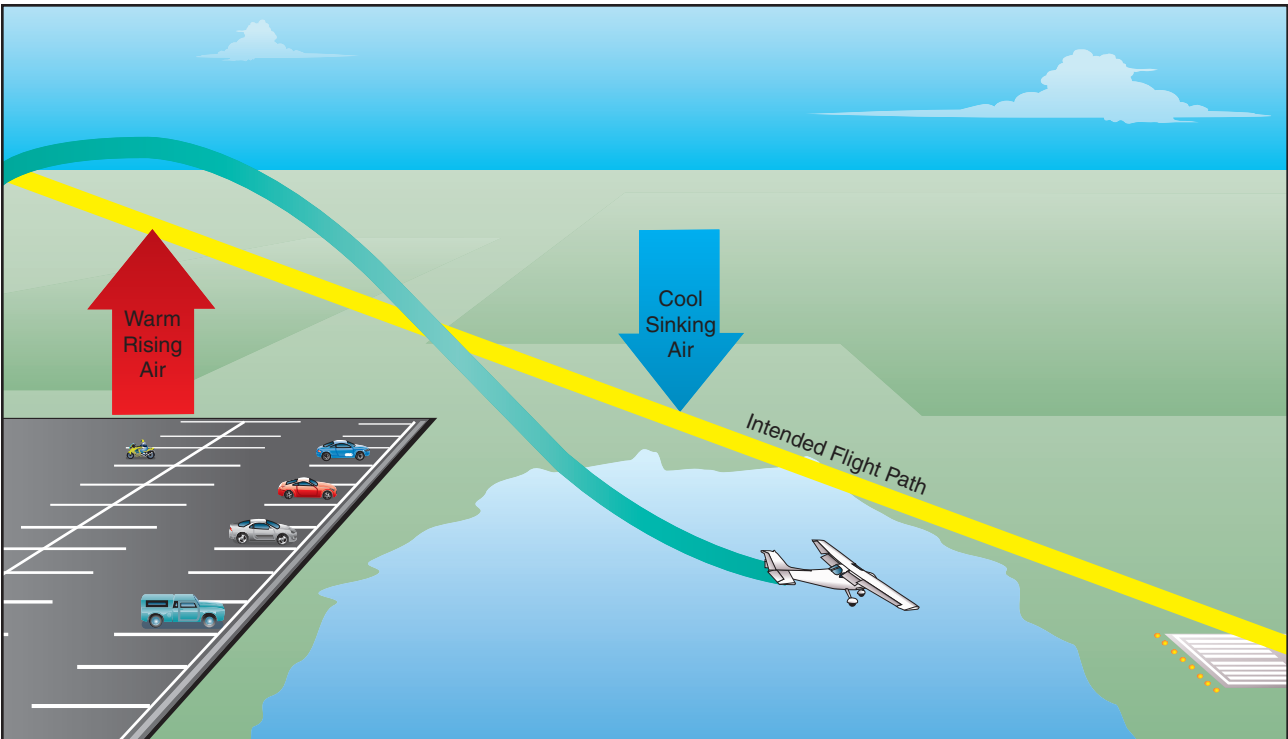


Figure 10-14. Currents generated by varying surface conditions.

is especially important to be vigilant when flying in or out of airports that have large buildings or natural obstructions located near the runway. [Figure 10-15]

The intensity of the turbulence associated with ground obstructions depends on the size of the obstacle and the primary velocity of the wind. This can affect the takeoff and landing performance of any aircraft and can present a very serious hazard. During the landing phase of flight, an aircraft may “drop in” due to the turbulent air and be too low to clear obstacles during the approach.

This same condition is even more noticeable when flying in mountainous regions. [Figure 10-16] While the wind flows smoothly up the windward side of the mountain and the upward currents help to carry an aircraft over the peak of the mountain, the wind on the leeward side does not act in a similar manner. As the air flows down the leeward side of the mountain, the air follows the contour of the terrain and is increasingly turbulent. This tends to push an aircraft into the side of a mountain. The stronger the wind, the greater the downward pressure and turbulence become.

Due to the effect terrain has on the wind in valleys or canyons, downdrafts can be severe. Thus, a prudent pilot is well advised to seek out a mountain qualified flight instructor and get a mountain checkout before conducting a flight in or near mountainous terrain.

## LOW-LEVEL WIND SHEAR

**Wind shear** is a sudden, drastic change in windspeed and/or direction over a very small area. Wind shear can subject an aircraft to violent updrafts and downdrafts as well as abrupt changes to the horizontal movement of the aircraft. While wind shear can occur at any altitude, low-level wind shear is especially hazardous due to the proximity of an aircraft to the ground. Directional wind changes of 180° and speed changes of 50 knots or more are associated with low-level wind shear. Low-level wind shear is commonly associated with passing frontal systems, thunderstorms, and temperature inversions with strong upper level winds (greater than 25 knots).

Wind shear is dangerous to an aircraft for several reasons. The rapid changes in wind direction and velocity changes the wind’s relation to the aircraft disrupting the normal flight attitude and performance of the aircraft. During a wind shear situation, the effects can be subtle or very dramatic depending on windspeed and direction of change. For example, a tailwind that quickly changes to a headwind will cause an increase in airspeed and performance. Conversely, when a headwind changes to a tailwind, the airspeed will rapidly decrease and there will be a corresponding decrease in performance. In either case, a pilot must be prepared to react immediately to the changes to maintain control of the aircraft.

**Wind Shear**—A sudden, drastic shift in windspeed, direction, or both that may occur in the horizontal or vertical plane.

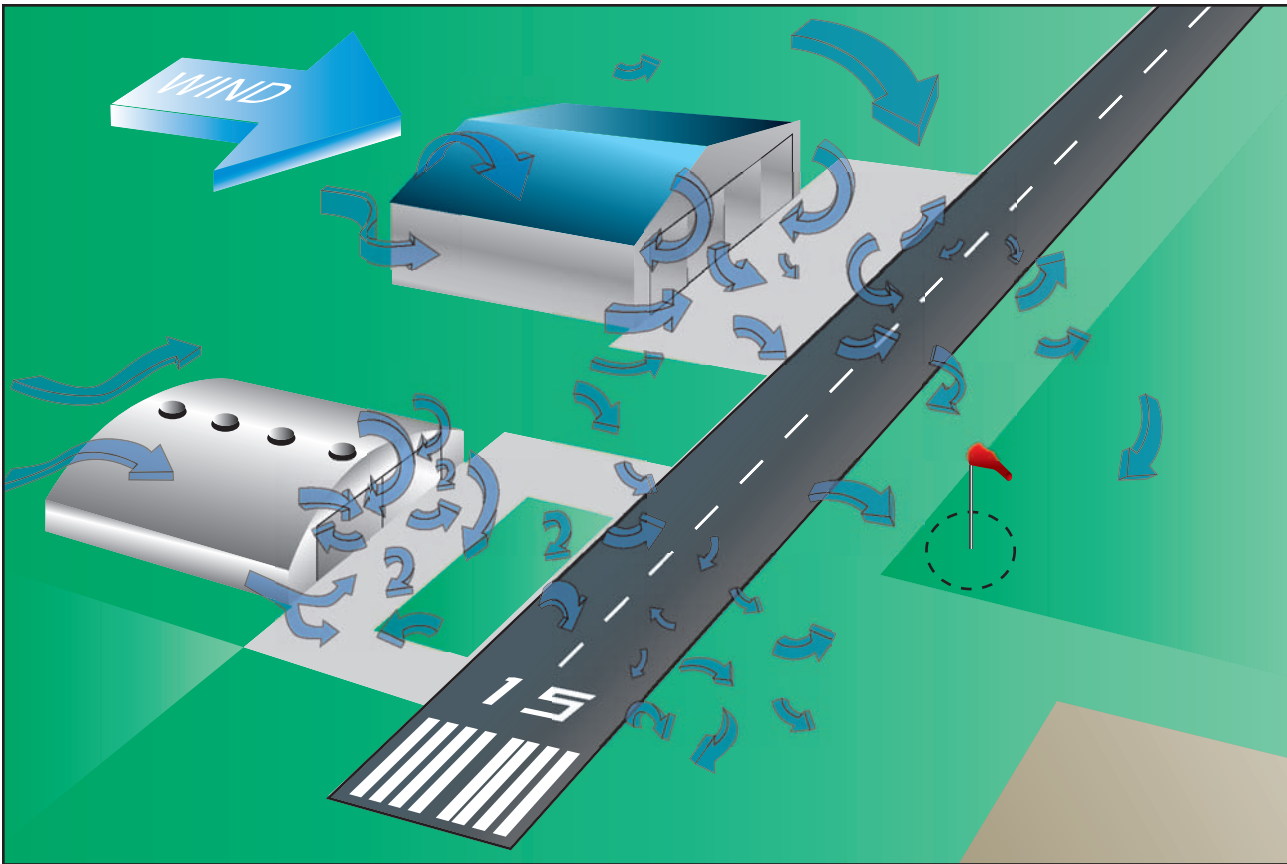


Figure 10-15. Turbulence caused by manmade obstructions.

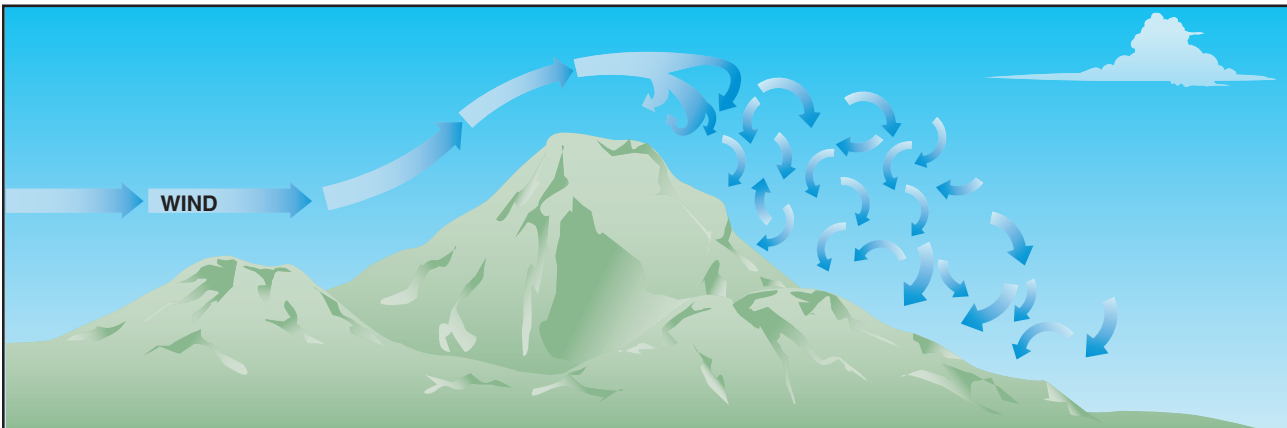


Figure 10-16. Turbulence encountered over and around mountainous regions.

In general, the most severe type of low-level wind shear is associated with convective precipitation or rain from thunderstorms. One critical type of shear associated with convective precipitation is known as a **microburst**. A typical microburst occurs in a space of less than 1 mile horizontally and within 1,000 feet vertically. The lifespan of a microburst is about 15 minutes during which it can produce downdrafts of up to 6,000 feet per minute. It can also produce a hazardous wind direction change of 45 knots or more, in a matter of seconds. When encountered close to the ground, these excessive downdrafts and rapid changes

in wind direction can produce a situation in which it is difficult to control the aircraft. [Figure 10-17] During an inadvertent takeoff into a microburst, the plane first experiences a performance-increasing headwind (#1), followed by performance-decreasing downdrafts (#2). Then the wind rapidly shears to a tailwind (#3), and can result in terrain impact or flight dangerously close to the ground (#4).

**Microburst**—A strong downdraft which normally occurs over horizontal distances of 1 NM or less and vertical distances of less than 1,000 feet. In spite of its small horizontal scale, an intense microburst could induce windspeeds greater than 100 knots and downdrafts as strong as 6,000 feet per minute.

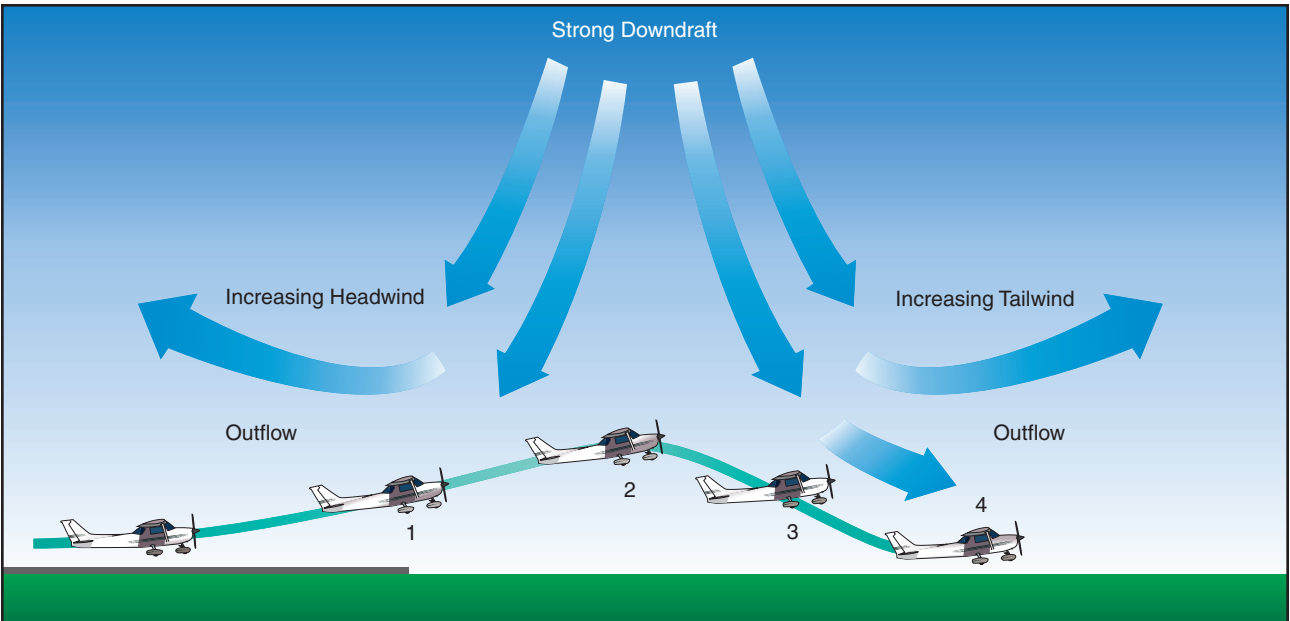
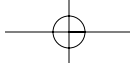


Figure 10-17. Effect of a microburst wind.

Microbursts are often difficult to detect because they occur in a relatively confined area. In an effort to warn pilots of low-level wind shear, alert systems have been installed at several airports around the country. A series of anemometers, placed around the airport, form a net to detect changes in windspeeds. When windspeeds differ by more than 15 knots, a warning for wind shear is given to pilots. This system is known as the low-level wind shear alert system, or LLWAS.

It is important to remember that wind shear can affect any flight and any pilot at any altitude. While wind shear may be reported, it often remains undetected and is a silent danger to aviation. Always be alert to the possibility of wind shear, especially when flying in and around thunderstorms and frontal systems.

**WIND AND PRESSURE REPRESENTATION ON SURFACE WEATHER MAPS**

Surface weather maps provide information about fronts, areas of high and low pressure, and surface winds and pressures for each station. This type of weather map allows pilots to see the locations of fronts and pressure systems, but more importantly, it depicts the wind and pressure at the surface for each location. For more information on surface analysis and weather depiction charts see Chapter 11.

Wind conditions are reported by an arrow attached to the station location circle. [Figure 10-18] The station circle represents the head of the arrow, with the arrow pointing in the direction from which the wind is blowing. Winds are described by the direction from which they blow, thus a northwest wind means that the wind is blowing from the northwest toward the southeast. The speed of the wind is depicted by barbs

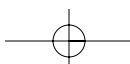
or pennants placed on the wind line. Each barb represents a speed of 10 knots, while half a barb is equal to 5 knots and a pennant is equal to 50 knots.

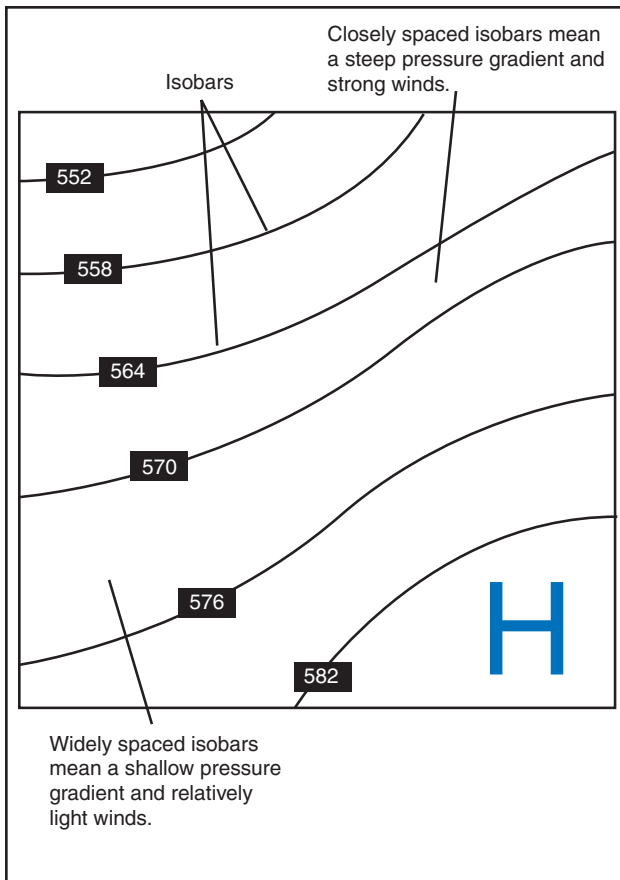
The pressure for each station is recorded on the weather chart and is shown in millibars. **Isobars** are lines drawn on the chart to depict areas of equal pressure. These lines result in a pattern that reveals the pressure gradient or change in pressure over distance. [Figure 10-19] Isobars are similar to contour lines on a topographic map that indicate terrain altitudes and slope steepness. For example, isobars that are closely spaced indicate a steep wind gradient and strong winds prevail. Shallow gradients, on the other hand, are represented by isobars that are spaced far apart, and are indicative of light winds. Isobars help identify low- and high-pressure systems as well as the location of ridges, troughs, and cols. A high is an area of high pressure

**Isobars—Lines which connect points of equal barometric pressure.**

Examples of wind speed and direction plots		
Calm 	NW / 5 kts 	SW / 20 kts 
E / 35 kts 	N / 50 kts 	W / 105 kts 

Figure 10-18. Depiction of winds on a surface weather chart.





**Figure 10-19.** Isobars reveal the pressure gradient of an area of high- or low-pressure areas.

surrounded by lower pressure; a low is an area of low pressure surrounded by higher pressure. A ridge is an elongated area of high pressure, and a trough is an elongated area of low pressure. A col is the intersection between a ridge and a trough, or an area of neutrality between two highs or two lows.

Isobars furnish valuable information about winds in the first few thousand feet above the surface. Close to the ground, wind direction is modified by the surface and windspeed decreases due to friction with the surface. At levels 2,000 to 3,000 feet above the surface, however, the speed is greater and the direction becomes more parallel to the isobars. Therefore, the surface winds are shown on the weather map as well as the winds at a slightly higher altitude.

Generally, the wind 2,000 feet above the ground will be  $20^\circ$  to  $40^\circ$  to the right of surface winds, and the wind-speed will be greater. The change of wind direction is greatest over rough terrain and least over flat surfaces, such as open water. In the absence of winds aloft information, this rule of thumb allows for a rough estimate of the wind conditions a few thousand feet above the surface.

## ATMOSPHERIC STABILITY

The stability of the atmosphere depends on its ability to resist vertical motion. A stable atmosphere makes vertical movement difficult, and small vertical disturbances dampen out and disappear. In an unstable atmosphere, small vertical air movements tend to become larger, resulting in turbulent airflow and convective activity. Instability can lead to significant turbulence, extensive vertical clouds, and severe weather.

Rising air expands and cools due to the decrease in air pressure as altitude increases. The opposite is true of descending air; as atmospheric pressure increases, the temperature of descending air increases as it is compressed. **Adiabatic heating**, or **adiabatic cooling**, are the terms used to describe this temperature change.

The adiabatic process takes place in all upward and downward moving air. When air rises into an area of lower pressure, it expands to a larger volume. As the molecules of air expand, the temperature of the air lowers. As a result, when a parcel of air rises, pressure decreases, volume increases, and temperature decreases. When air descends, the opposite is true. The rate at which temperature decreases with an increase in altitude is referred to as its lapse rate. As air ascends through the atmosphere, the average rate of temperature change is  $2^\circ\text{C}$  ( $3.5^\circ\text{F}$ ) per 1,000 feet.

Since water vapor is lighter than air, moisture decreases air density, causing it to rise. Conversely, as moisture decreases, air becomes denser and tends to sink. Since moist air cools at a slower rate, it is generally less stable than dry air since the moist air must rise higher before its temperature cools to that of the surrounding air. The dry adiabatic lapse rate (unsaturated air) is  $3^\circ\text{C}$  ( $5.4^\circ\text{F}$ ) per 1,000 feet. The moist adiabatic lapse rate varies from  $1.1^\circ\text{C}$  to  $2.8^\circ\text{C}$  ( $2^\circ\text{F}$  to  $5^\circ\text{F}$ ) per 1,000 feet.

The combination of moisture and temperature determine the stability of the air and the resulting weather. Cool, dry air is very stable and resists vertical movement, which leads to good and generally clear weather. The greatest instability occurs when the air is moist and warm, as it is in the tropical regions in the summer. Typically, thunderstorms appear on a daily basis in these regions due to the instability of the surrounding air.

**Adiabatic heating**—A process of heating dry air through compression. As air moves downward it is compressed, resulting in a temperature increase.

**Adiabatic cooling**—A process of cooling the air through expansion. For example, as air moves upward, it expands with the reduction of atmospheric pressure and cools as it expands.

## INVERSION

As air rises and expands in the atmosphere, the temperature decreases. There is an atmospheric anomaly that can occur, however, that changes this typical pattern of atmospheric behavior. When the temperature of the air rises with altitude, a temperature inversion exists. **Inversion** layers are commonly shallow layers of smooth, stable air close to the ground. The temperature of the air increases with altitude to a certain point, which is the top of the inversion. The air at the top of the layer acts as a lid, keeping weather and pollutants trapped below. If the relative humidity of the air is high, it can contribute to the formation of clouds, fog, haze, or smoke, resulting in diminished visibility in the inversion layer.

Surface based temperature inversions occur on clear, cool nights when the air close to the ground is cooled by the lowering temperature of the ground. The air within a few hundred feet of the surface becomes cooler than the air above it. Frontal inversions occur when warm air spreads over a layer of cooler air, or cooler air is forced under a layer of warmer air.

## MOISTURE AND TEMPERATURE

The atmosphere, by nature, contains moisture in the form of water vapor. The amount of moisture present in the atmosphere is dependent upon the temperature of the air. Every 20°F increase in temperature doubles the amount of moisture the air can hold. Conversely, a decrease of 20°F cuts the capacity in half.

Water is present in the atmosphere in three states: liquid, solid, and gaseous. All three forms can readily change to another, and all are present within the temperature ranges of the atmosphere. As water changes from one state to another, an exchange of heat takes place. These changes occur through the processes of **evaporation**, **sublimation**, **condensation**, **deposition**, melting, or freezing. However, water vapor is added into the atmosphere only by the processes of evaporation and sublimation.

Evaporation is the changing of liquid water to water vapor. As water vapor forms, it absorbs heat from the nearest available source. This heat exchange is known as the latent heat of evaporation. A good example of this is when the body's perspiration evaporates. The net effect is a cooling sensation as heat is extracted from the body. Similarly, sublimation is the changing of ice directly to water vapor, completely bypassing the liquid stage. Though dry ice is not made of water, but rather carbon dioxide, it demonstrates the principle of sublimation, when a solid turns directly into vapor.

## RELATIVE HUMIDITY

Humidity refers to the amount of water vapor present in the atmosphere at a given time. Relative humidity is

the actual amount of moisture in the air compared to the total amount of moisture the air could hold at that temperature. For example, if the current relative humidity is 65 percent, the air is holding 65 percent of the total amount of moisture that it is capable of holding at that temperature and pressure. While much of the western United States rarely sees days of high humidity, relative humidity readings of 75 to 90 percent are not uncommon in the southern United States during warmer months. [Figure 10-20]

## TEMPERATURE/DEWPOINT RELATIONSHIP

The relationship between **dewpoint** and temperature defines the concept of relative humidity. The dewpoint, given in degrees, is the temperature at which the air can hold no more moisture. When the temperature of the air is reduced to the dewpoint, the air is completely saturated and moisture begins to condense out of the air in the form of fog, dew, frost, clouds, rain, hail, or snow.

As moist, unstable air rises, clouds often form at the altitude where temperature and dewpoint reach the same value. When lifted, unsaturated air cools at a rate of 5.4°F per 1,000 feet and the dewpoint temperature decreases at a rate of 1°F per 1,000 feet. This results in a convergence of temperature and dewpoint at a rate of 4.4°F. Apply the convergence rate to the reported temperature and dewpoint to determine the height of the cloud base.

### Given:

Temperature (T) = 85°F

Dewpoint (DP) = 71°F

Convergence Rate (CR) = 4.4°

$T - DP = \text{Temperature Dewpoint Spread (TDS)}$

$TDS \div CR = X$

$X \times 1,000 \text{ feet} = \text{height of cloud base AGL}$

### Example:

$85^\circ\text{F} - 71^\circ\text{F} = 14^\circ\text{F}$

$14^\circ\text{F} \div 4.4^\circ\text{F} = 3.18$

$3.18 \times 1,000 = 3,180 \text{ feet AGL}$

The height of the cloud base is 3,180 feet AGL.

**Inversion**—An increase in temperature with altitude.

**Evaporation**—The transformation of a liquid to a gaseous state, such as the change of water to water vapor.

**Sublimation**—Process by which a solid is changed to a gas without going through the liquid state.

**Condensation**—A change of state of water from a gas (water vapor) to a liquid.

**Deposition**—The direct transformation of a gas to a solid state, in which the liquid state is bypassed. Some sources use the term sublimation to describe this process instead of deposition.

**Dewpoint**—The temperature at which air reaches a state where it can hold no more water.



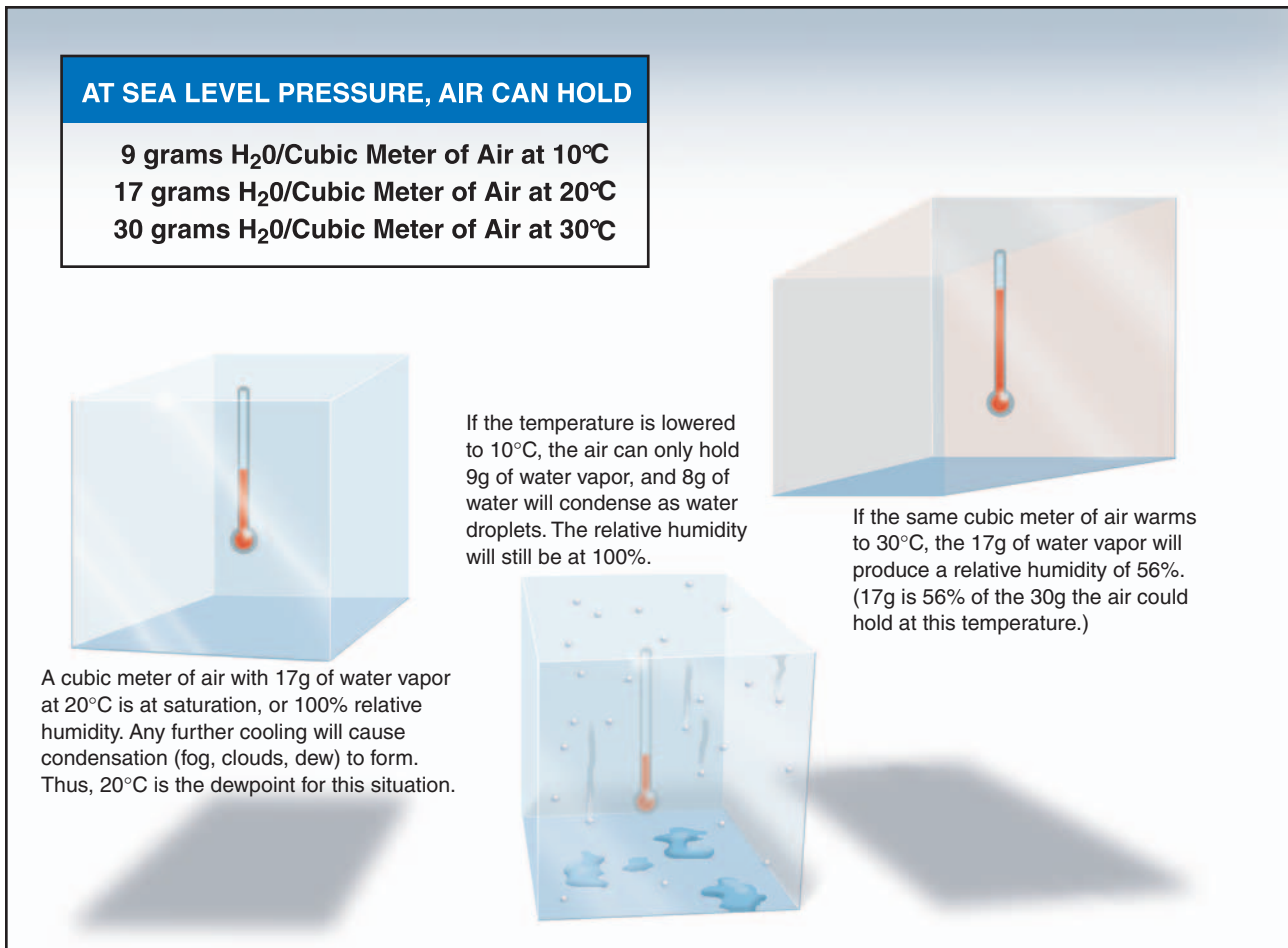


Figure 10-20. The relationship between relative humidity, temperature, and dewpoint.

### Explanation:

With an outside air temperature (OAT) of 85°F at the surface, and dewpoint at the surface of 71°F, the spread is 14°. Divide the temperature dewpoint spread by the convergence rate of 4.4°F, and multiply by 1,000 to determine the approximate height of the cloud base.

### METHODS BY WHICH AIR REACHES THE SATURATION POINT

If air reaches the saturation point while temperature and dewpoint are close together, it is highly likely that fog, low clouds, and precipitation will form. There are four methods by which air can reach the complete saturation point. First, when warm air moves over a cold surface, the air's temperature drops and reaches the saturation point. Second, the saturation point may be reached when cold air and warm air mix. Third, when air cools at night through contact with the cooler ground, air reaches its saturation point. The fourth method occurs when air is lifted or is forced upward in the atmosphere.

As air rises, it uses heat energy to expand. As a result, the rising air loses heat rapidly. Unsaturated air loses heat at a rate of 3.0°C (5.4°F) for every 1,000 feet of

altitude gain. No matter what causes the air to reach its saturation point, saturated air brings clouds, rain, and other critical weather situations.

### DEW AND FROST

On cool, calm nights, the temperature of the ground and objects on the surface can cause temperatures of the surrounding air to drop below the dewpoint. When this occurs, the moisture in the air condenses and deposits itself on the ground, buildings, and other objects like cars and aircraft. This moisture is known as dew and sometimes can be seen on grass in the morning. If the temperature is below freezing, the moisture will be deposited in the form of frost. While dew poses no threat to an aircraft, frost poses a definite flight safety hazard. Frost disrupts the flow of air over the wing and can drastically reduce the production of lift. It also increases drag, which, when combined with lowered lift production, can eliminate the ability to take off. An aircraft must be thoroughly cleaned and free of frost prior to beginning a flight.

### FOG

Fog, by definition, is a cloud that begins within 50 feet of the surface. It typically occurs when the temperature of air near the ground is cooled to the air's dewpoint.

At this point, water vapor in the air condenses and becomes visible in the form of fog. Fog is classified according to the manner in which it forms and is dependent upon the current temperature and the amount of water vapor in the air.

On clear nights, with relatively little to no wind present, radiation fog may develop. [Figure 10-21] Usually, it forms in low-lying areas like mountain valleys. This type of fog occurs when the ground cools rapidly due to terrestrial radiation, and the surrounding air temperature reaches its dewpoint. As the sun rises and the temperature increases, radiation fog will lift and eventually burn off. Any increase in wind will also speed the dissipation of radiation fog. If radiation fog is less than 20 feet thick, it is known as ground fog.



Figure 10-21. Radiation fog.

When a layer of warm, moist air moves over a cold surface, advection fog is likely to occur. Unlike radiation fog, wind is required to form advection fog. Winds of up to 15 knots allow the fog to form and intensify; above a speed of 15 knots, the fog usually lifts and forms low stratus clouds. Advection fog is common in coastal areas where sea breezes can blow the air over cooler landmasses.

In these same coastal areas, upslope fog is likely as well. Upslope fog occurs when moist, stable air is forced up sloping land features like a mountain range. This type of fog also requires wind for formation and continued existence. Upslope and advection fog, unlike radiation fog, may not burn off with the morning sun, but instead can persist for days. They also can extend to greater heights than radiation fog.

Steam fog, or sea smoke, forms when cold, dry air moves over warm water. As the water evaporates, it rises and resembles smoke. This type of fog is common over bodies of water during the coldest times of the year. Low-level turbulence and icing are commonly associated with steam fog.

Ice fog occurs in cold weather when the temperature is much below freezing and water vapor forms directly into ice crystals. Conditions favorable for its formation are the same as for radiation fog except for cold temperature, usually  $-25^{\circ}\text{F}$  or colder. It occurs mostly in the arctic regions, but is not unknown in middle latitudes during the cold season.

## CLOUDS

Clouds are visible indicators and are often indicative of future weather. For clouds to form, there must be adequate water vapor and condensation nuclei, as well as a method by which the air can be cooled. When the air cools and reaches its saturation point, the invisible water vapor changes into a visible state. Through the processes of deposition (also referred to as sublimation) and condensation, moisture condenses or sublimates onto miniscule particles of matter like dust, salt, and smoke known as **condensation nuclei**. The nuclei are important because they provide a means for the moisture to change from one state to another.

Cloud type is determined by its height, shape, and behavior. They are classified according to the height of their bases as low, middle, or high clouds, as well as clouds with vertical development. [Figure 10-22]

Low clouds are those that form near the Earth's surface and extend up to 6,500 feet AGL. They are made primarily of water droplets, but can include supercooled water droplets that induce hazardous aircraft icing. Typical low clouds are stratus, stratocumulus, and nimbostratus. Fog is also classified as a type of low cloud formation. Clouds in this family create low ceilings, hamper visibility, and can change rapidly. Because of this, they influence flight planning and can make VFR flight impossible.

Middle clouds form around 6,500 feet AGL and extend up to 20,000 feet AGL. They are composed of water, ice crystals, and **supercooled water droplets**. Typical middle-level clouds include altostratus and altocumulus. These types of clouds may be encountered on cross-country flights at higher altitudes. Altostratus clouds can produce turbulence and may contain moderate icing. Altocumulus clouds, which usually form when altostratus clouds are breaking apart, also may contain light turbulence and icing.

**Condensation Nuclei**—Small particles of solid matter in the air on which water vapor condenses.

**Supercooled Water Droplets**—Water droplets that have been cooled below the freezing point, but are still in a liquid state.

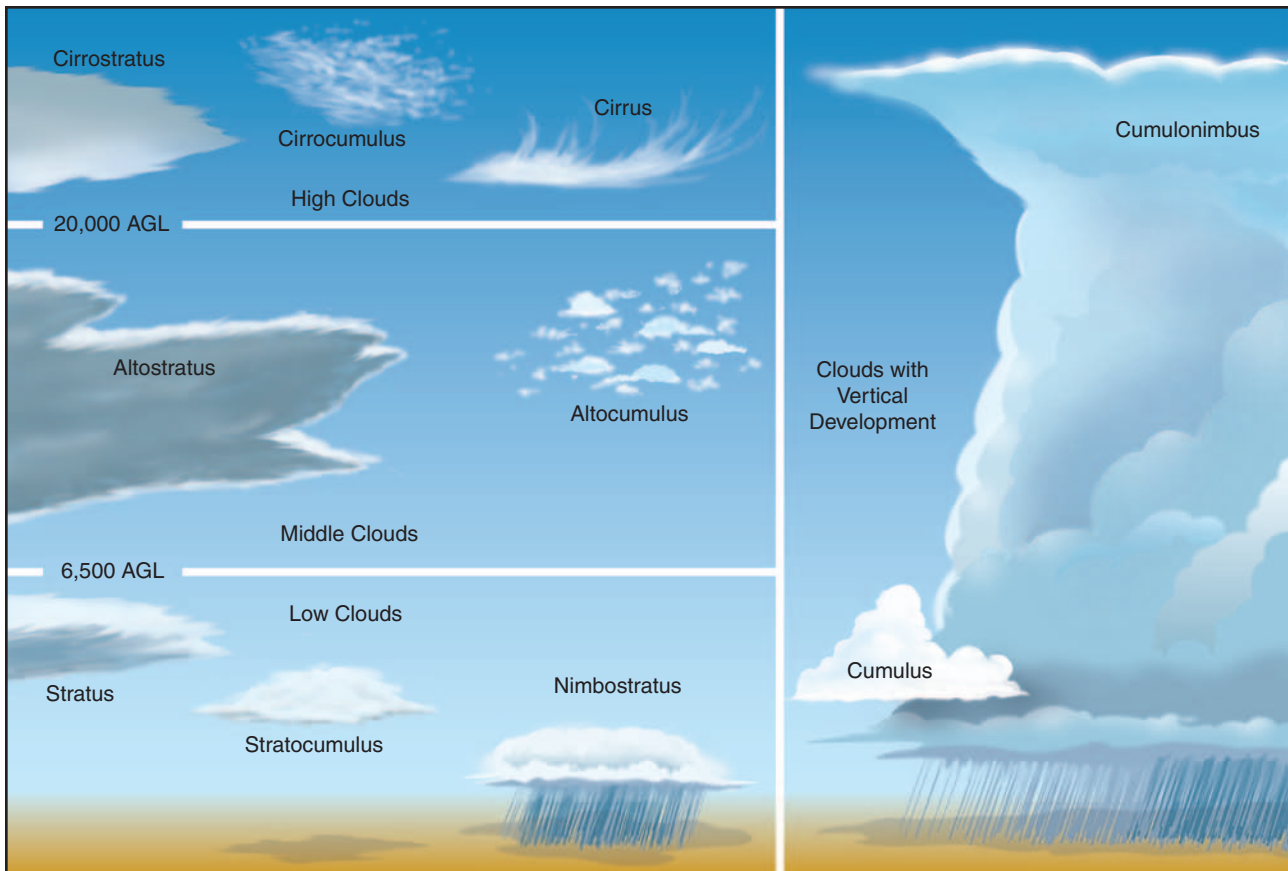


Figure 10-22. Basic cloud types.

High clouds form above 20,000 feet AGL and usually form only in stable air. They are made up of ice crystals and pose no real threat of turbulence or aircraft icing. Typical high-level clouds are cirrus, cirrostratus, and cirrocumulus.

Clouds with extensive vertical development are cumulus clouds that build vertically into towering cumulus or cumulonimbus clouds. The bases of these clouds form in the low to middle cloud base region but can extend into high altitude cloud levels. Towering cumulus clouds indicate areas of instability in the atmosphere, and the air around and inside them is turbulent. These types of clouds often develop into cumulonimbus clouds or thunderstorms. Cumulonimbus clouds contain large amounts of moisture and unstable air, and usually produce hazardous weather phenomena such as lightning, hail, tornadoes, gusty winds, and wind shear. These extensive vertical clouds can be obscured by other cloud formations and are not always visible from the ground or while in flight. When this happens, these clouds are said to be embedded, hence the term, embedded thunderstorms.

Cloud classification can be further broken down into specific cloud types according to the outward

appearance and cloud composition. Knowing these terms can help identify visible clouds.

The following is a list of cloud classifications:

- Cumulus—Heaped or piled clouds.
- Stratus—Formed in layers.
- Cirrus—Ringlets; fibrous clouds; also high-level clouds above 20,000 feet.
- Castellanus—Common base with separate vertical development; castle-like.
- Lenticularus—Lens shaped; formed over mountains in strong winds.
- Nimbus—Rain bearing clouds.
- Fracto—Ragged or broken.
- Alto—Meaning high; also middle-level clouds existing at 5,000 to 20,000 feet.

To pilots, the cumulonimbus cloud is perhaps the most dangerous cloud type. It appears individually or in groups and is known as either an air mass or orographic thunderstorm. Heating of the air near the Earth's surface creates an air mass thunderstorm; the upslope

motion of air in the mountainous regions causes orographic thunderstorms. Cumulonimbus clouds that form in a continuous line are nonfrontal bands of thunderstorms or squall lines.

Since rising air currents cause cumulonimbus clouds, they are extremely turbulent and pose a significant hazard to flight safety. For example, if an aircraft enters a thunderstorm, the aircraft could experience updrafts and downdrafts that exceed 3,000 feet per minute. In addition, thunderstorms can produce large hailstones, damaging lightning, tornadoes, and large quantities of water, all of which are potentially hazardous to aircraft.

A thunderstorm makes its way through three distinct stages before dissipating. It begins with the cumulus stage, in which lifting action of the air begins. If sufficient moisture and instability are present, the clouds continue to increase in vertical height. Continuous, strong updrafts prohibit moisture from falling. The updraft region grows larger than the individual thermals feeding the storm. Within approximately 15 minutes, the thunderstorm reaches the mature stage, which is the most violent time period of the thunderstorm's life cycle. At this point, drops of moisture, whether rain or ice, are too heavy for the cloud to support and begin falling in the form of rain or hail. This creates a downward motion of the air. Warm, rising air; cool, precipitation-induced descending air; and violent turbulence all exist within and near the cloud. Below the cloud, the down-rushing air increases surface winds and decreases the temperature. Once the

vertical motion near the top of the cloud slows down, the top of the cloud spreads out and takes on an anvil-like shape. At this point, the storm enters the dissipating stage. This is when the downdrafts spread out and replace the updrafts needed to sustain the storm. [Figure 10-23]

It is impossible to fly over thunderstorms in light aircraft. Severe thunderstorms can punch through the tropopause and reach staggering heights of 50,000 to 60,000 feet depending on latitude. Flying under thunderstorms can subject aircraft to rain, hail, damaging lightning, and violent turbulence. A good rule of thumb is to circumnavigate thunderstorms by at least 5 nautical miles (NM) since hail may fall for miles outside of the clouds. If flying around a thunderstorm is not an option, stay on the ground until it passes.

### CEILING

A **ceiling**, for aviation purposes, is the lowest layer of clouds reported as being broken or overcast, or the vertical visibility into an obscuration like fog or haze. Clouds are reported as broken when five-eighths to seven-eighths of the sky is covered with clouds. Overcast means the entire sky is covered with clouds. Current ceiling information is reported by the aviation routine weather report (METAR) and automated weather stations of various types.

**Ceiling**—The height above the Earth's surface of the lowest layer of clouds reported as broken or overcast, or the vertical visibility into an obscuration.

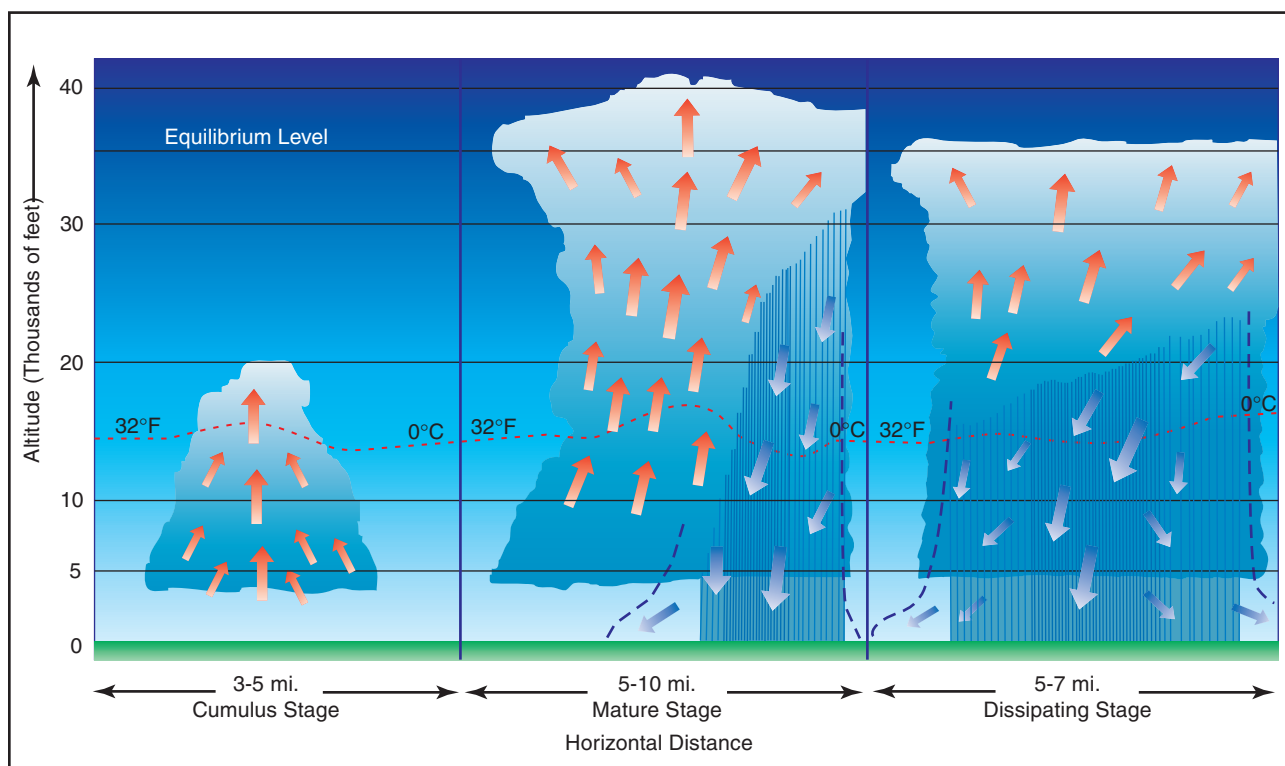


Figure 10-23. Life cycle of a thunderstorm.



## VISIBILITY

Closely related to cloud cover and reported ceilings is visibility information. Visibility refers to the greatest horizontal distance at which prominent objects can be viewed with the naked eye. Current visibility is also reported in METAR and other aviation weather reports, as well as automated weather stations. Visibility information, as predicted by meteorologists, is available during a preflight weather briefing.

## PRECIPITATION

Precipitation refers to any form of water particles that form in the atmosphere and fall to the ground. It has a profound impact on flight safety. Depending on the form of precipitation, it can reduce visibility, create icing situations, and affect landing and takeoff performance of an aircraft.

Precipitation occurs because water or ice particles in clouds grow in size until the atmosphere can no longer support them. It can occur in several forms as it falls toward the Earth, including drizzle, rain, ice pellets, hail, and ice.

Drizzle is classified as very small water droplets, smaller than 0.02 inches in diameter. Drizzle usually accompanies fog or low stratus clouds. Water droplets of larger size are referred to as rain. Rain that falls through the atmosphere but evaporates prior to striking the ground is known as virga. Freezing rain and freezing drizzle occur when the temperature of the surface is below freezing; the rain freezes on contact with the cooler surface.

If rain falls through a temperature inversion, it may freeze as it passes through the underlying cold air and fall to the ground in the form of ice pellets. Ice pellets are an indication of a temperature inversion and that freezing rain exists at a higher altitude. In the case of hail, freezing water droplets are carried up and down by drafts inside clouds, growing larger in size as they come in contact with more moisture. Once the updrafts can no longer hold the freezing water, it falls to the Earth in the form of hail. Hail can be pea-sized, or it can grow as large as 5 inches in diameter, larger than a softball.

Snow is precipitation in the form of ice crystals that falls at a steady rate or in snow showers that begin, change in intensity, and end rapidly. Falling snow also varies in size, being very small grains or large flakes. Snow grains are the equivalent of drizzle in size.

Precipitation in any form poses a threat to safety of flight. Often, precipitation is accompanied by low ceilings and reduced visibility. Aircraft that have ice, snow, or frost on their surfaces must be carefully

cleaned prior to beginning a flight because of the possible airflow disruption and loss of lift. Rain can contribute to water in the fuel tanks. Precipitation can create hazards on the runway surface itself, making takeoffs and landings difficult, if not impossible, due to snow, ice, or pooling water and very slick surfaces.

## AIR MASSES

Air masses are large bodies of air that take on the characteristics of the surrounding area, or source region. A source region is typically an area in which the air remains relatively stagnant for a period of days or longer. During this time of stagnation, the **air mass** takes on the temperature and moisture characteristics of the source region. Areas of stagnation can be found in polar regions, tropical oceans, and dry deserts. Air masses are classified based on their region of origination:

- Polar or Tropical
- Maritime or Continental

A continental polar air mass forms over a polar region and brings cool, dry air with it. Maritime tropical air masses form over warm tropical waters like the Caribbean Sea and bring warm, moist air. As the air mass moves from its source region and passes over land or water, the air mass is subjected to the varying conditions of the land or water, and these modify the nature of the air mass. [Figure 10-24]

An air mass passing over a warmer surface will be warmed from below, and convective currents form, causing the air to rise. This creates an unstable air mass with good surface visibility. Moist, unstable air causes cumulus clouds, showers, and turbulence to form. Conversely, an air mass passing over a colder surface does not form convective currents, but instead creates a stable air mass with poor surface visibility. The poor surface visibility is due to the fact that smoke, dust, and other particles cannot rise out of the air mass and are instead trapped near the surface. A stable air mass can produce low stratus clouds and fog.

## FRONTS

As air masses move across bodies of water and land, they eventually come in contact with another air mass with different characteristics. The boundary layer between two types of air masses is known as a front. An approaching front of any type always means changes to the weather are imminent.

**Air Mass**—An extensive body of air having fairly uniform properties of temperature and moisture.



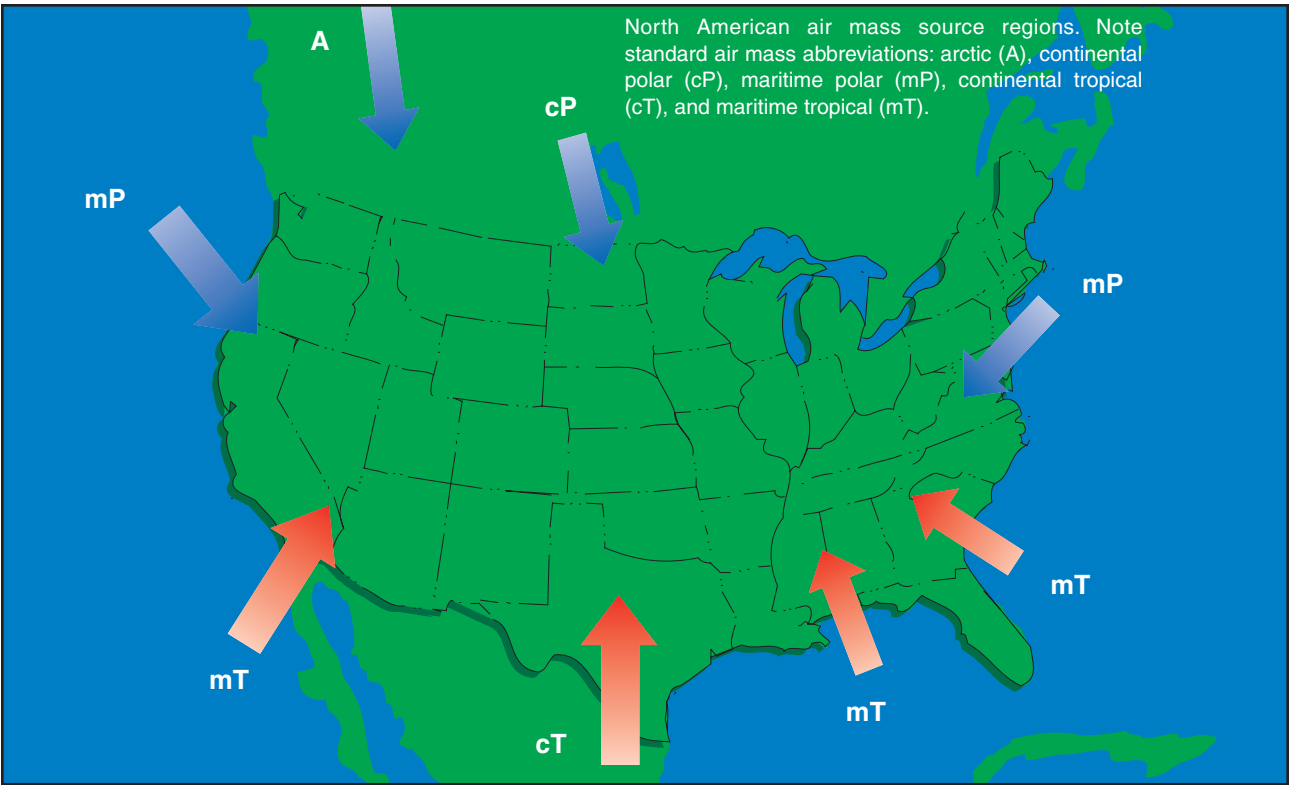
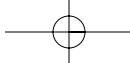


Figure 10-24. Air mass source regions.

There are four types of fronts, which are named according to the temperature of the advancing air as it relates to the temperature of the air it is replacing. [Figure 10-25]

- Warm Front
- Cold Front
- Stationary Front
- Occluded Front

Any discussion of frontal systems must be tempered with the knowledge that no two fronts are the same. However, generalized weather conditions are associated with a specific type of front that helps identify the front.

**WARM FRONT**

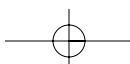
A **warm front** occurs when a warm mass of air advances and replaces a body of colder air. Warm fronts move slowly, typically 10 to 25 miles per hour (m.p.h.). The slope of the advancing front slides over the top of the cooler air and gradually pushes it out of the area. Warm fronts contain warm air that often has very high humidity. As the warm air is lifted, the temperature drops and condensation occurs.

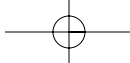
**Warm Front**—The boundary between two air masses where warm air is replacing cold air.

Generally, prior to the passage of a warm front, cirriform or stratiform clouds, along with fog, can be expected to form along the frontal boundary. In the summer months, cumulonimbus clouds (thunderstorms) are likely to develop. Light to moderate precipitation is probable, usually in the form of rain, sleet, snow, or drizzle, punctuated by poor visibility. The wind blows from the south-southeast, and the outside temperature is cool or cold, with increasing dewpoint. Finally, as the warm front approaches, the barometric pressure continues to fall until the front passes completely.

Table A	
Symbols for Surface Fronts and Other Significant Lines Shown on the Surface Analysis Chart	
	Warm Front (red)*
	Cold Front (blue)*
	Stationary Front (red/blue)*
	Occluded Front (purple)*
* Note : Fronts may be black and white or color, depending on their source. Also, fronts shown in color code will not necessarily show frontal symbols.	

Figure 10-25. Common chart symbology to depict weather front location.





During the passage of a warm front, stratiform clouds are visible and drizzle may be falling. The visibility is generally poor, but improves with variable winds. The temperature rises steadily from the inflow of relatively warmer air. For the most part, the dewpoint remains steady and the pressure levels off.

After the passage of a warm front, stratocumulus clouds predominate and rain showers are possible. The visibility eventually improves, but hazy conditions may exist for a short period after passage. The wind blows from the south-southwest. With warming temperatures, the dewpoint rises and then levels off. There is generally a slight rise in barometric pressure, followed by a decrease of barometric pressure.

### FLIGHT TOWARD AN APPROACHING WARM FRONT

By studying a typical warm front, much can be learned about the general patterns and atmospheric conditions that exist when a warm front is encountered in flight. Figure 10-26 depicts a warm front advancing eastward from St. Louis, Missouri, toward Pittsburgh, Pennsylvania.

At the time of departure from Pittsburgh, the weather is good VFR with a scattered layer of cirrus clouds at 15,000 feet. As the flight progresses westward to Columbus and closer to the oncoming warm front, the

clouds deepen and become increasingly stratiform in appearance with a ceiling of 6,000 feet. The visibility decreases to 6 miles in haze with a falling barometric pressure. Approaching Indianapolis, the weather deteriorates to broken clouds at 2,000 feet with 3 miles visibility and rain. With the temperature and dewpoint the same, fog is likely. At St. Louis, the sky is overcast with low clouds and drizzle and the visibility is 1 mile. Beyond Indianapolis, the ceiling and visibility would be too low to continue VFR. Therefore, it would be wise to remain in Indianapolis until the warm front had passed, which might require a day or two.

### COLD FRONT

A **cold front** occurs when a mass of cold, dense, and stable air advances and replaces a body of warmer air. Cold fronts move more rapidly than warm fronts, progressing at a rate of 25 to 30 m.p.h. However, extreme cold fronts have been recorded moving at speeds of up to 60 m.p.h. A typical cold front moves in a manner opposite that of a warm front; because it is so dense, it stays close to the ground and acts like a snowplow, sliding under the warmer air and forcing the less dense air aloft. The rapidly ascending air causes

**Cold Front**—The boundary between two air masses where cold air is replacing warm air.

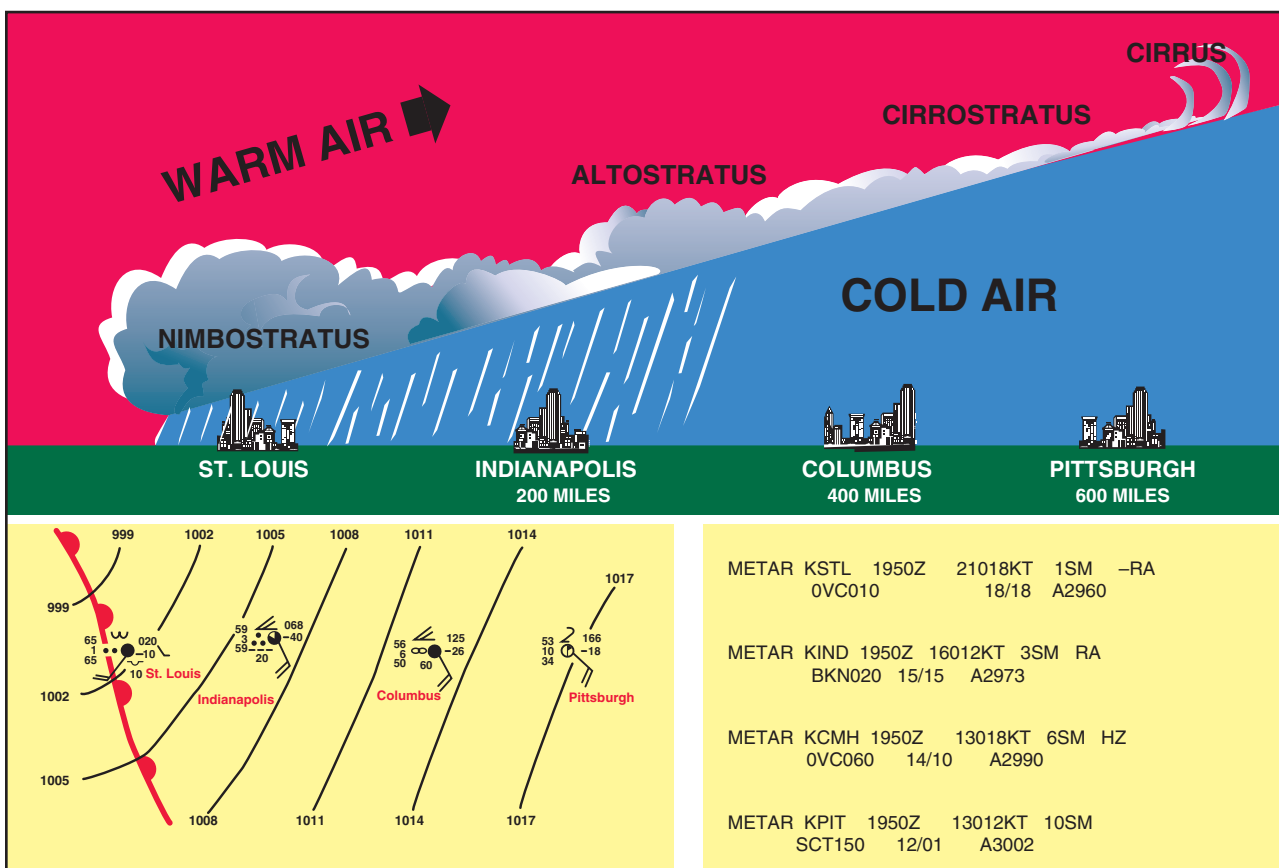
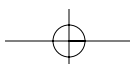


Figure 10-26. Warm front cross-section with surface weather chart depiction and associated METAR.



the temperature to decrease suddenly, forcing the creation of clouds. The type of clouds that form depends on the stability of the warmer air mass. A cold front in the Northern Hemisphere is normally oriented in a northeast to southwest manner and can be several hundred miles long, encompassing a large area of land.

Prior to the passage of a typical cold front, cirriform or towering cumulus clouds are present, and cumulonimbus clouds are possible. Rain showers and haze are possible due to the rapid development of clouds. The wind from the south-southwest helps to replace the warm temperatures with the relative colder air. A high dewpoint and falling barometric pressure are indicative of imminent cold front passage.

As the cold front passes, towering cumulus or cumulonimbus clouds continue to dominate the sky. Depending on the intensity of the cold front, heavy rain showers form and might be accompanied by lightning, thunder, and/or hail. More severe cold fronts can also produce tornadoes. During cold front passage, the visibility will be poor, with winds variable and gusty, and the temperature and dewpoint drop rapidly. A quickly falling barometric pressure bottoms out during frontal passage, then begins a gradual increase.

After frontal passage, the towering cumulus and cumulonimbus clouds begin to dissipate to cumulus clouds with a corresponding decrease in the precipitation. Good visibility eventually prevails with the winds from the west-northwest. Temperatures remain cooler and the barometric pressure continues to rise.

### **FAST-MOVING COLD FRONT**

Fast-moving cold fronts are pushed by intense pressure systems far behind the actual front. The friction between the ground and the cold front retards the movement of the front and creates a steeper frontal surface. This results in a very narrow band of weather, concentrated along the leading edge of the front. If the warm air being overtaken by the cold front is relatively stable, overcast skies and rain may occur for some distance ahead of the front. If the warm air is unstable, scattered thunderstorms and rain showers may form. A continuous line of thunderstorms, or a squall line, may form along or ahead of the front. Squall lines present a serious hazard to pilots as squall type thunderstorms are intense and move quickly. Behind a fast moving cold front, the skies usually clear rapidly and the front leaves behind gusty, turbulent winds and colder temperatures.

### **FLIGHT TOWARD AN APPROACHING COLD FRONT**

Like warm fronts, not all cold fronts are the same. Examining a flight toward an approaching cold front,

pilots can get a better understanding of the type of conditions that can be encountered in flight. Figure 10-27 shows a flight from Pittsburgh, Pennsylvania, toward St. Louis, Missouri.

At the time of departure from Pittsburgh, the weather is VFR with 3 miles visibility in smoke and a scattered layer of clouds at 3,500 feet. As the flight progresses westward to Columbus and closer to the oncoming cold front, the clouds show signs of vertical development with a broken layer at 2,500 feet. The visibility is 6 miles in haze with a falling barometric pressure. Approaching Indianapolis, the weather has deteriorated to overcast clouds at 1,000 feet, and 3 miles visibility with thunderstorms and heavy rain showers. At St. Louis, the weather gets better with scattered clouds at 1,000 feet and a 10 mile visibility.

A pilot using sound judgment based on the knowledge of frontal conditions, would most likely remain in Indianapolis until the front had passed. Trying to fly below a line of thunderstorms or a squall line is hazardous and foolish, and flight over the top of or around the storm is not an option. Thunderstorms can extend up to well over the capability of small airplanes and can extend in a line for 300 to 500 miles.

### **COMPARISON OF COLD AND WARM FRONTS**

Warm fronts and cold fronts are very different in nature as are the hazards associated with each front. They vary in speed, composition, weather phenomenon, and prediction. Cold fronts, which move at 20 to 35 m.p.h., move very quickly in comparison to warm fronts, which move at only 10 to 25 m.p.h. Cold fronts also possess a steeper frontal slope. Violent weather activity is associated with cold fronts and the weather usually occurs along the frontal boundary, not in advance. However, squall lines can form during the summer months as far as 200 miles in advance of a severe cold front. Whereas warm fronts bring low ceilings, poor visibility, and rain, cold fronts bring sudden storms, gusty winds, turbulence, and sometimes hail or tornadoes.

Cold fronts are fast approaching with little or no warning, and they make a complete weather change in just a few hours. The weather clears rapidly after passage and drier air with unlimited visibilities prevail. Warm fronts, on the other hand, provide advance warning of their approach and can take days to pass through a region.

### **WIND SHIFTS**

Wind around a high-pressure system rotates in a clockwise fashion, while low-pressure winds rotate in a counter-clockwise manner. When two high-pressure systems are adjacent, the winds are almost in direct

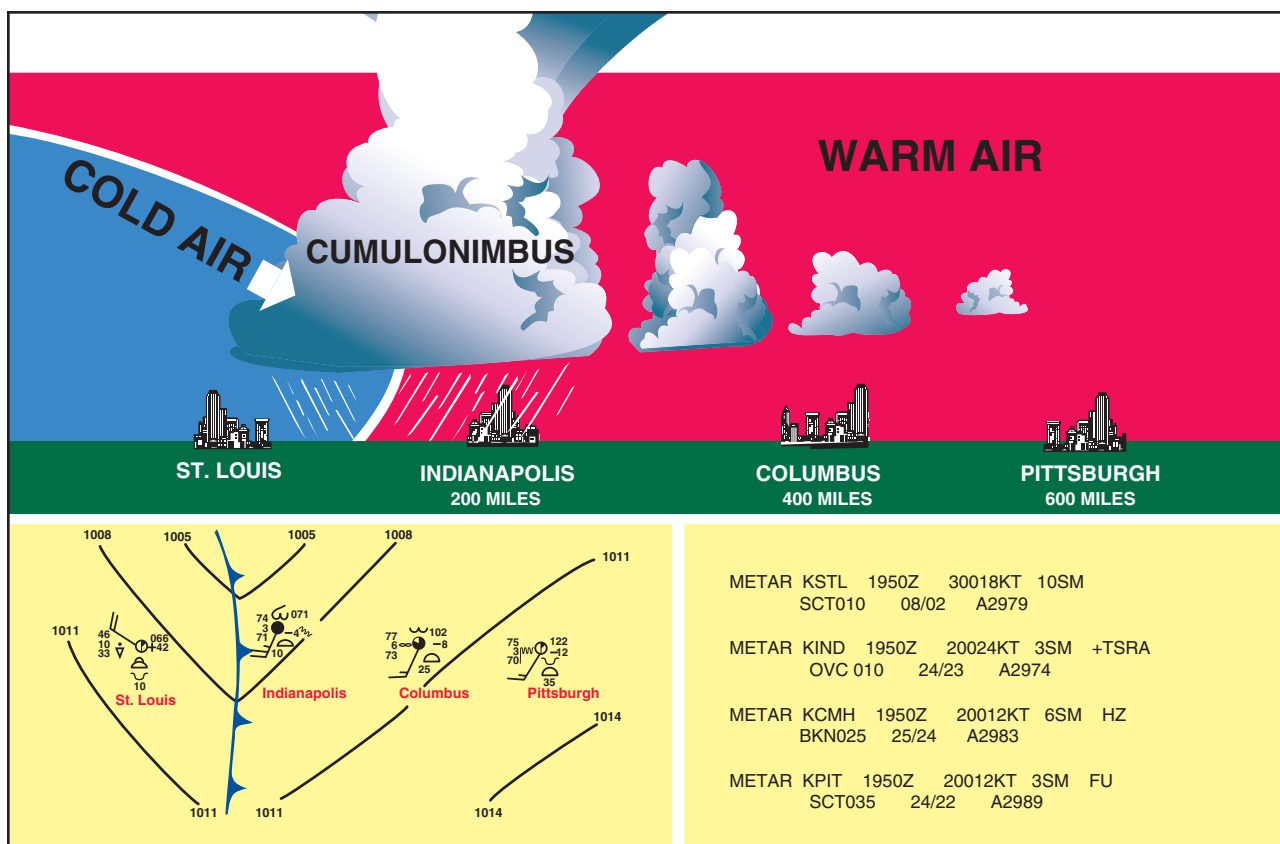


Figure 10-27. Cold front cross-section with surface weather chart depiction and associated METAR.

opposition to each other at the point of contact. Fronts are the boundaries between two areas of pressure, and therefore, wind shifts are continually occurring within a front. Shifting wind direction is most pronounced in conjunction with cold fronts.

### STATIONARY FRONT

When the forces of two air masses are relatively equal, the boundary or front that separates them remains stationary and influences the local weather for days. This front is called a **stationary front**. The weather associated with a stationary front is typically a mixture that can be found in both warm and cold fronts.

### OCCLUDED FRONT

An **occluded front** occurs when a fast-moving cold front catches up with a slow-moving warm front. As the occluded front approaches, warm front weather prevails, but is immediately followed by cold front weather. There are two types of occluded fronts that can occur, and the temperatures of the colliding frontal systems play a large part in defining the type of front and the resulting weather. A cold front occlusion occurs when a fast-moving cold front is colder than the air ahead of the slow-moving warm front. When this occurs, the cold air replaces the cool air and forces the warm front aloft into the atmosphere. Typically, the cold front occlusion creates a mixture of weather found in both warm and cold fronts, providing the air is

relatively stable. A warm front occlusion occurs when the air ahead of the warm front is colder than the air of the cold front. When this is the case, the cold front rides up and over the warm front. If the air forced aloft by the warm front occlusion is unstable, the weather will be more severe than the weather found in a cold front occlusion. Embedded thunderstorms, rain, and fog are likely to occur.

Figure 10-28 depicts a cross-section of a typical cold front occlusion. The warm front slopes over the prevailing cooler air and produces the warm front type weather. Prior to the passage of the typical occluded front, cirriform and stratiform clouds prevail, light to heavy precipitation is falling, visibility is poor, dewpoint is steady, and barometric pressure is falling. During the passage of the front, nimbostratus and cumulonimbus clouds predominate, and towering cumulus may also be possible. Light to heavy precipitation is falling, visibility is poor, winds are variable, and the barometric pressure is leveling off. After the passage of the front, nimbostratus and altostratus clouds are visible, precipitation is decreasing and clearing, and visibility is improving.

**Stationary Front**—A boundary between two air masses that are relatively balanced.

**Occluded Front**—A frontal occlusion occurs when a fast-moving cold front catches up with a slow-moving warm front. The difference in temperature within each frontal system is a major factor in determining whether a cold or warm front occlusion occurs.

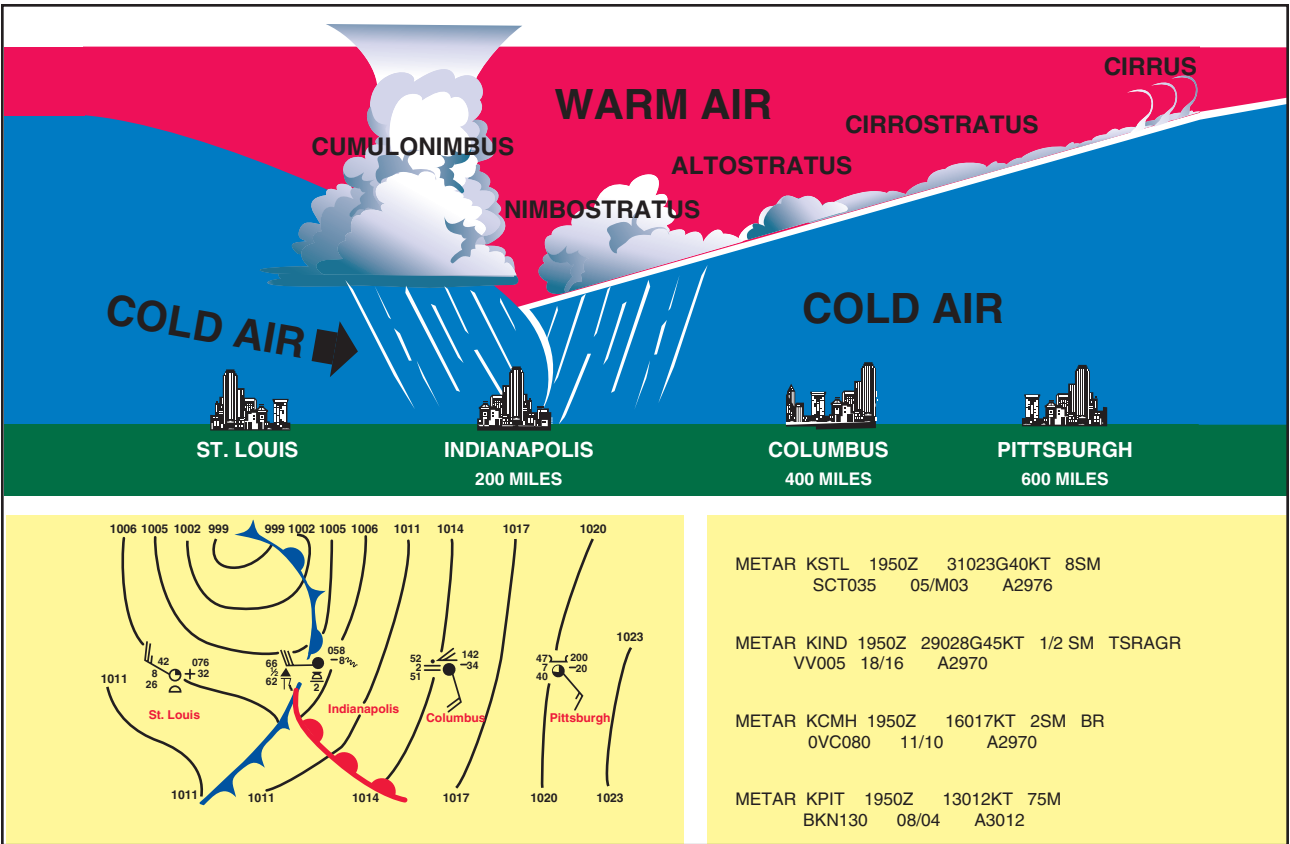
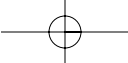
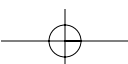
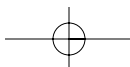
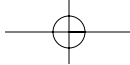


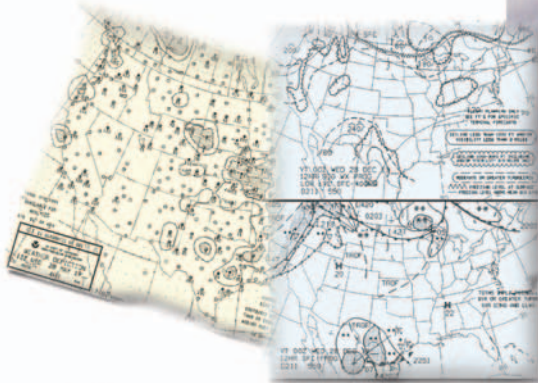
Figure 10-28. Occluded front cross-section with a weather chart depiction and associated METAR.







## Chapter 11



# Weather Reports, Forecasts, and Charts

In aviation, weather service is a combined effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), the Department of Defense (DOD), and other aviation groups and individuals. Because of the increasing need for worldwide weather services, foreign weather organizations also provide vital input.

While weather forecasts are not 100 percent accurate, meteorologists, through careful scientific study and computer modeling, have the ability to predict the weather patterns, trends, and characteristics with increasing accuracy. Through a complex system of weather services, government agencies, and independent weather observers, pilots and other aviation professionals receive the benefit of this vast knowledge base in the form of up-to-date weather reports and forecasts. These reports and forecasts enable pilots to make informed decisions regarding weather and flight safety.

### OBSERVATIONS

The data gathered from surface and upper altitude observations form the basis of all weather forecasts, advisories, and briefings. There are three types of weather observations: surface, upper air, and radar.

### SURFACE AVIATION WEATHER OBSERVATIONS

Surface aviation weather observations (METARs) are a compilation of weather elements of the current weather at ground stations across the United States. The network is made up of government run facilities and privately contracted facilities that provide up-to-date

weather information. Automated weather sources such as **automated weather observing systems** (AWOS) and **automated surface observing systems** (ASOS), as well as other automated facilities, also play a major role in the gathering of surface observations.

Surface observations provide local weather conditions and other relevant information. This information includes the type of report, station identifier, date and time, modifier (as required), wind, visibility, runway visual range (RVR), weather phenomena, sky condition, temperature/dewpoint, altimeter reading, and applicable remarks. The information gathered for the surface observation may be from a person, an automated station, or an automated station that is updated or enhanced by a weather observer. In any form, the surface observation provides valuable information about airports around the country.

### UPPER AIR OBSERVATIONS

Observations of upper air weather prove to be more challenging than surface observations. There are only two methods by which upper air weather phenomena can be observed: **radiosonde** observations and pilot

**Automated Weather Observing System (AWOS)**—Automated weather reporting system consisting of various sensors, a processor, a computer-generated voice subsystem, and a transmitter to broadcast weather data.

**Automated Surface Observation System (ASOS)**—Weather reporting system which provides surface observations every minute via digitized voice broadcasts and printed reports.

**Radiosonde**—A weather instrument that observes and reports meteorological conditions from the upper atmosphere. This instrument is typically carried into the atmosphere by some form of weather balloon.

weather reports (PIREPs). Using radio telemetry, radiosonde observations are made by sounding balloons from which weather data is received twice daily. These upper air observations provide temperature, humidity, pressure, and wind data for heights up to and above 100,000 feet. In addition to this, pilots provide vital information regarding upper air weather observations. Pilots remain the only real-time source of information regarding turbulence, icing, and cloud heights, which is gathered from pilots in flight, through the filing of pilot weather reports or PIREPs. Together, pilot reports and radiosonde observations provide information on upper air conditions important for flight planning. Many U.S. and international airlines have equipped their aircraft with instrumentation that automatically transmits in-flight weather observations through the DataLink system to the airline dispatcher who disseminates the data to appropriate weather forecasting authorities.

### **RADAR OBSERVATIONS**

Weather observers use three types of radar to provide information about precipitation, wind, and weather systems. The WSR-88D NEXRAD radar, commonly called Doppler radar, provides in-depth observations that inform surrounding communities of impending weather. FAA terminal doppler weather radar (TDWR), installed at some major airports around the country, also aids in providing severe weather alerts and warnings to airport traffic controllers. Terminal radar ensures pilots are aware of wind shear, gust fronts, and heavy precipitation, all of which are dangerous to arriving and departing aircraft. The third type of radar commonly used in the detection of precipitation is the FAA airport surveillance radar. This radar is used primarily to detect aircraft; however, it also detects the location and intensity of precipitation which is used to route aircraft traffic around severe weather in an airport environment.

### **SERVICE OUTLETS**

Service outlets are government or private facilities that provide aviation weather services. Several different government agencies, including the Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), and the National Weather Service (NWS) work in conjunction with private aviation companies to provide different means of accessing weather information.

### **FAA FLIGHT SERVICE STATION**

The FAA Flight Service Station (FSS) is the primary source for preflight weather information. A preflight weather briefing from an automated FSS (AFSS) can be obtained 24 hours a day by calling 1-800-WX BRIEF almost anywhere in the U.S. In areas not served by an AFSS, National Weather Service facilities may

provide pilot weather briefings. Telephone numbers for NWS facilities and additional numbers for FSSs/AFSSs can be found in the *Airport/Facility Directory (A/FD)* or in the U.S. Government section of the telephone book.

Flight Service Stations also provide in-flight weather briefing services, as well as scheduled and unscheduled weather broadcasts. An FSS may also furnish weather advisories to flights within the FSS region of authority.

### **TRANSCRIBED INFORMATION BRIEFING SERVICE (TIBS)**

The Transcribed Information Briefing Service (TIBS) is a service which is prepared and disseminated by selected Automated Flight Service Stations. It provides continuous telephone recordings of meteorological and aeronautical information. Specifically, TIBS provides area and route briefings, airspace procedures, and special announcements. It is designed to be a preliminary briefing tool and is not intended to replace a standard briefing from an FSS specialist.

The TIBS service is available 24 hours a day and is updated when conditions change, but it can only be accessed by a TOUCH-TONE® phone. The phone numbers for the TIBS service are listed in the A/FD.

### **DIRECT USER ACCESS TERMINAL SERVICE (DUATS)**

The Direct User Access Terminal Service, which is funded by the FAA, allows any pilot with a current medical certificate to access weather information and file a flight plan via computer. Two methods of access are available to connect with DUATS. The first is on the Internet through DynCorp at <http://www.duats.com> or Data Transformation Corporation at <http://www.duat.com>. The second method requires a modem and a communications program supplied by a DUATS provider. To access the weather information and file a flight plan by this method, pilots use a toll free telephone number to connect the user's computer directly to the DUATS computer. The current vendors of DUATS service and the associated phone numbers are listed in Chapter 7 of the *Aeronautical Information Manual (AIM)*.

### **ENROUTE FLIGHT ADVISORY SERVICE**

A service specifically designed to provide timely enroute weather information upon pilot request is known as the enroute flight advisory service (EFAS), or Flight Watch. EFAS provides a pilot with weather advisories tailored to the type of flight, route, and cruising altitude. EFAS can be one of the best sources for current weather information along the route of flight.

A pilot can usually contact an EFAS specialist from 6 a.m. to 10 p.m. anywhere in the conterminous U.S. and

Puerto Rico. The common EFAS frequency, 122.0 MHz, is established for pilots of aircraft flying between 5,000 feet AGL and 17,500 feet MSL.

### HAZARDOUS IN-FLIGHT WEATHER ADVISORY (HIWAS)

HIWAS is a national program for broadcasting hazardous weather information continuously over selected nav aids. The broadcasts include advisories such as **AIRMETS**, **SIGMETS**, **convective SIGMETS**, and **urgent PIREPs**. These broadcasts are only a summary of the information, and pilots should contact an FSS or EFAS for detailed information. Nav aids that have HIWAS capability are depicted on sectional charts with an “H” in the upper right corner of the identification box. [Figure 11-1]

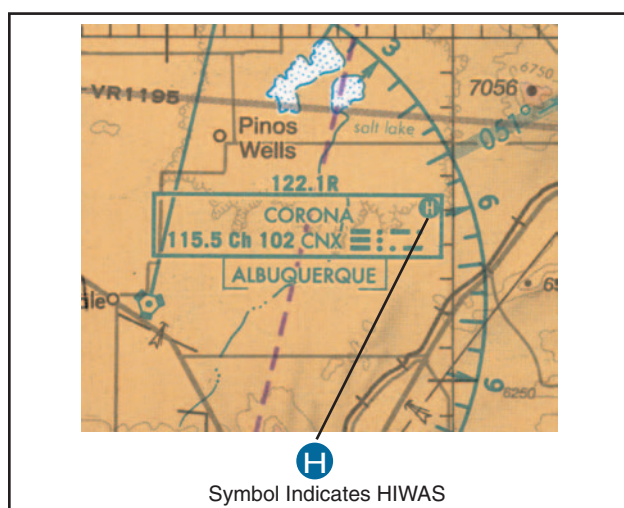


Figure 11-1. HIWAS availability is shown on sectional chart.

### TRANSCRIBED WEATHER BROADCAST (TWEB)

A transcribed weather broadcast is a weather report transmitted continuously over selected nav aids. On a sectional chart, a “T” in the upper right-hand corner of the navaid box indicates TWEB availability. TWEB weather usually consists of route-orientated data

**AIRMET**—In-flight weather advisory concerning moderate icing, moderate turbulence, sustained winds of 30 knots or more at the surface, and widespread areas of ceilings less than 1,000 feet and/or visibility less than 3 miles.

**SIGMET**—An in-flight weather advisory that is considered significant to all aircraft. SIGMET criteria include severe icing, severe and extreme turbulence, duststorms, sandstorms, volcanic eruptions, and volcanic ash that lower visibility to less than 3 miles.

**Convective SIGMET**—A weather advisory concerning convective weather significant to the safety of all aircraft. Convective SIGMETs are issued for tornadoes, lines of thunderstorms, thunderstorms over a wide area, embedded thunderstorms, wind gusts to 50 knots or greater, and/or hail  $\frac{3}{4}$  inch in diameter or greater.

**Urgent PIREP**—Any pilot report that contains any of the following weather phenomena: tornadoes, funnel clouds, or waterspouts; severe or extreme turbulence, including clear air turbulence; severe icing; hail; volcanic ash; or low-level wind shear.

including route forecasts, forecast outlook, winds aloft, and other selected weather reports for an area within 50 nautical miles (NM) of the FSS or for a 50-mile wide corridor along a specific route. A TWEB forecast is valid for 12 hours and is updated four times a day.

### WEATHER BRIEFINGS

Prior to every flight, pilots should gather all information vital to the nature of the flight. This includes an appropriate weather briefing obtained from a specialist at an FSS, AFSS, or NWS.

For weather specialists to provide an appropriate weather briefing, they need to know which of the three types of briefings is needed—a standard briefing, an abbreviated briefing, or an outlook briefing. Other helpful information is whether the flight is visual flight rule (VFR) or instrument flight rule (IFR), aircraft identification and type, departure point, estimated time of departure (ETD), flight altitude, route of flight, destination, and estimated time en route (ETE).

This information is recorded in the flight plan system, and a note is made regarding the type of weather briefing provided. If necessary, it can be referenced later to file or amend a flight plan. It is also used when an aircraft is overdue or is reported missing.

### STANDARD BRIEFING

A standard briefing is the most complete report and provides the overall weather picture. This type of briefing should be obtained prior to the departure of any flight and should be used during flight planning. A standard briefing provides the following information in sequential order if it is applicable to the route of flight.

1. **Adverse Conditions**—This includes information about adverse conditions that may influence a decision to cancel or alter the route of flight. Adverse conditions includes significant weather, such as thunderstorms or aircraft icing, or other important items such as airport closings.
2. **VFR Flight NOT RECOMMENDED**—If the weather for the route of flight is below VFR minimums, or if it is doubtful the flight could be made under VFR conditions due to the forecast weather, the briefer may state that VFR is not recommended. It is the pilot's decision whether or not to continue the flight under VFR, but this advisory should be weighed carefully.
3. **Synopsis**—The synopsis is an overview of the larger weather picture. Fronts and major weather systems that affect the general area are provided.



4. **Current Conditions**—This portion of the briefing contains the current ceilings, visibility, winds, and temperatures. If the departure time is more than 2 hours away, current conditions will not be included in the briefing.
5. **En Route Forecast**—The en route forecast is a summary of the weather forecast for the proposed route of flight.
6. **Destination Forecast**—The destination forecast is a summary of the expected weather for the destination airport at the estimated time of arrival (ETA).
7. **Winds and Temperatures Aloft**—Winds and temperatures aloft is a report of the winds at specific altitudes for the route of flight. However, the temperature information is provided only on request.
8. **Notices to Airmen**—This portion supplies NOTAM information pertinent to the route of flight which has not been published in the Notice to Airmen publication. Published NOTAM information is provided during the briefing only when requested.
9. **ATC Delays**—This is an advisory of any known air traffic control (ATC) delays that may affect the flight.
10. **Other Information**—At the end of the standard briefing, the FSS specialist will provide the radio frequencies needed to open a flight plan and to contact en route flight advisory service (EFAS). Any additional information requested is also provided at this time.

### ABBREVIATED BRIEFING

An abbreviated briefing is a shortened version of the standard briefing. It should be requested when a departure has been delayed or when specific weather information is needed to update the previous briefing. When this is the case, the weather specialist needs to know the time and source of the previous briefing so the necessary weather information will not be omitted inadvertently.

### OUTLOOK BRIEFING

An outlook briefing should be requested when a planned departure is 6 or more hours away. It provides initial forecast information that is limited in scope due to the timeframe of the planned flight. This type of briefing is a good source of flight planning information that can influence decisions regarding route of flight, altitude, and ultimately the go, no-go decision. A

follow-up briefing prior to departure is advisable since an outlook briefing generally only contains information based on weather trends and existing weather in geographical areas at or near the departure airport.

## AVIATION WEATHER REPORTS

Aviation weather reports are designed to give accurate depictions of current weather conditions. Each report provides current information that is updated at different times. Some typical reports are aviation routine weather reports (METAR), pilot weather reports (PIREPs), and radar weather reports (SDs).

### AVIATION ROUTINE WEATHER REPORT (METAR)

An aviation routine weather report, or METAR, is an observation of current surface weather reported in a standard international format. While the METAR code has been adopted worldwide, each country is allowed to make modifications to the code. Normally, these differences are minor but necessary to accommodate local procedures or particular units of measure. This discussion of METAR will cover elements used in the United States.

#### Example:

```
METAR KGGG 161753Z AUTO 14021G26 3/4SM
+TSRA BR BKN008 OVC012CB 18/17 A2970 RMK
PRESFR
```

A typical METAR report contains the following information in sequential order:

1. **Type of Report**—There are two types of METAR reports. The first is the routine METAR report that is transmitted every hour. The second is the aviation selected special weather report (SPECI). This is a special report that can be given at any time to update the **METAR** for rapidly changing weather conditions, aircraft mishaps, or other critical information.
2. **Station Identifier**—Each station is identified by a four-letter code as established by the International Civil Aviation Organization (ICAO). In the 48 contiguous states, a unique three-letter identifier is preceded by the letter "K." For example, Gregg County Airport in Longview, Texas, is identified by the letters "KGGG," K being the country designation and GGG being the airport identifier. In other regions of the world, including Alaska and Hawaii, the first two letters of the four-letter ICAO identifier indicate the region, country,



or state. Alaska identifiers always begin with the letters “PA” and Hawaii identifiers always begin with the letters “PH.” A list of station identifiers can be found at an FSS or NWS office.

3. **Date and Time of Report**—The date and time (**161753Z**) are depicted in a six-digit group. The first two digits of the six-digit group are the date. The last four digits are the time of the METAR, which is always given in Coordinated Universal Time (UTC). A “Z” is appended to the end of the time to denote the time is given in **Zulu time** (UTC) as opposed to local time.
4. **Modifier**—Modifiers denote that the METAR came from an automated source or that the report was corrected. If the notation “**AUTO**” is listed in the METAR, the report came from an automated source. It also lists “**AO1**” or “**AO2**” in the remarks section to indicate the type of precipitation sensors employed at the automated station.

When the modifier “**COR**” is used, it identifies a corrected report sent out to replace an earlier report that contained an error.

**Example:**

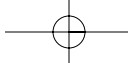
METAR KGGG 161753Z COR

5. **Wind**—Winds are reported with five digits (**14021**) unless the speed is greater than 99 knots, in which case the wind is reported with six digits. The first three digits indicate the direction the wind is blowing in tens of degrees. If the wind is variable, it is reported as “**VRB**.” The last two digits indicate the speed of the wind in knots (KT) unless the wind is greater than 99 knots, in which case it is indicated by three digits. If the winds are gusting, the letter “**G**” follows the windspeed (**G26**). After the letter “**G**,” the peak gust recorded is provided. If the wind varies more than 60° and the windspeed is greater than 6 knots, a separate group of numbers, separated by a “**V**,” will indicate the extremes of the wind directions.
6. **Visibility**—The prevailing visibility (**3/4 SM**) is reported in statute miles as denoted by the letters “**SM**.” It is reported in both miles and fractions of miles. At times, RVR, or runway visual range is reported following the

**Zulu Time**—A term used in aviation for coordinated universal time (UTC) which places the entire world on one time standard.

prevailing visibility. RVR is the distance a pilot can see down the runway in a moving aircraft. When RVR is reported, it is shown with an R, then the runway number followed by a slant, then the visual range in feet. For example, when the RVR is reported as **R17L/1400FT**, it translates to a visual range of 1,400 feet on runway 17 left.

7. **Weather**—Weather can be broken down into two different categories: qualifiers and weather phenomenon (**+TSRA BR**). First, the qualifiers of intensity, proximity, and the descriptor of the weather will be given. The intensity may be light (-), moderate ( ), or heavy (+). Proximity only depicts weather phenomena that are in the airport vicinity. The notation “**VC**” indicates a specific weather phenomenon is in the vicinity of 5 to 10 miles from the airport. Descriptors are used to describe certain types of precipitation and obscurations. Weather phenomena may be reported as being precipitation, obscurations, and other phenomena such as squalls or funnel clouds. Descriptions of weather phenomena as they begin or end, and hailstone size are also listed in the remarks sections of the report. [Figure 11-2]
8. **Sky Condition**—Sky condition (**BKN008 OVC012CB**) is always reported in the sequence of amount, height, and type or indefinite ceiling/height (vertical visibility). The heights of the cloud bases are reported with a three-digit number in hundreds of feet above the ground. Clouds above 12,000 feet are not detected or reported by an automated station. The types of clouds, specifically towering cumulus (TCU) or cumulonimbus (CB) clouds, are reported with their height. Contractions are used to describe the amount of cloud coverage and obscuring phenomena. The amount of sky coverage is reported in eighths of the sky from horizon to horizon. [Figure 11-3]
9. **Temperature and Dewpoint**—The air temperature and dewpoint are always given in degrees Celsius (**18/17**). Temperatures below 0°C are preceded by the letter “**M**” to indicate minus.
10. **Altimeter Setting**—The altimeter setting is reported as inches of mercury in a four-digit number group (**A2970**). It is always preceded by the letter “**A**.” Rising or falling pressure may also be denoted in the remarks sections as “**PRESRR**” or “**PRESFR**” respectively.



Qualifier		Weather Phenomena		
Intensity or Proximity 1	Descriptor 2	Precipitation 3	Obscuration 4	Other 5
- Light  Moderate (no qualifier)  + Heavy  VC in the vicinity	<b>MI</b> Shallow <b>BC</b> Patches <b>DR</b> Low Drifting <b>BL</b> Blowing <b>SH</b> Showers <b>TS</b> Thunderstorms <b>FZ</b> Freezing <b>PR</b> Partial	<b>DZ</b> Drizzle <b>RA</b> Rain <b>SN</b> Snow <b>SG</b> Snow grains <b>IC</b> Ice Crystals (diamond dust) <b>PL</b> Ice Pellets <b>GR</b> Hail <b>GS</b> Small hail or snow pellets <b>UP</b> *Unknown Precipitation	<b>BR</b> Mist <b>FG</b> Fog <b>FU</b> Smoke <b>DU</b> Dust <b>SA</b> Sand <b>HZ</b> Haze <b>PY</b> Spray <b>VA</b> Volcanic ash	<b>PO</b> Dust/sand whirls <b>SQ</b> Squalls <b>FC</b> Funnel cloud <b>+FC</b> Tornado or Waterspout <b>SS</b> Sandstorm <b>DS</b> Dust storm
The weather groups are constructed by considering columns 1-5 in this table, in sequence; i.e., intensity, followed by descriptor, followed by weather phenomena; i.e., heavy rain showers(s) is coded as +SHRA. * Automated stations only				

Figure 11-2. Descriptors and weather phenomena used in a typical METAR.

Sky Cover	Less than 1/8 (Clear)	1/8 - 2/8 (Few)	3/8 - 4/8 (Scattered)	5/8 - 7/8 (Broken)	8/8 or Overcast (Overcast)
Contraction	<b>SKC</b> <b>CLR</b> <b>FEW</b>	<b>FEW</b>	<b>SCT</b>	<b>BKN</b>	<b>OVC</b>

Figure 11-3. Reportable contractions for sky condition.

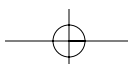
**11. Remarks**—Comments may or may not appear in this section of the METAR. The information contained in this section may include wind data, variable visibility, beginning and ending times of particular phenomenon, pressure information, and various other information deemed necessary. An example of a remark regarding weather phenomenon that does not fit in any other category would be: OCNL LTGICCG. This translates as occasional lightning in the clouds, and from cloud to ground. Automated stations also use the remarks section to indicate the equipment needs maintenance. The remarks section always begins with the letters “**RMK.**”

**Example:**

METAR BTR 161753Z 14021G26 3/4SM -RA BR BKN008 OVC012 18/17 A2970 RMK PRESFR

**Explanation:**

Type of Report: .....Routine METAR  
 Location: .....Baton Rouge, Louisiana  
 Date: .....16<sup>th</sup> day of the month  
 Time: .....1753 Zulu  
 Modifier: .....None shown  
 Wind Information: .....Winds 140° at 21 knots gusting to 26 knots  
 Visibility: .....3/4 statute mile  
 Weather: .....light rain and mist  
 Sky Conditions: .....Skies broken 800 feet, overcast 1,200  
 Temperature: .....Temperature 18°C, dewpoint 17°C  
 Altimeter: .....29.70 in. Hg.  
 Remarks: .....Barometric pressure is falling.





### RADAR WEATHER REPORTS (SD)

Areas of precipitation and thunderstorms are observed by radar on a routine basis. Radar weather reports are issued by radar stations at 35 minutes past the hour, with special reports issued as needed.

Radar weather reports provide information on the type, intensity, and location of the echo top of the precipitation. [Figure 11-5] These reports may also include direction and speed of the area of precipitation as well as the height and base of the precipitation in hundreds of feet MSL. RAREPs are especially valuable for preflight planning to help avoid areas of severe weather. However, radar only detects objects in the atmosphere that are large enough to be considered precipitation. Cloud bases and tops, ceilings, and visibility are not detected by radar.

A typical RAREP will include:

- Location identifier and time of radar observation.

SYMBOL	MEANING
R	Rain
RW	Rain Shower
S	Snow
SW	Snow Shower
T	Thunderstorm
SYMBOL	INTENSITY
-	Light
(none)	Moderate
+	Heavy
++	Very Heavy
X	Intense
XX	Extreme
CONTRACTION	OPERATIONAL STATUS
PPINE	Radar is operating normally but there are no echoes being detected.
PPINA	Radar observation is not available.
PPIOM	Radar is inoperative or out of service.
AUTO	Automated radar report from WSR-88D.

Figure 11-5. Radar weather report codes.

- Echo pattern:
  1. Line (LN)—A line of precipitation echoes at least 30 miles long, at least four times as long as it is wide, and at least 25 percent coverage within the line.
  2. Area (AREA)—A group of echoes of similar type and not classified as a line.
  3. Single Cell (CELL)—A single isolated convective echo such as a rain shower.
- Area coverage in tenths.
- Type and intensity of weather.
- Azimuth, referenced to true north, and range, in nautical miles, from the radar site, of points defining the echo pattern. For lines and areas, there will be two azimuth and range sets that define the pattern. For cells, there will be only one azimuth and range set.
- Dimension of echo pattern—The dimension of an echo pattern is given when the azimuth and range define only the center line of the pattern.
- Cell movement—Movement is only coded for cells; it will not be coded for lines or areas.
- Maximum top of precipitation and location. Maximum tops may be coded with the symbols “MT” or “MTS.” If it is coded with “MTS,” it means that satellite data as well as radar information was used to measure the top of the precipitation.
- If the word “AUTO” appears in the report, it means the report is automated from WSR-88D weather radar data.
- The last section is primarily used to prepare radar summary charts, but can be used during preflight to determine the maximum precipitation intensity within a specific grid box. The higher the number, the greater the intensity. Two or more numbers appearing after a grid box reference, such as PM34, indicates precipitation in consecutive grid boxes.

**Example:**

TLX 1935 LN 8 TRW++ 86/40 199/115  
 20W C2425 MTS 570 AT 159/65 AUTO  
 ^MO1 NO2 ON3 PM34 QM3 RL2=



**Explanation:**

The radar report gives the following information: The report is automated from Oklahoma City and was made at 1935 UTC. The echo pattern for this radar report indicates a line of echos covering 8/10ths of the area. Thunderstorms and very heavy rain showers are indicated. The next set of numbers indicate the azimuth that defines the echo (86° at 40 NM and 199° at 115 NM). Next, the dimension of this echo is given as 20 nautical miles wide (10 nautical miles on either side of the line defined by the azimuth and range). The cells within the line are moving from 240° at 25 knots. The maximum top of the precipitation, as determined by radar and satellite, is 57,000 feet and it is located on the 159° radial, 65 NM out. The last line indicates the intensity of the precipitation, for example in grid QM the intensity is 3 or heavy precipitation. (1 is light and 6 is extreme.)

**AVIATION FORECASTS**

Observed weather condition reports are often used in the creation of forecasts for the same area. A variety of different forecast products are produced and designed to be used in the preflight planning stage. The printed forecasts that pilots need to be familiar with are the terminal aerodrome forecast (TAF), aviation area forecast (FA), in-flight weather advisories (SIGMET, AIRMET), and the winds and temperatures aloft forecast (FD).

**TERMINAL AERODROME FORECASTS (TAF)**

A terminal aerodrome forecast is a report established for the 5 statute mile radius around an airport. TAF reports are usually given for larger airports. Each TAF is valid for a 24-hour time period, and is updated four times a day at 0000Z, 0600Z, 1200Z, and 1800Z. The TAF utilizes the same descriptors and abbreviations as used in the METAR report.

The terminal forecast includes the following information in sequential order:

1. **Type of Report**—A TAF can be either a routine forecast (TAF) or an amended forecast (TAF AMD).
2. **ICAO Station Identifier**—The station identifier is the same as that used in a METAR.
3. **Date and Time of Origin**—Time and date of TAF origination is given in the six-number code with the first two being the date, the last four being the time. Time is always given in UTC as denoted by the Z following the number group.
4. **Valid Period Date and Time**—The valid forecast time period is given by a six-digit number group. The first two numbers indicate the date, followed by the two-digit beginning time for the valid period, and the last two digits are the ending time.
5. **Forecast Wind**—The wind direction and speed forecast are given in a five-digit number group. The first three indicate the direction of the wind in reference to true north. The last two digits state the windspeed in knots as denoted by the letters “KT.” Like the METAR, winds greater than 99 knots are given in three digits.
6. **Forecast Visibility**—The forecast visibility is given in statute miles and may be in whole numbers or fractions. If the forecast is greater than 6 miles, it will be coded as “P6SM.”
7. **Forecast Significant Weather**—Weather phenomenon is coded in the TAF reports in the same format as the METAR. If no significant weather is expected during the forecast time period, the denotation “NSW” will be included in the “becoming” or “temporary” weather groups.
8. **Forecast Sky Condition**—Forecast sky conditions are given in the same manner as the METAR. Only cumulonimbus (CB) clouds are forecast in this portion of the TAF report as opposed to CBs and towering cumulus in the METAR.
9. **Forecast Change Group**—For any significant weather change forecast to occur during the TAF time period, the expected conditions and time period are included in this group. This information may be shown as From (FM), Becoming (BECMG), and Temporary (TEMPO). “From” is used when a rapid and significant change, usually within an hour, is expected. “Becoming” is used when a gradual change in the weather is expected over a period of no more than 2 hours. “Temporary” is used for temporary fluctuations of weather, expected to last for less than an hour.
10. **Probability Forecast**—The probability forecast is given percentage that describes the probability of thunderstorms and precipitation occurring in the coming hours. This forecast is not used for the first 6 hours of the 24-hour forecast.



**Example:**

TAF  
 KPIR 111130Z 111212 15012KT P6SM BKN090  
 TEMPO 1214 5SM BR  
 FM1500 16015G25KT P6SM SCT040 BKN250  
 FM0000 14012KT P6SM BKN080 OVC150 PROB40  
 0004 3SM TSRA BKN030CB  
 FM0400 1408KT P6SM SCT040 OVC080 TEMPO  
 0408 3SM TSRA OVC030CB  
 BECMG 0810 32007KT=

**Explanation:**

Routine TAF for Pierre, South Dakota...on the 11<sup>th</sup> day of the month, at 1130Z...valid for 24 hours from 1200Z on the 11<sup>th</sup> to 1200Z on the 12<sup>th</sup>...wind from 150° at 12 knots...visibility greater than 6 statute miles...broken clouds at 9,000 feet...temporarily, between 1200Z and 1400Z, visibility 5 statute miles in mist...from 1500Z winds from 160° at 15 knots, gusting to 25 knots visibility greater than 6 statute miles...clouds scattered at 4,000 feet and broken at 25,000 feet...from 0000Z wind from 140° at 12 knots...visibility greater than 6 statute miles...clouds broken at 8,000 feet, overcast at 15,000 feet...between 0000Z and 0400Z, there is 40 percent probability of visibility 3 statute miles...thunderstorm with moderate rain showers...clouds broken at 3,000 feet with cumulonimbus clouds...from 0400Z...winds from 140° at 8 knots...visibility greater than 6 miles...clouds at 4,000 scattered and overcast at 8,000...temporarily between 0400Z and 0800Z...visibility 3 miles...thunderstorms with moderate rain showers...clouds overcast at 3,000 feet with cumulonimbus clouds...becoming between 0800Z and 1000Z...wind from 320° at 7 knots...end of report (=).

**AREA FORECASTS (FA)**

The aviation area forecast (FA) gives a picture of clouds, general weather conditions, and visual meteorological conditions (VMC) expected over a large area encompassing several states. There are six areas for which area forecasts are published in the contiguous 48 states. Area forecasts are issued three times a day and are valid for 18 hours. This type of forecast gives information vital to en route operations as well as forecast information for smaller airports that do not have terminal forecasts.

Area forecasts are typically disseminated in four sections and include the following information:

1. **Header**—This gives the location identifier of the source of the FA, the date and time of issuance, the valid forecast time, and the area of coverage.

11-10

**Example:**

DFWC FA 120945  
 SYNOPSIS AND VFR CLDS/WX  
 SYNOPSIS VALID UNTIL 130400  
 CLDS/WX VALID UNTIL 122200...OTLK VALID  
 122200-130400  
 OK TX AR LA MS AL AND CSTL WTRS

**Explanation:**

The area forecast shows information given by Dallas Fort Worth, for the region of Oklahoma, Texas, Arkansas, Louisiana, Mississippi, and Alabama, as well as a portion of the gulf coastal waters. It was issued on the 12<sup>th</sup> day of the month at 0945. The synopsis is valid from the time of issuance until 0400 hours on the 13<sup>th</sup>. VFR clouds and weather information on this area forecast is valid until 2200 hours on the 12<sup>th</sup> and the outlook is valid until 0400 hours on the 13<sup>th</sup>.

2. **Precautionary Statements**—IFR conditions, mountain obscurations, and thunderstorm hazards are described in this section. Statements made here regarding height are given in MSL, and if given otherwise, AGL or CIG (ceiling) will be noted.

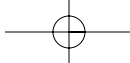
**Example:**

SEE AIRMET SIERRA FOR IFR CONDS AND  
 MTN OBSCN.  
 TS IMPLY SEV OR GTR TURB SEV ICE LLWS  
 AND IFR CONDS.  
 NON MSL HGTS DENOTED BY AGL OR CIG.

**Explanation:**

The area forecast covers VFR clouds and weather, so the precautionary statement warns that AIRMET Sierra should be referenced for IFR conditions and mountain obscuration. The code TS indicates the possibility of thunderstorms and implies there may be an occurrence of severe or greater turbulence, severe icing, low-level wind shear, and IFR conditions. The final line of the precautionary statement alerts the user that heights, for the most part, are mean sea level (MSL). Those that are not MSL will be above ground level (AGL) or ceiling (CIG).

3. **Synopsis**—The synopsis gives a brief summary identifying the location and movement of pressure systems, fronts, and circulation patterns.



**Example:**

SYNOPSIS...LOW PRES TROF 10Z OK/TX PNHDL AREA FCST MOV EWD INTO CNTRL-SWRN OK BY 04Z. WRMFNT 10Z CNTRL OK-SRN AR-NRN MS FCST LIFT NWD INTO NERN OK-NRN AR EXTRM NRN MS BY 04Z.

**Explanation:**

As of 1000 Zulu, there is a low pressure trough over the Oklahoma and Texas panhandle area, which is forecast to move eastward into central southwestern Oklahoma by 0400 Zulu. A warm front located over central Oklahoma, southern Arkansas, and northern Mississippi at 1000 Zulu is forecast to lift northwestward into northeastern Oklahoma, northern Arkansas, and extreme northern Mississippi by 0400 Zulu.

- 4. **VFR Clouds and Weather**—This section lists expected sky conditions, visibility, and weather for the next 12 hours and an outlook for the following 6 hours.

**Example:**

S CNTRL AND SERN TX AGL SCT-BKN010. TOPS 030. VIS 3-5SM BR. 14-16Z BECMG AGL SCT030. 19Z AGL SCT050. OTLK...VFR

**OK**

PNDL AND NW...AGL SCT030 SCT-BKN100. TOPS FL200. 15Z AGL SCT040 SCT100. AFT 20Z SCT TSRA DVLPG..FEW POSS SEV. CB TOPS FL450. OTLK...VFR

**Explanation:**

In south central and southeastern Texas, there is a scattered to broken layer of clouds from 1,000 feet AGL with tops at 3,000 feet, visibility is 3 to 5 statute miles in mist. Between 1400 Zulu and 1600 Zulu, the cloud bases are expected to increase to 3,000 feet AGL. After 1900 Zulu, the cloud bases are expected to continue to increase to 5,000 feet AGL and the outlook is VFR.

In northwestern Oklahoma and panhandle, the clouds are scattered at 3,000 feet with another scattered to broken layer at 10,000 feet AGL, with the tops at 20,000 feet. At 1500 Zulu, the lowest cloud base is expected to increase to 4,000 feet AGL with a scattered layer at 10,000 feet AGL. After 2000 Zulu, the forecast calls for scattered thunderstorms with rain developing and a few becoming severe; the cumulonimbus clouds will have tops at flight level 450 or 45,000 feet MSL.

It should be noted that when information is given in the area forecast, locations may be given by states, regions, or specific geological features such as mountain ranges. Figure 11-6 shows an area forecast chart with

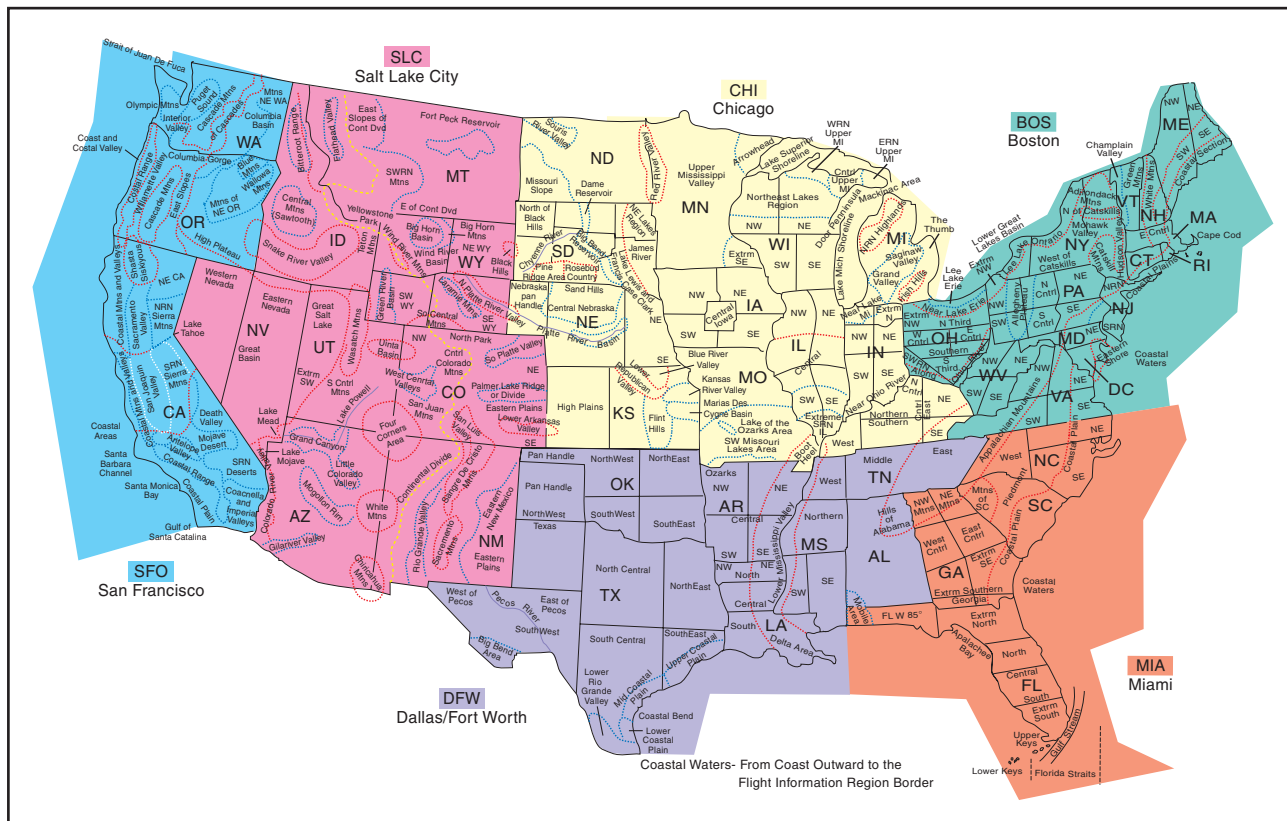
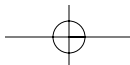


Figure 11-6. Area forecast region map.



six regions of forecast, states, regional areas, and common geographical features.

### IN-FLIGHT WEATHER ADVISORIES

In-flight weather advisories, which are provided to en route aircraft, are forecasts that detail potentially hazardous weather. These advisories are also available to pilots prior to departure for flight planning purposes. An in-flight weather advisory is issued in the form of either an AIRMET, SIGMET, or Convective SIGMET.

### AIRMAN'S METEOROLOGICAL INFORMATION (AIRMET)

AIRMETs (WAs) are examples of in-flight weather advisories that are issued every 6 hours with intermediate updates issued as needed for a particular area forecast region. The information contained in an AIRMET is of operational interest to all aircraft, but the weather section concerns phenomena considered potentially hazardous to light aircraft and aircraft with limited operational capabilities.

An AIRMET includes forecast of moderate icing, moderate turbulence, sustained surface winds of 30 knots or greater, widespread areas of ceilings less than 1,000 feet and/or visibilities less than 3 miles, and extensive mountain obscurement.

Each AIRMET bulletin has a fixed alphanumeric designator, numbered sequentially for easy identification, beginning with the first issuance of the day. SIERRA is the AIRMET code used to denote instrument flight rules (IFR) and mountain obscuration; TANGO is used to denote turbulence, strong surface winds, and low-level wind shear; and ZULU is used to denote icing and freezing levels.

#### Example:

DFWT WA 241650  
AIRMET TANGO UPDT 3 FOR TURBC... STG  
SFC WINDS AND LLWS VALID UNTIL 242000

AIRMET TURBC... OK TX...UPDT  
FROM OKC TO DFW TO SAT TO MAF TO CDS  
TO OKC OCNL MDT TURBC BLO 60 DUE TO  
STG AND GUSTY LOW LVL WINDS. CONDS  
CONTG BYD 2000Z

#### Explanation:

This AIRMET was issued by Dallas Fort Worth on the 24<sup>th</sup> day of the month, at 1650 Zulu time. On this third update, the AIRMET Tango is issued for turbulence, strong surface winds, and low-level wind shear until 2000 Zulu on the same day. The turbulence section of the AIRMET is an update for Oklahoma and Texas. It

defines an area from Oklahoma City to Dallas, Texas, to San Antonio, to Midland, Texas, to Childress, Texas, to Oklahoma City that will experience occasional moderate turbulence below 6,000 feet due to strong and gusty low-level winds. It also notes that these conditions are forecast to continue beyond 2000 Zulu.

### SIGNIFICANT METEOROLOGICAL INFORMATION (SIGMET)

SIGMETs (WSs) are in-flight advisories concerning non-convective weather that is potentially hazardous to all aircraft. They report weather forecasts that include severe icing not associated with thunderstorms, severe or extreme turbulence or clear air turbulence (CAT) not associated with thunderstorms, dust storms or sandstorms that lower surface or in-flight visibilities to below 3 miles, and volcanic ash.

SIGMETs are unscheduled forecasts that are valid for 4 hours, but if the SIGMET relates to hurricanes, it is valid for 6 hours.

A SIGMET is issued under an alphabetic identifier, from November through Yankee, excluding Sierra and Tango. The first issuance of a SIGMET is designated as a UWS, or Urgent Weather SIGMET. Re-issued SIGMETs for the same weather phenomenon are sequentially numbered until the weather phenomenon ends.

#### Example:

SFOR WS 100130  
SIGMET ROME02 VALID UNTIL 100530  
OR WA  
FROM SEA TO PDT TO EUG TO SEA  
OCNL MOGR CAT BTN 280 AND 350 EXPCD  
DUE TO JTSTR.  
CONDS BNGG AFT 0200Z CONTG BYD 0530Z .

#### Explanation:

This is SIGMET Romeo 2, the second issuance for this weather phenomenon. It is valid until the 10th day of the month at 0530 Zulu time. This SIGMET is for Oregon and Washington, for a defined area from Seattle to Portland to Eugene to Seattle. It calls for occasional moderate or greater clear air turbulence between 28,000 and 35,000 feet due to the location of the jetstream. These conditions will be beginning after 0200 Zulu and will continue beyond the forecast scope of this SIGMET of 0530 Zulu.

### CONVECTIVE SIGNIFICANT METEOROLOGICAL INFORMATION (WST)

A Convective SIGMET (WST) is an in-flight weather advisory issued for hazardous convective weather that affects the safety of every flight. Convective SIGMETs

are issued for severe thunderstorms with surface winds greater than 50 knots, hail at the surface greater than or equal to 3/4 inch in diameter, or tornadoes. They are also issued to advise pilots of embedded thunderstorms, lines of thunderstorms, or thunderstorms with heavy or greater precipitation that affect 40 percent or more of a 3,000 square foot or greater region.

Convective SIGMETs are issued for each area of the contiguous 48 states but not Alaska or Hawaii. Convective SIGMETs are issued for the eastern (E), western (W), and central (C) United States. Each report is issued at 55 minutes past the hour, but special reports can be issued during the interim for any reason. Each forecast is valid for 2 hours. They are numbered sequentially each day from 1-99, beginning at 00 Zulu time. If no hazardous weather exists, the Convective SIGMET will still be issued; however, it will state "CONVECTIVE SIGMET.... NONE."

#### Example:

```
MKCC WST 221855
CONVECTIVE SIGMET 21C
VALID UNTIL 2055
KS OK TX
VCNTY GLD-CDS LINE
NO SGFNT TSTMS RPRTD
LINE TSTMS DVLPNG BY 1955Z WILL MOV EWD
30-35 KT THRU 2055Z
HAIL TO 2 IN PSBL
```

#### Explanation:

This Convective SIGMET provides the following information: The WST indicates this report is a Convective SIGMET. The current date is the 22<sup>nd</sup> of the month and it was issued at 1855 Zulu. It is Convective SIGMET number 21C, indicating that it is the 21st consecutive report issued for the central United States. This report is valid for 2 hours until 2055 Zulu time. The Convective SIGMET is for an area from Kansas to Oklahoma to Texas, in the vicinity of a line from Goodland, Kansas, to Childress, Texas. No significant thunderstorms are being reported, but a line of thunderstorms will develop by 1955 Zulu time and will move eastward at a rate of 30-35 knots through 2055 Zulu. Hail up to 2 inches in size is possible with the developing thunderstorms.

### WINDS AND TEMPERATURE ALOFT FORECAST (FD)

Winds and temperatures aloft forecasts provide wind and temperature forecasts for specific locations in the contiguous United States, including network locations in Hawaii and Alaska. The forecasts are made twice a day based on the radiosonde upper air observations taken at 0000Z and 1200Z.

Through 12,000 feet are true altitudes and above 18,000 feet are pressure altitudes. Wind direction is always in reference to true north and windspeed is given in knots. The temperature is given in degrees Celsius. No winds are forecast when a given level is within 1,500 feet of the station elevation. Similarly, temperatures are not forecast for any station within 2,500 feet of the station elevation.

If the windspeed is forecast to be greater than 100 knots but less than 199 knots, the computer adds 50 to the direction and subtracts 100 from the speed. To decode this type of data group, the reverse must be accomplished. For example, when the data appears as "731960," subtract 50 from the 73 and add 100 to the 19, and the wind would be 230° at 119 knots with a temperature of -60°C. If the windspeed is forecast to be 200 knots or greater, the wind group is coded as 99 knots. For example, when the data appears as "7799," subtract 50 from 77 and add 100 to 99, and the wind is 270° at 199 knots or greater. When the forecast windspeed is calm or less than 5 knots, the data group is coded "9900," which means light and variable. [Figure 11-7]

FD KWBC 151640							
BASED ON 151200Z DATA							
VALID 151800Z FOR USE 1700-2100Z							
TEMPS NEGATIVE ABV 24000							
FD	3000	6000	9000	12000	18000	24000	30000
AMA		2714	2725+00	2625-04	2531-15	2542-27	265842
DEN			2321-04	2532-08	2434-19	2441-31	235347

Figure 11-7. Winds and temperatures aloft forecast.

#### Explanation of figure 11-7:

The heading indicates that this FD was transmitted on the 15th of the month at 1640Z and is based on the 1200 Zulu radiosonde. The valid time is 1800 Zulu on the same day and should be used for the period between 1700Z and 2100Z. The heading also indicates that the temperatures above 24,000 feet MSL are negative. Since the temperatures above 24,000 feet are negative, the minus sign is omitted.

A 4-digit data group shows the wind direction in reference to true north, and the windspeed in knots. The elevation at Amarillo, TX (AMA) is 3,605 feet, so the lowest reportable altitude is 6,000 feet for the forecast winds. In this case, "2714" means the wind is forecast to be from 270° at a speed of 14 knots.

A 6-digit group includes the forecast temperature aloft. The elevation at Denver (DEN) is 5,431 feet, so the lowest reportable altitude is 9,000 feet for the winds and temperature forecast. In this case, "2321-04" indicates the wind is forecast to be from 230° at a speed of 21 knots with a temperature of -4°C.



## WEATHER CHARTS

Weather charts are graphic charts that depict current or forecast weather. They provide an overall picture of the United States and should be used in the beginning stages of flight planning. Typically, weather charts show the movement of major weather systems and fronts. Surface analysis, weather depiction, and radar summary charts are sources of current weather information. Significant weather prognostic charts provide an overall forecast weather picture.

### SURFACE ANALYSIS CHART

The surface analysis chart, depicts an analysis of the current surface weather. [Figure 11-8] This chart is a computer prepared report that is transmitted every 3 hours and covers the contiguous 48 states and adjacent areas. A surface analysis chart shows the areas of high and low pressure, fronts, temperatures, dewpoints, wind directions and speeds, local weather, and visual obstructions.

Surface weather observations for reporting points across the United States are also depicted on this chart. Each of these reporting points is illustrated by a station model. [Figure 11-9] A station model will include:

- **Type of Observation**—A round model indicates an official weather observer made the observation. A square model indicates the

observation is from an automated station. Stations located offshore give data from ships, buoys, or offshore platforms.

- **Sky Cover**—The station model depicts total sky cover and will be shown as clear, scattered, broken, overcast, or obscured/partially obscured.
- **Clouds**—Cloud types are represented by specific symbols. Low cloud symbols are placed beneath the station model, while middle and high cloud symbols are placed directly above the station model. Typically, only one type of cloud will be depicted with the station model.
- **Sea Level Pressure**—Sea level pressure given in three digits to the nearest tenth of a millibar. For 1000 mbs or greater, prefix a 10 to the three digits. For less than 1000 mbs, prefix a 9 to the three digits.
- **Pressure Change/Tendency**—Pressure change in tenths of millibars over the past 3 hours. This is depicted directly below the sea level pressure.
- **Precipitation**—A record of the precipitation that has fallen over the last 6 hours to the nearest hundredth of an inch.
- **Dewpoint**—Dewpoint is given in degrees Fahrenheit.

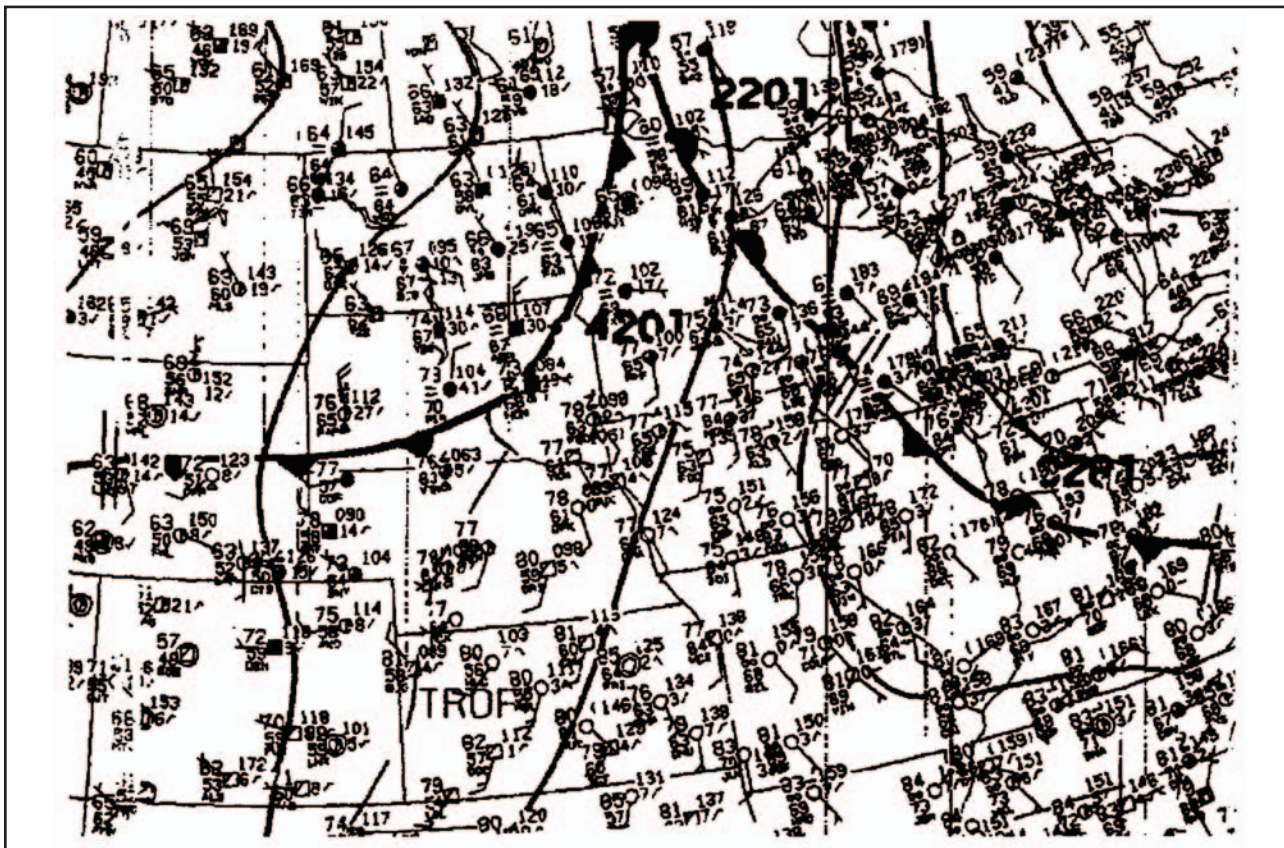


Figure 11-8. Surface analysis chart.



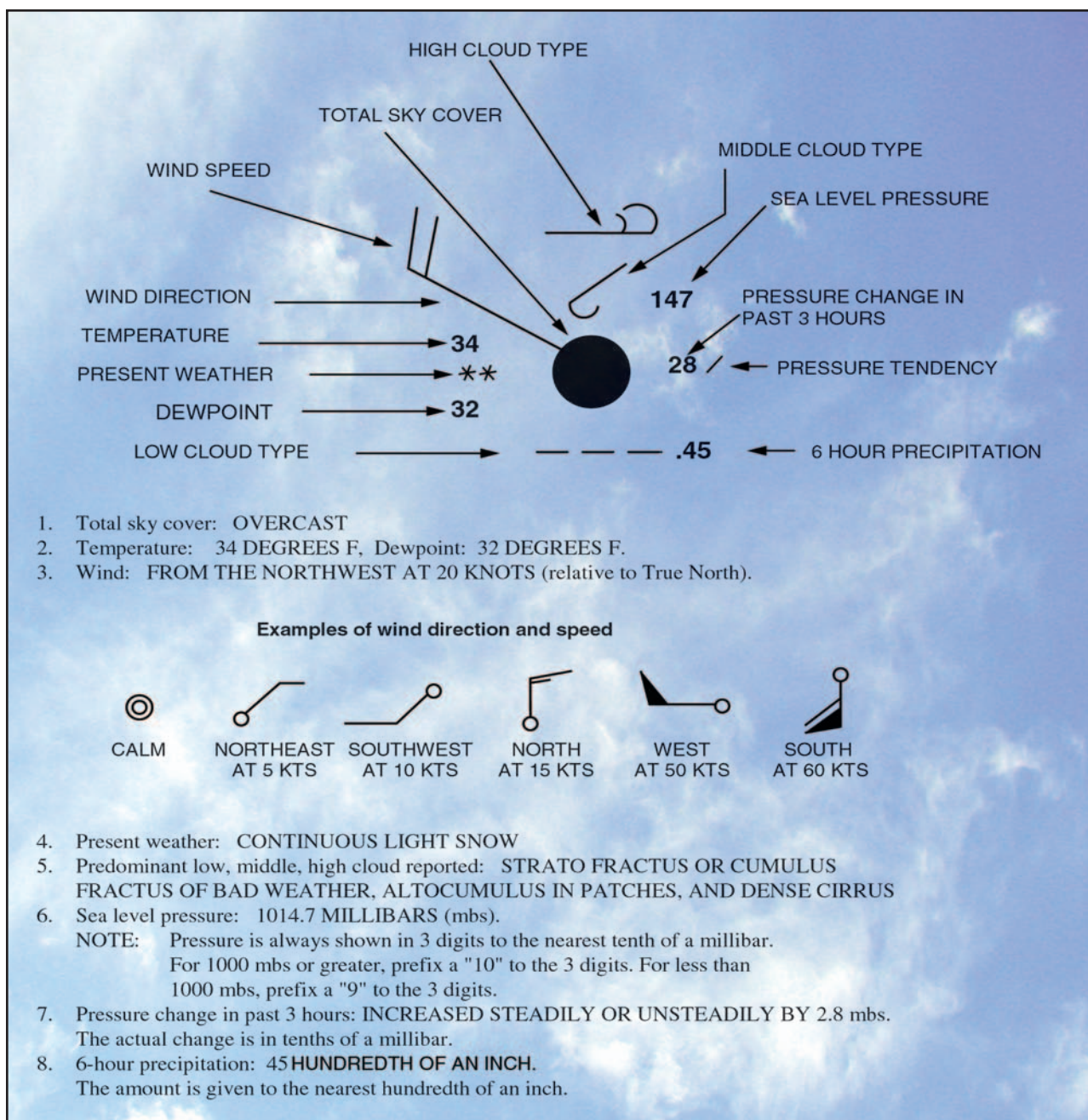


Figure 11-9. Sample station model and weather chart symbols.

- **Present Weather**—Over 100 different weather symbols are used to describe the current weather.
- **Temperature**—Temperature is given in degrees Fahrenheit.
- **Wind**—True direction of wind is given by the wind pointer line, indicating the direction from which the wind is coming. A short barb is equal to 5 knots of wind, a long barb is equal to 10 knots of wind, and a pennant is equal to 50 knots.

### WEATHER DEPICTION CHART

A weather depiction chart details surface conditions as derived from METAR and other surface observations.

The weather depiction chart is prepared and transmitted by computer every 3 hours beginning at 0100 Zulu time, and is valid at the time of the plotted data. It is designed to be used for flight planning by giving an overall picture of the weather across the United States. [Figure 11-10]

This type of chart typically displays major fronts or areas of high and low pressure. The weather depiction chart also provides a graphic display of IFR, VFR, and MVFR (marginal VFR) weather. Areas of IFR conditions (ceilings less than 1,000 feet and visibility less than 3 miles) are shown by a hatched area outlined by a smooth line. MVFR regions (ceilings 1,000 to 3,000 feet, visibility 3 to 5 miles) are shown by a

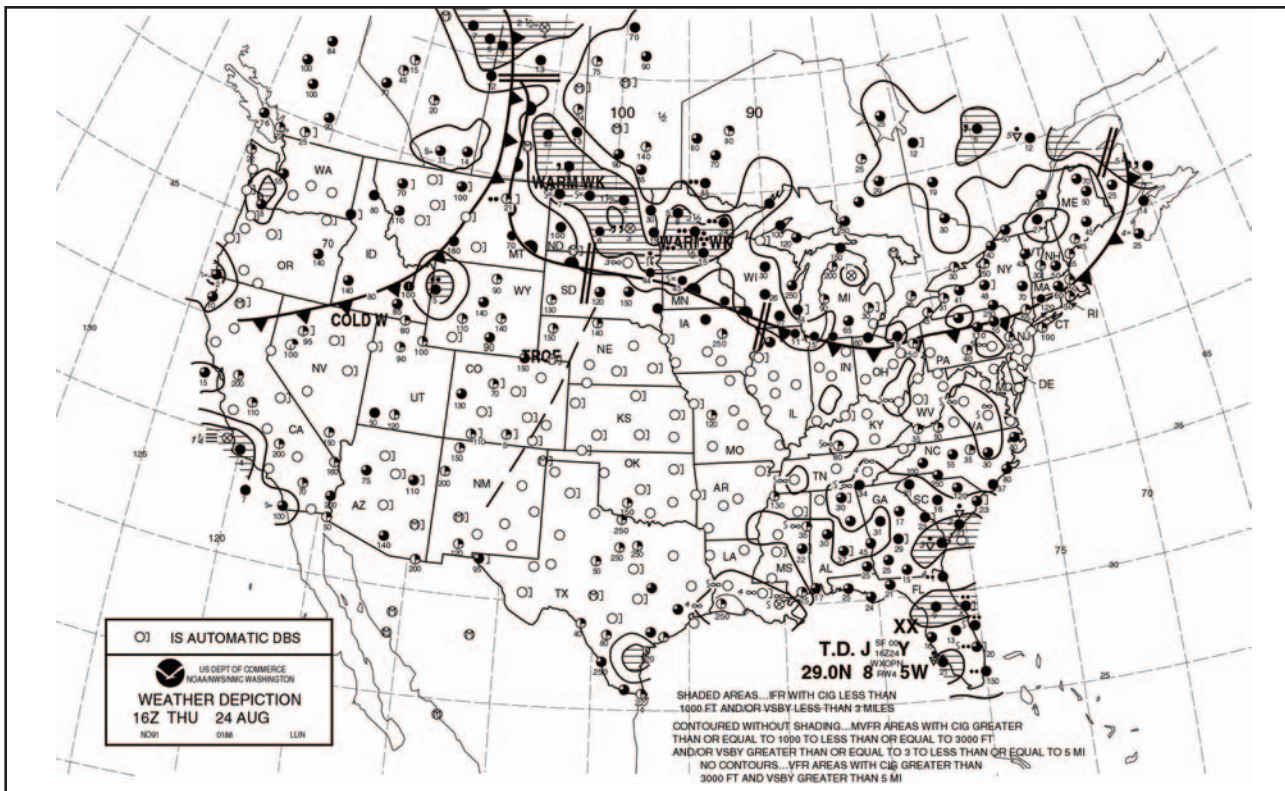


Figure 11-10. Weather depiction chart.

non-hatched area outlined by a smooth line. Areas of VFR (no ceiling or ceiling greater than 3,000 feet and visibility greater than 5 miles) are not outlined.

Weather depiction charts show a modified station model that provides sky conditions in the form of total sky cover, cloud height or ceiling, weather, and obstructions to visibility, but does not include winds or pressure readings like the surface analysis chart. A bracket ( ) symbol to the right of the station indicates the observation was made by an automated station. A detailed explanation of a station model is depicted in the previous discussion of surface analysis charts.

### RADAR SUMMARY CHART

A radar summary chart is a graphically depicted collection of radar weather reports (SDs). [Figure 11-11] The chart is published hourly at 35 minutes past the hour. It displays areas of precipitation as well as information regarding the characteristics of the precipitation. [Figure 11-12] A radar summary chart includes:

- **No information**—If information is not reported, the chart will say “NA.” If no echoes are detected, the chart will say “NE.”
- **Precipitation intensity contours**—Intensity can be described as one of six levels and is shown on the chart by three contour intervals.

- **Height of tops**—The heights of the echo tops are given in hundreds of feet MSL.
- **Movement of cells**—Individual cell movement is indicated by an arrow pointing in the direction of movement. The speed of movement in knots is the number at the top of the arrow head. “LM” indicates little movement.
- **Type of precipitation**—The type of precipitation is marked on the chart using specific symbols. These symbols are not the same as used on the METAR charts.
- **Echo configuration**—Echoes are shown as being areas, cells, or lines.
- **Weather watches**—Severe weather watch areas for tornadoes and severe thunderstorms are depicted by boxes outlined with heavy dashed lines.

The radar summary chart is a valuable tool for preflight planning. It does, however, contain several limitations for the usage of the chart. This chart depicts only areas of precipitation. It will not show areas of clouds and fog with no appreciable precipitation, or the height of the tops and bases of the clouds. Radar summary charts are a depiction of current precipitation and should be used in conjunction with current METAR and weather forecasts.



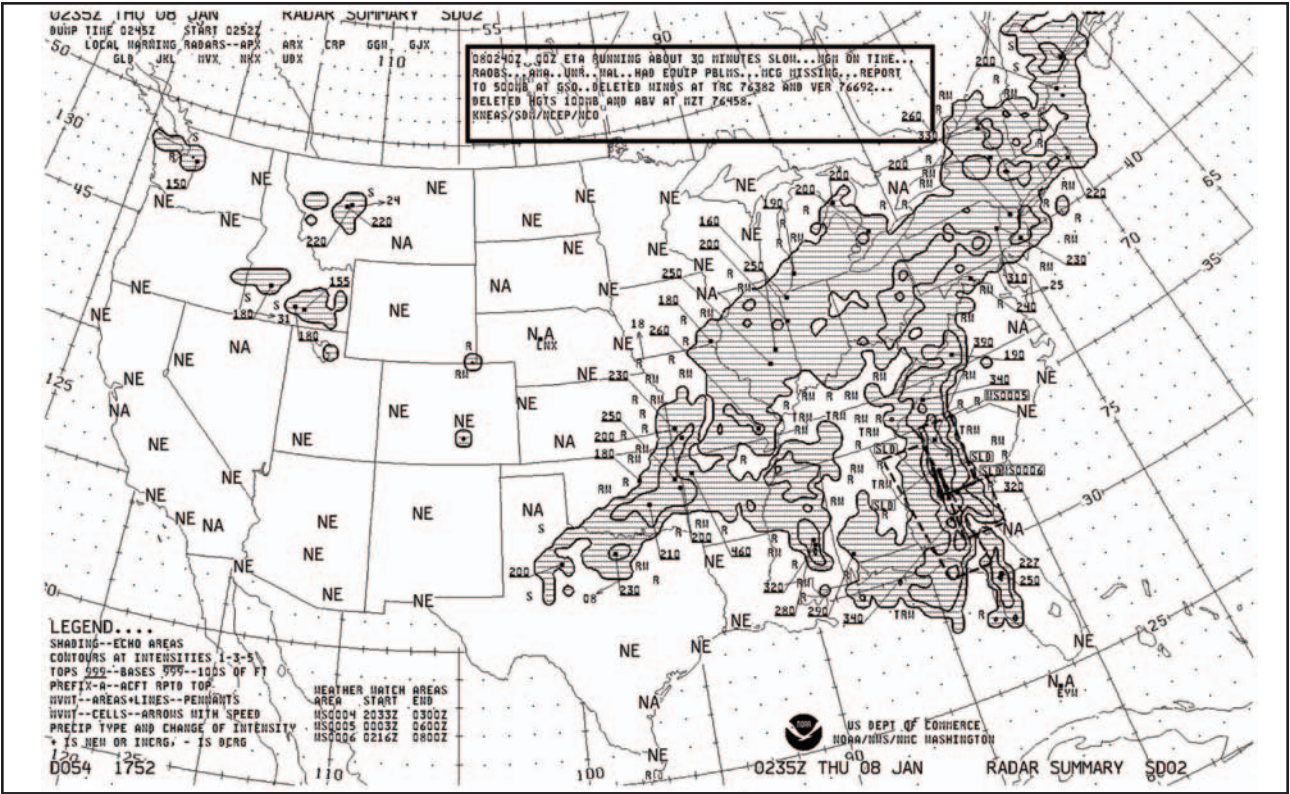


Figure 11-11. Radar summary chart.

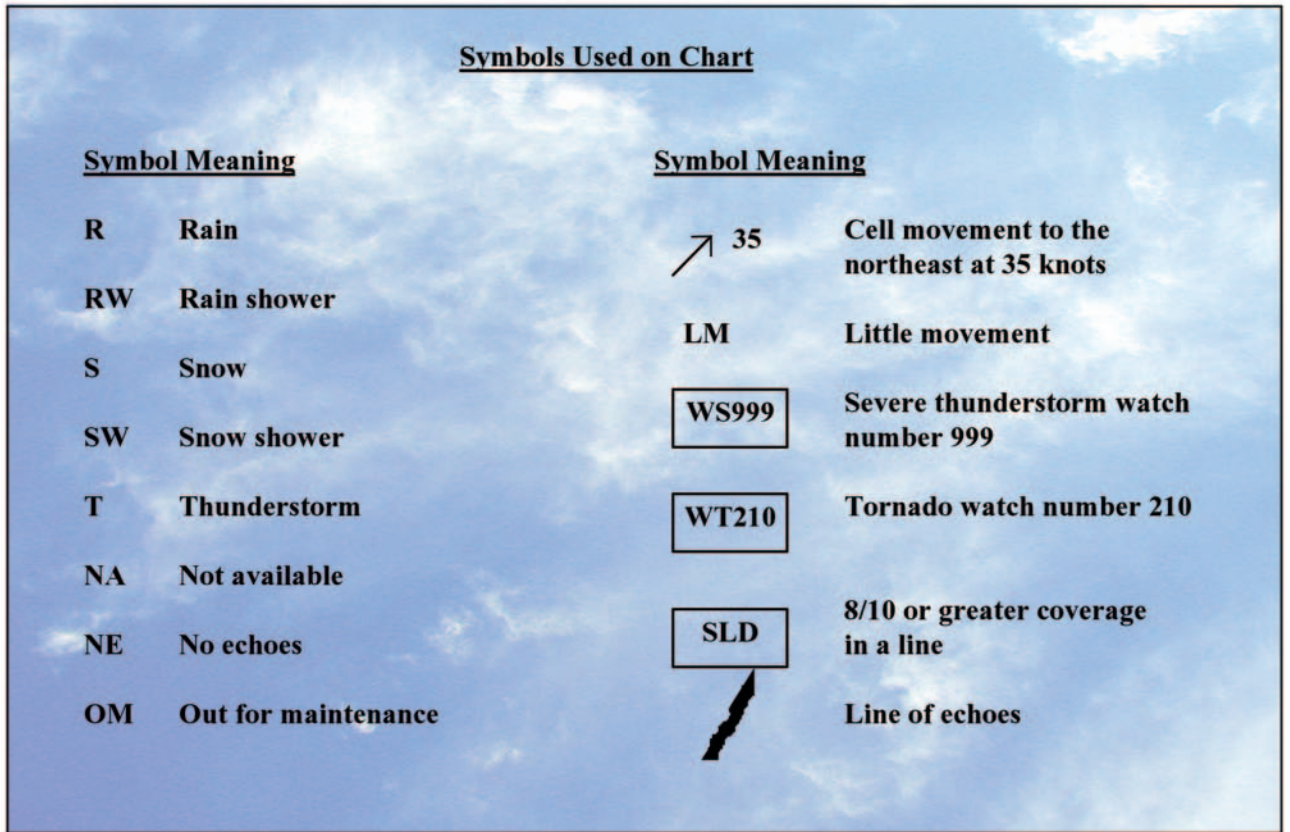
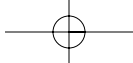


Figure 11-12. Intensity levels and contours, and precipitation type symbols.





## SIGNIFICANT WEATHER PROGNOSTIC CHARTS

Significant Weather Prognostic Charts are available for low-level significant weather from the surface to FL240 (24,000 feet), also referred to as the 400 millibar level, and high-level significant weather from FL250 to FL600 (25,000 to 60,000 feet). The primary concern of this discussion is the low-level significant weather prognostic chart.

The low-level chart comes in two forms: the 12- and 24-hour forecast chart, and the 36 and 48 surface only forecast chart. The first chart is a four-panel chart that includes 12- and 24-hour forecasts for significant weather and surface weather. Charts are issued four times a day at 0000Z, 0600Z, 1200Z, and 1800Z. The valid time for the chart is printed on the lower left-hand corner of each panel.

The upper two panels show forecast significant weather, which may include nonconvective turbulence, freezing levels, and IFR or MVFR weather. Areas of moderate or greater turbulence are enclosed in dashed lines. Numbers within these areas give the height of the turbulence in hundreds of feet MSL. Figures below the line show the anticipated base, while figures above the line show the top of the zone of turbulence. Also shown on this panel are areas of VFR, IFR, and MVFR. IFR areas are enclosed by solid lines, MVFR areas are enclosed by scalloped lines, and the remaining, unenclosed area is designated VFR. Zigzag lines and the letters "SFC" indicate freezing levels in that area

are at the surface. Freezing level height contours for the highest freezing level are drawn at 4,000-foot intervals with dashed lines.

The lower two panels show the forecast surface weather and depicts the forecast locations and characteristics of pressure systems, fronts, and precipitation. Standard symbols are used to show fronts and pressure centers. Direction of movement of the pressure center is depicted by an arrow. The speed, in knots, is shown next to the arrow. In addition, areas of forecast precipitation and thunderstorms are outlined. Areas of precipitation that are shaded indicate at least one-half of the area is being affected by the precipitation. Unique symbols indicate the type of precipitation and the manner in which it occurs.

Figure 11-13 depicts a typical significant weather prognostic chart as well as the symbols typically used to depict precipitation. Prognostic charts are an excellent source of information for preflight planning; however, this chart should be viewed in light of current conditions and specific local area forecasts.

The 36- and 48-hour significant weather prognostic chart is an extension of the 12- and 24-hour forecast. It provides information regarding only surface weather forecasts and includes a discussion of the forecast. This chart is issued only two times a day. It typically contains forecast positions and characteristics of pressure patterns, fronts, and precipitation. An example of a 36- and 48-hour surface prognostic chart is shown in figure 11-14.

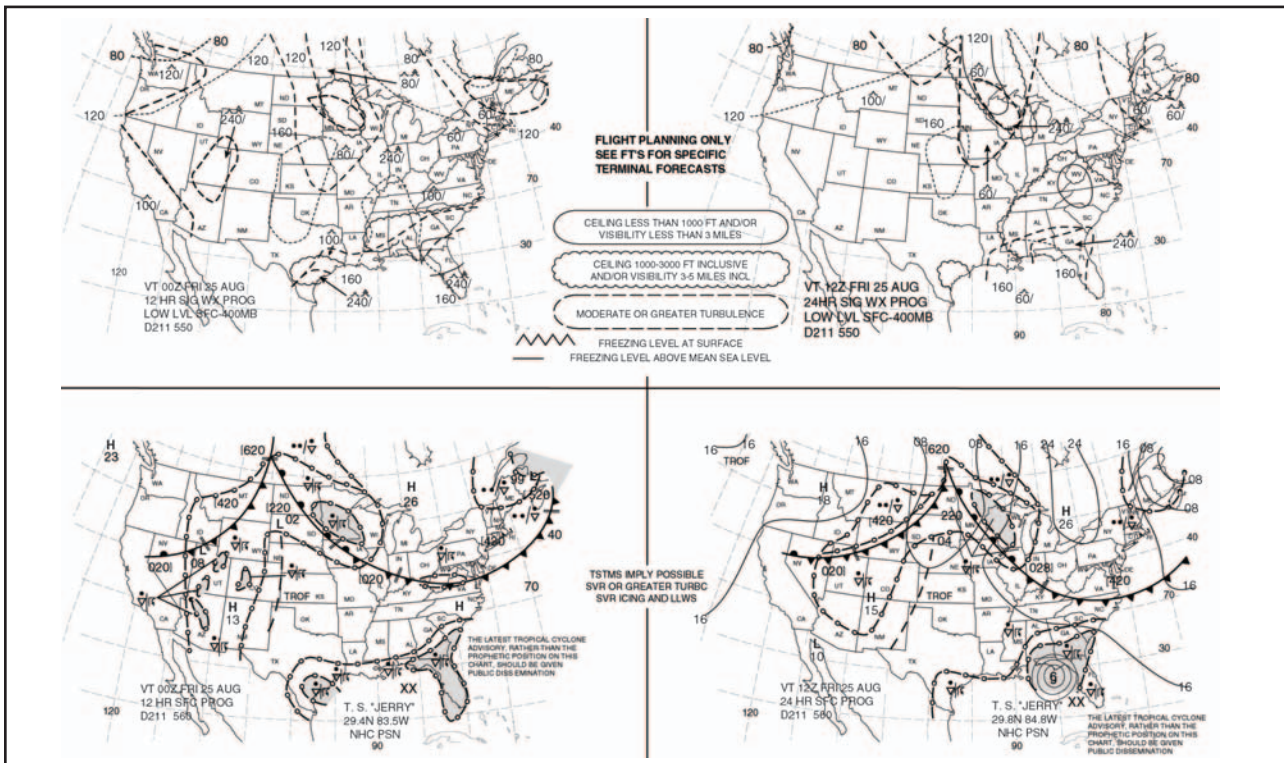
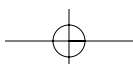


Figure 11-13. Significant weather prognostic chart.





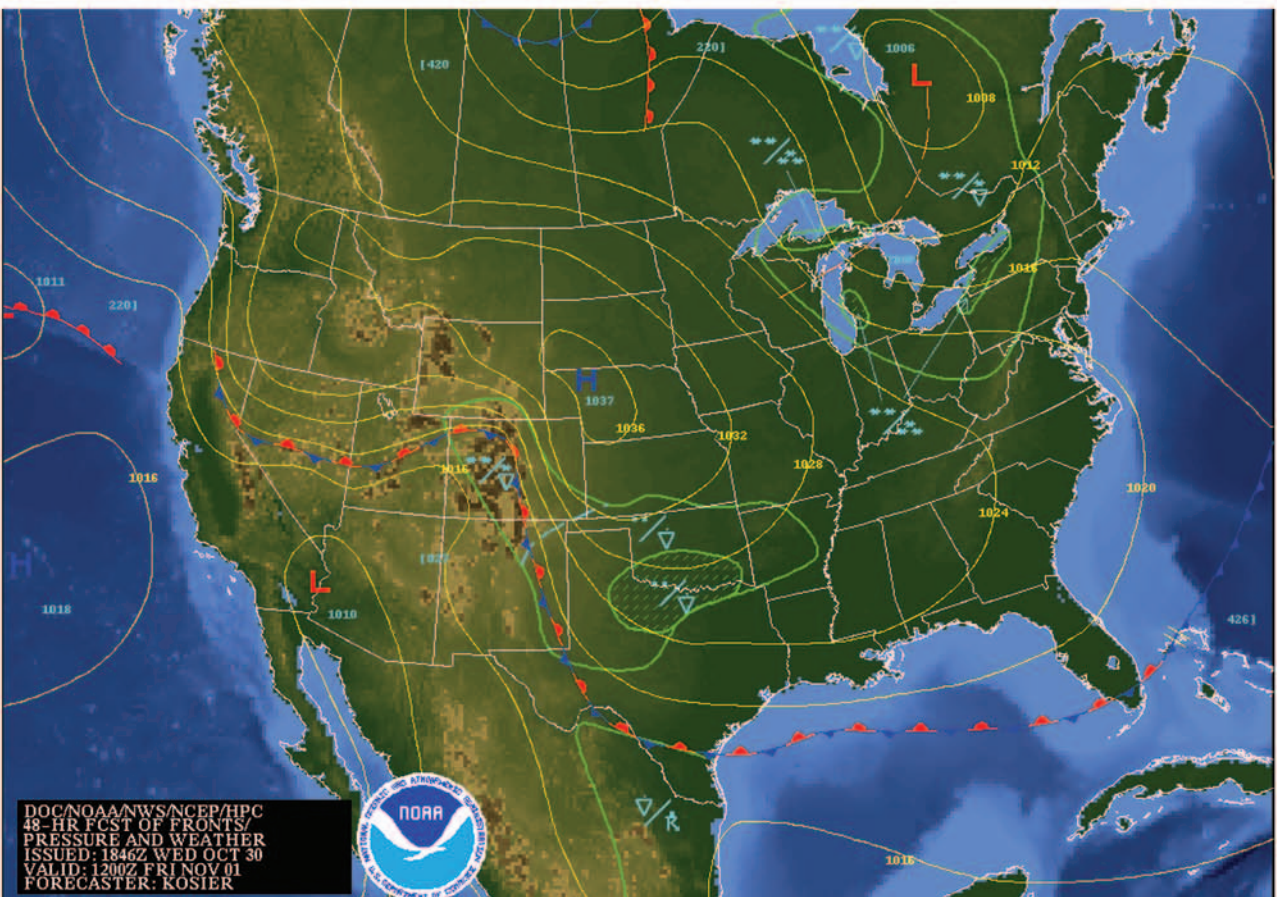
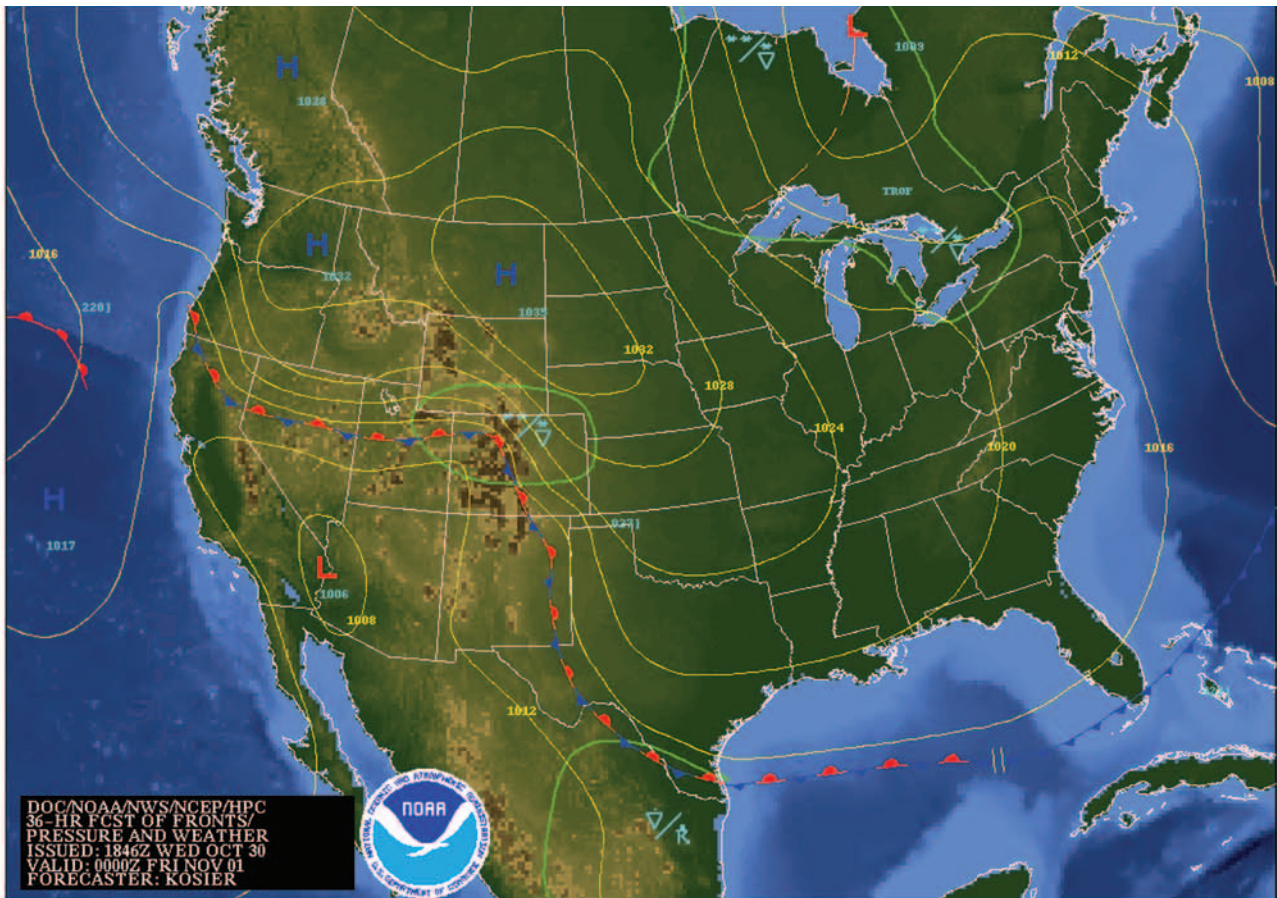
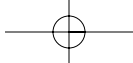
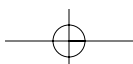
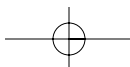
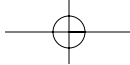


Figure 11-14. 36- and 48-hour surface prognostic chart.







## Chapter 12



# Airport Operations

Each time a pilot operates an airplane, the flight normally begins and ends at an airport. An airport may be a small sod field or a large complex utilized by air carriers. This chapter discusses airport operations and identifies features of an airport complex, as well as provides information on operating on or in the vicinity of an airport.

### TYPES OF AIRPORTS

There are two types of airports.

- Controlled Airport
- Uncontrolled Airport

#### CONTROLLED AIRPORT

A controlled airport has an operating control tower. Air traffic control (ATC) is responsible for providing for the safe, orderly, and expeditious flow of air traffic at airports where the type of operations and/or volume of traffic requires such a service. Pilots operating from a controlled airport are required to maintain two-way radio communication with air traffic controllers, and to acknowledge and comply with their instructions.

Pilots must advise ATC if they cannot comply with the instructions issued and request amended instructions. A pilot may deviate from an air traffic instruction in an emergency, but must advise ATC of the deviation as soon as possible.

#### UNCONTROLLED AIRPORT

An uncontrolled airport does not have an operating control tower. Two-way radio communications are not required, although it is a good operating practice for pilots to transmit their intentions on the specified frequency for the benefit of other traffic in the area. Figure 12-1 lists recommended communication procedures.

More information on radio communications will be discussed later in this chapter.

### SOURCES FOR AIRPORT DATA

When a pilot flies into a different airport, it is important to review the current data for that airport. This data can provide the pilot with information, such as communication frequencies, services available, closed runways, or airport construction. Three common sources of information are:

- Aeronautical Charts
- *Airport/Facility Directory (A/FD)*
- Notices to Airmen (NOTAMs)

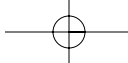
#### AERONAUTICAL CHARTS

Aeronautical charts provide specific information on airports. Chapter 14 contains an excerpt from an aeronautical chart and an aeronautical chart legend, which provides guidance on interpreting the information on the chart.

#### AIRPORT/FACILITY DIRECTORY

The *Airport/Facility Directory (A/FD)* provides the most comprehensive information on a given airport. It contains information on airports, heliports, and sea-plane bases that are open to the public. The A/FDs are contained in seven books, which are organized by regions. These A/FDs are revised every 8 weeks. Figure 12-2 contains an excerpt from a directory. For a complete listing of information provided in an A/FD and how the information may be decoded, refer to the “Directory Legend Sample” located in the front of each A/FD.

In the back of each A/FD, there is information such as special notices, parachute jumping areas, and facility



FACILITY AT AIRPORT	FREQUENCY USE	COMMUNICATION/BROADCAST PROCEDURES		
		OUTBOUND	INBOUND	PRACTICE INSTRUMENT APPROACH
UNICOM (No Tower or FSS)	Communicate with UNICOM station on published CTAF frequency (122.7, 122.8, 122.725, 122.975, or 123.0). If unable to contact UNICOM station, use self-announce procedures on CTAF.	Before taxiing and before taxiing on the runway for departure.	10 miles out. Entering downwind, base, and final. Leaving the runway.	
No Tower, FSS, or UNICOM	Self-announce on MULTICOM frequency 122.9	Before taxiing and before taxiing on the runway for departure.	10 miles out. Entering downwind, base, and final. Leaving the runway.	Departing final approach fix (name) or on final approach segment inbound.
No Tower in operation, FSS open	Communicate with FSS on CTAF frequency.	Before taxiing and before taxiing on the runway for departure.	10 miles out. Entering downwind, base, and final. Leaving the runway.	Approach completed/terminated.
FSS closed (No Tower)	Self-announce on CTAF.	Before taxiing and before taxiing on the runway for departure.	10 miles out. Entering downwind, base, and final. Leaving the runway.	
Tower or FSS not in operation	Self-announce on CTAF.	Before taxiing and before taxiing on the runway for departure.	10 miles out. Entering downwind, base, and final. Leaving the runway.	

Figure 12-1. Recommended communication procedures.

### ARKANSAS 27

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**FORREST CITY MUNI** (FCY) 4 S UTC-6(-5DT) N34°56.52' W90°46.50'

249 B FUEL 100LL, JET A

RWY 18-36: H3014X50 (ASPH) S-20 MIRL

RWY 36: Trees.

**AIRPORT REMARKS:** Attended Mon-Fri 1400-2300Z±. 494 ft lgtd twr 3 miles north on centerline. Numerous glider ops launched by air tow sunrise-sunset.

**COMMUNICATIONS:** CTAF/UNICOM 122.8

JONESBORO FSS (JBR) TF 1-800-WX-BRIEF. NOTAM FILE JBR.

Ⓜ MEMPHIS CENTER APP/DEP CON 135.3

**RADIO AIDS TO NAVIGATION:** NOTAM FILE JBR.

GILMORE (L) VORW/DME 113.0 GQE Chan 77 N35°20.82' W90°28.69' 207° 28.3 NM to fld. 211/4E.

NDB (MHW) 332 FCY N34°56.46' W90°46.42' at fld.

Unmonitored Sun, and Mon-Sat 2300-1400Z±.

MEMPHIS  
L-14F  
IAP

---

**FORT SMITH REGIONAL** (FSM) 3 SE UTC-6(-5DT) N35°20.20' W94°22.05'

469 B S4 FUEL 100LL, JET A ARFF Index A

RWY 07-25: H8000X150 (ASPH-GRVD) S-75, D-175, DT-295 HIRL 0.6% up W

RWY 07: MALSR. Tree. Arresting device.

RWY 25: MALSR. VASI(V4L)—GA 2.9° TCH 60'. Tree. Arresting device.

RWY 01-19: H5002X150 (ASPH-GRVD) S-55, D-70, DT-120 MIRL

RWY 01: Railroad. RWY 19: PAPI(P4L)—GA 3.0° TCH 40'. Tree.

**RUNWAY DECLARED DISTANCE INFORMATION**

RWY 01: TORA-5002 TODA-5002 ASDA-5002 LDA-5002

RWY 19: TORA-5002 TODA-5002 ASDA-5002 LDA-5002

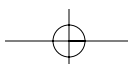
RWY 07: TORA-8000 TODA-8000 ASDA-8000 LDA-8000

RWY 25: TORA-8000 TODA-8000 ASDA-8000 LDA-8000

**AIRPORT REMARKS:** Attended continuously. Rwy 01-19 restricted to prop acft unless crosswinds on Rwy 07-25 exceed acft safe operating capability. Acft training prohibited on Rwy 01-19 (including practice approaches, touch and

MEMPHIS  
H-4G, L-6H, 13D  
IAP, AD

Figure 12-2. Airport/Facility Directory excerpt.



telephone numbers. It would be helpful to review an A/FD to become familiar with the information it contains.

### NOTICES TO AIRMEN

Notices to Airmen (NOTAMs) provide the most current information available. They provide time-critical information on airports and changes that affect the national airspace system and are of concern to instrument flight rule (IFR) operations. NOTAM information is classified into three categories. These are NOTAM-D or distant, NOTAM-L or local, and flight data center (FDC) NOTAMs. NOTAM-Ds are attached to hourly weather reports and are available at flight service stations (AFSS/FSS). NOTAM-Ls include items of a local nature, such as taxiway closures or construction near a runway. These NOTAMs are maintained at the FSS nearest the airport affected. NOTAM-Ls must be requested from an FSS other than the one nearest the local airport for which the NOTAM was issued. FDC NOTAMs are issued by the National Flight Data Center and contain regulatory information, such as temporary flight restrictions or an amendment to instrument approach procedures. The NOTAM-Ds and FDC NOTAMs are contained in the Notices to Airmen publication, which is issued every 28 days. Prior to any flight, pilots should check for any NOTAMs that could affect their intended flight.

### AIRPORT MARKINGS AND SIGNS

There are markings and signs used at airports, which provide directions and assist pilots in airport operations. Some of the most common markings and signs will be discussed. Additional information may be found in the *Aeronautical Information Manual* (AIM).

### RUNWAY MARKINGS

Runway markings vary depending on the type of operations conducted at the airport. Figure 12-3 shows a runway that is approved as a precision instrument approach runway and also shows some other common runway markings. A basic VFR runway may only have centerline markings and runway numbers.

Since aircraft are affected by the wind during takeoffs and landings, runways are laid out according to the local prevailing winds. Runway numbers are in reference to magnetic north. Certain airports have two or even three runways laid out in the same direction. These are referred to as parallel runways and are distinguished by a letter being added to the runway number. Examples are runway 36L (left), 36C (center), and 36R (right).

Another feature of some runways is a displaced threshold. A threshold may be displaced because of an obstruction near the end of the runway. Although this

portion of the runway is not to be used for landing, it may be available for taxiing, takeoff, or landing rollout.

Some airports may have a blast pad/stopway area. The blast pad is an area where a propeller or jet blast can dissipate without creating a hazard. The stopway area is paved in order to provide space for an airplane to decelerate and stop in the event of an aborted takeoff. These areas cannot be used for takeoff or landing.

### TAXIWAY MARKINGS

Airplanes use taxiways to transition from parking areas to the runway. Taxiways are identified by a continuous yellow centerline stripe. A taxiway may include edge markings to define the edge of the taxiway. This is usually done when the taxiway edge does not correspond with the edge of the pavement. If an edge marking is a continuous line, the paved shoulder is not intended to be used by an airplane. If it is a dashed marking, an airplane may use that portion of the pavement. Where a taxiway approaches a runway, there may be a holding position marker. These consist of four yellow lines (two solid and two dashed). The solid lines are where the airplane is to hold. At some controlled airports, holding position markings may be found on a runway. They are used when there are intersecting runways, and air traffic control issues instructions such as “cleared to land—hold short of runway 30.”

### OTHER MARKINGS

Some of the other markings found on the airport include vehicle roadway markings, VOR receiver checkpoint markings, and non-movement area boundary markings.

Vehicle roadway markings are used when necessary to define a pathway for vehicle crossing areas that are also intended for aircraft. These markings usually consist of a solid white line to delineate each edge of the roadway and a dashed line to separate lanes within the edges of the roadway.

A VOR receiver checkpoint marking consists of a painted circle with an arrow in the middle. The arrow is aligned in the direction of the checkpoint azimuth. This allows pilots to check aircraft instruments with navigational aid signals.

A non-movement area boundary marking delineates a movement area under air traffic control. These markings are yellow and located on the boundary between the movement and non-movement area. They normally consist of two yellow lines (one solid and one dashed).

### AIRPORT SIGNS

There are six types of signs that may be found at airports. The more complex the layout of an airport, the



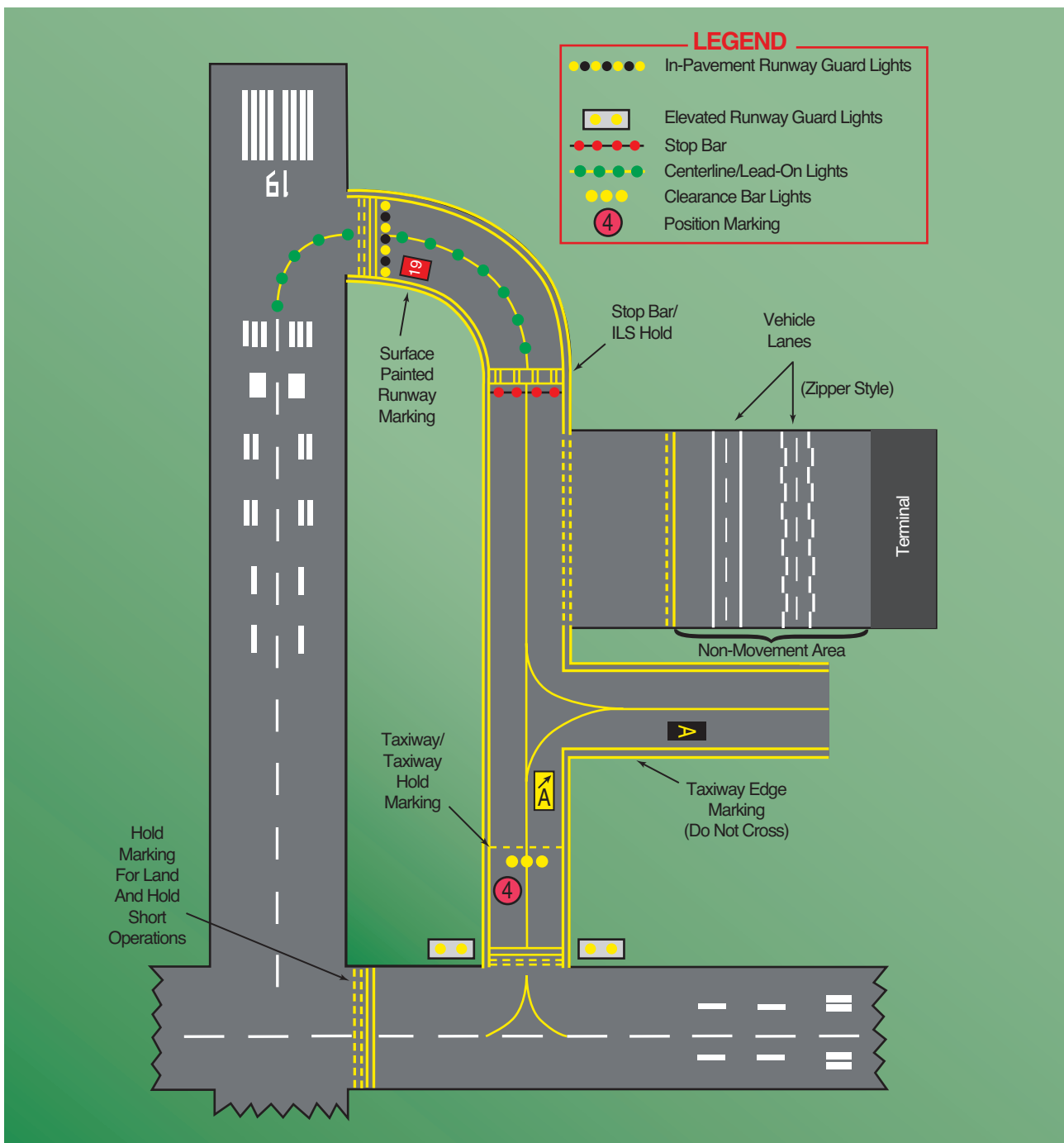


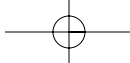
Figure 12-3. Selected airport markings and surface lighting.

more important the signs become to pilots. Figure 12-4 shows examples of signs, their purpose, and appropriate pilot action. The six types of signs are:

- **Mandatory Instruction Signs**—have a red background with a white inscription. These signs denote an entrance to a runway, a critical area, or a prohibited area.
- **Location Signs**—are black with yellow inscription and a yellow border and do not have arrows. They are used to identify a taxiway or runway location, to identify the boundary of the runway,

or identify an instrument landing system (ILS) critical area.

- **Direction Signs**—have a yellow background with black inscription. The inscription identifies the designation of the intersecting taxiway(s) leading out of an intersection.
- **Destination Signs**—have a yellow background with black inscription and also contain arrows. These signs provide information on locating things, such as runways, terminals, cargo areas, and civil aviation areas.














AIRPORT SIGN SYSTEMS	
TYPE OF SIGN AND ACTION OR PURPOSE	TYPE OF SIGN AND ACTION OR PURPOSE
<b>4-22</b> Taxiway/Runway Hold Position: Hold short of runway on taxiway	 <b>Runway Safety Area/Obstacle Free Zone Boundary:</b> Exit boundary of runway protected areas
<b>26-8</b> Runway/Runway Hold Position: Hold short of intersecting runway	 <b>ILS Critical Area Boundary:</b> Exit boundary of ILS critical area
<b>8-APCH</b> Runway Approach Hold Position: Hold short of aircraft on approach	 <b>Taxiway Direction:</b> Defines direction & designation of intersecting taxiway(s)
<b>ILS</b> ILS Critical Area Hold Position: Hold short of ILS approach critical area	 <b>Runway Exit:</b> Defines direction & designation of exit taxiway from runway
 <b>No Entry:</b> Identifies paved areas where aircraft entry is prohibited	 <b>Outbound Destination:</b> Defines directions to takeoff runways
 <b>Taxiway Location:</b> Identifies taxiway on which aircraft is located	 <b>Inbound Destination:</b> Defines directions for arriving aircraft
 <b>Runway Location:</b> Identifies runway on which aircraft is located	 <b>Taxiway Ending Marker</b> Indicates taxiway does not continue
<b>4</b> Runway Distance Remaining Provides remaining runway length in 1,000 foot increments	 <b>Direction Sign Array:</b> Identifies location in conjunction with multiple intersecting taxiways

Figure 12-4. Airport signs.

- Information Signs**—have a yellow background with black inscription. These signs are used to provide the pilot with information on such things as areas that cannot be seen from the control tower, applicable radio frequencies, and noise abatement procedures. The airport operator determines the need, size, and location of these signs.
- Runway Distance Remaining Signs**—have a black background with white numbers. The numbers indicate the distance of the remaining runway in thousands of feet.

### AIRPORT LIGHTING

The majority of airports have some type of lighting for night operations. The variety and type of lighting systems depends on the volume and complexity of operations at a given airport. Airport lighting is standardized so that airports use the same light colors for runways and taxiways.

### AIRPORT BEACON

Airport beacons help a pilot identify an airport at night. The beacons are operated from dusk till dawn and sometimes they are turned on if the ceiling is less than 1,000 feet and/or the ground visibility is less than 3 statute miles (visual flight rules minimums). However, there is no requirement for this, so a pilot has the responsibility of determining if the weather is VFR.

The beacon has a vertical light distribution to make it most effective from 1-10° above the horizon, although it can be seen well above or below this spread. The beacon may be an omnidirectional capacitor-discharge device, or it may rotate at a constant speed, which produces the visual effect of flashes at regular intervals. The combination of light colors from an airport beacon indicates the type of airport. [Figure 12-5]

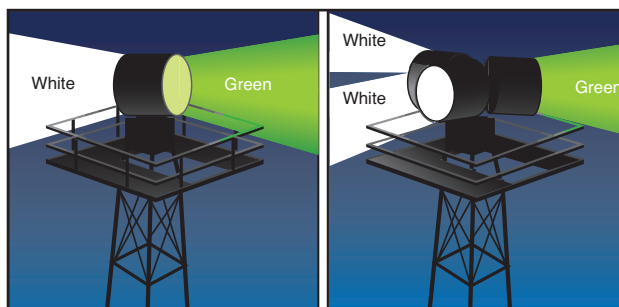
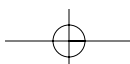
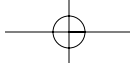


Figure 12-5. Airport rotating beacons.

Some of the most common beacons are:

- Flashing white and green for civilian land airports.
- Flashing white and yellow for a water airport.
- Flashing white, yellow, and green for a heliport.
- Two quick white flashes followed by a green flash identifies a military airport.





## APPROACH LIGHT SYSTEMS

Approach light systems are primarily intended to provide a means to transition from instrument flight to visual flight for landing. The system configuration depends on whether the runway is a precision or nonprecision instrument runway. Some systems include sequenced flashing lights, which appear to the pilot as a ball of light traveling toward the runway at high speed. Approach lights can also aid pilots operating under VFR at night.

## VISUAL GLIDESLOPE INDICATORS

Visual glideslope indicators provide the pilot with glidepath information that can be used for day or night approaches. By maintaining the proper glidepath as provided by the system, a pilot should have adequate obstacle clearance and should touch down within a specified portion of the runway.

## VISUAL APPROACH SLOPE INDICATOR

Visual approach slope indicator (VASI) installations are the most common visual glidepath systems in use. The VASI provides obstruction clearance within 10° of the runway extended runway centerline, and to 4 nautical miles (NM) from the runway threshold.

A VASI consists of light units arranged in bars. There are 2-bar and 3-bar VASIs. The 2-bar VASI has near and far light bars and the 3-bar VASI has near, middle, and far light bars. Two-bar VASI installations provide one visual glidepath which is normally set at 3°. The 3-bar system provides two glidepaths with the lower glidepath normally set at 3° and the upper glidepath one-fourth degree above the lower glidepath.

The basic principle of the VASI is that of color differentiation between red and white. Each light unit projects a beam of light having a white segment in the upper part of the beam and a red segment in the lower part of the beam. The lights are arranged so the pilot will see the combination of lights shown in figure 12-6 to indicate below, on, or above the glidepath.

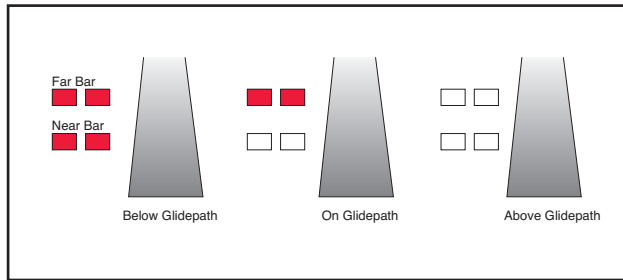


Figure 12-6. 2-Bar VASI system.

## OTHER GLIDEPATH SYSTEMS

A precision approach path indicator (PAPI) uses lights similar to the VASI system except they are installed in a single row, normally on the left side of the runway. [Figure 12-7]

A tri-color system consists of a single light unit projecting a three-color visual approach path. A below the glidepath indication is red, on the glidepath color is green, and above the glidepath is indicated by amber. When descending below the glidepath, there is a small area of dark amber. Pilots should not mistake this area for an “above the glidepath” indication. [Figure 12-8]

There are also pulsating systems, which consist of a single light unit projecting a two-color visual approach path. A below the glidepath indication is shown by a steady red light, slightly below is indicated by pulsating red, on the glidepath is indicated by a steady white light, and a pulsating white light indicates above the glidepath. [Figure 12-9]

## RUNWAY LIGHTING

There are various lights that identify parts of the runway complex. These assist a pilot in safely making a takeoff or landing during night operations.

## RUNWAY END IDENTIFIER LIGHTS

Runway end identifier lights (REIL) are installed at many airfields to provide rapid and positive identifi-

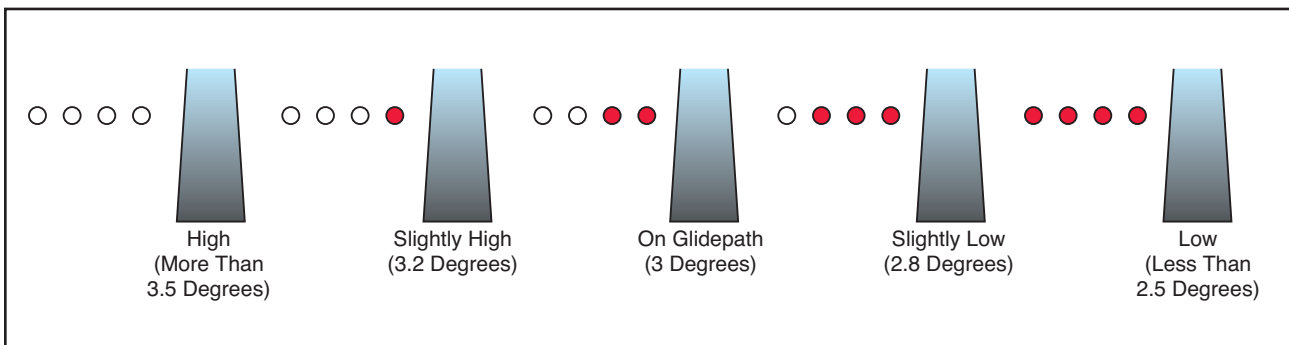
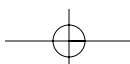


Figure 12-7. Precision approach path indicator.



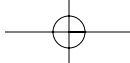


Figure 12-8. Tri-color visual approach slope indicator.

cation of the approach end of a particular runway. The system consists of a pair of synchronized flashing lights located laterally on each side of the runway threshold. REILs may be either omnidirectional or unidirectional facing the approach area.

**RUNWAY EDGE LIGHTS**

Runway edge lights are used to outline the edges of runways at night or during low visibility conditions. These lights are classified according to the intensity they are capable of producing. They are classified as high intensity runway lights (HIRL), medium intensity runway lights (MIRL), or low intensity runway lights (LIRL). The HIRL and MIRL have variable intensity settings. These lights are white, except on instrument runways, where amber lights are used on the last 2,000 feet or half the length of the runway, whichever is less. The lights marking the end of the runway are red.

**IN-RUNWAY LIGHTING**

Touchdown zone lights (TDZL), runway centerline lights (RCLS), and taxiway turnoff lights are installed

on some precision runways to facilitate landing under adverse visibility conditions. TDZLs are two rows of transverse light bars disposed symmetrically about the runway centerline in the runway touchdown zone. RCLS consists of flush centerline lights spaced at 50 foot intervals beginning 75 feet from the landing threshold. Taxiway turnoff lights are flush lights, which emit a steady green color.

**CONTROL OF AIRPORT LIGHTING**

Airport lighting is controlled by air traffic controllers at controlled airports. At uncontrolled airports, the lights may be on a timer, or where an FSS is located at an airport, the FSS personnel may control the lighting. A pilot may request various light systems be turned on or off and also request a specified intensity, if available, from ATC or FSS personnel. At selected uncontrolled airports, the pilot may control the lighting by using the radio. This is done by selecting a specified frequency and clicking the radio microphone. For information on pilot controlled lighting at

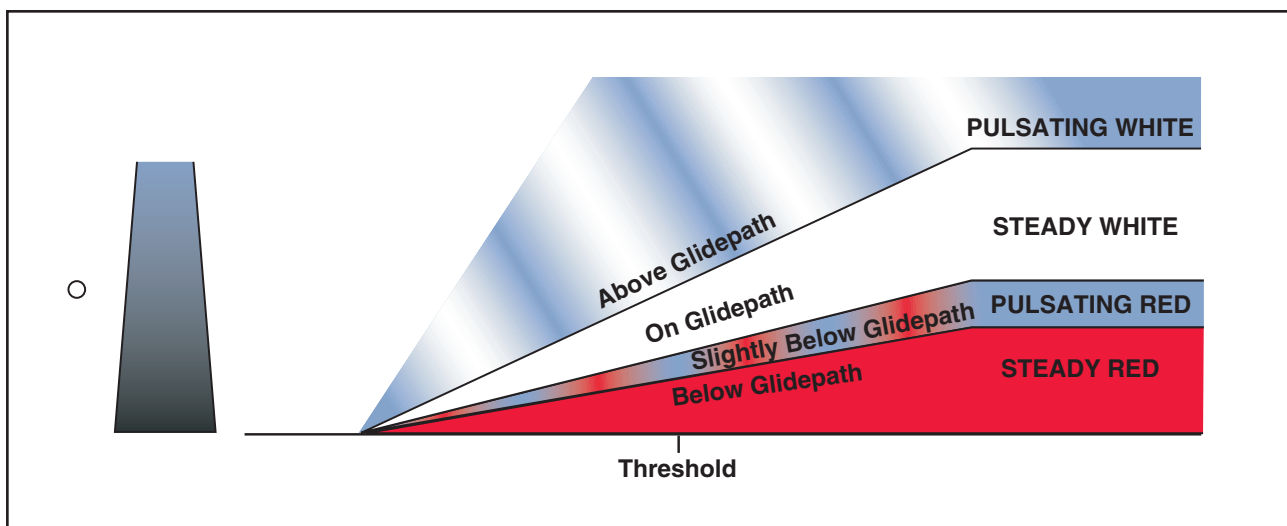
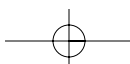


Figure 12-9. Pulsating visual approach slope indicator.





various airports, refer to the *Airport/Facility Directory*. [Figure 12-10]

KEY MIKE	FUNCTION
7 times within 5 seconds	Highest intensity available
5 times within 5 seconds	Medium or lower intensity (Lower REIL or REIL off)
3 times within 5 seconds	Lowest intensity available (Lower REIL or REIL off)

Figure 12-10. Radio control runway lighting.

## TAXIWAY LIGHTS

Omnidirectional taxiway lights outline the edges of the taxiway and are blue in color. At many airports, these edge lights may have variable intensity settings that may be adjusted by an air traffic controller when deemed necessary or when requested by the pilot. Some airports also have taxiway centerline lights that are green in color.

## OBSTRUCTION LIGHTS

Obstructions are marked or lighted to warn pilots of their presence during daytime and nighttime conditions. Obstruction lighting can be found both on and off an airport to identify obstructions. They may be marked or lighted in any of the following conditions.

- **Red Obstruction Lights**—either flash or emit a steady red color during nighttime operations, and the obstructions are painted orange and white for daytime operations.
- **High Intensity White Obstruction Light**—flashes high intensity white lights during the daytime with the intensity reduced for nighttime.
- **Dual Lighting**—is a combination of flashing red beacons and steady red lights for nighttime operation, and high intensity white lights for daytime operations.

## WIND DIRECTION INDICATORS

It is important for a pilot to know the direction of the wind. At facilities with an operating control tower, this information is provided by ATC. Information may also be provided by FSS personnel located at a particular airport or by requesting information on a common traffic advisory frequency (CTAF) at airports that have the capacity to receive and broadcast on this frequency.

When none of these services is available, it is possible to determine wind direction and runway in use by visual wind indicators. A pilot should check these wind indicators even when information is provided on the CTAF at a given airport because there is no assurance that the information provided is accurate.

Wind direction indicators include a wind sock, wind tee, or tetrahedron. These are usually located in a central location near the runway and may be placed in the center of a segmented circle, which will identify the traffic pattern direction, if it is other than the standard left-hand pattern. [Figures 12-11 and 12-12]

The wind sock is a good source of information since it not only indicates wind direction, but allows the pilot to estimate the wind velocity and gusts or factor. The wind sock extends out straighter in strong winds and will tend to move back and forth when the wind is gusty. Wind tees and tetrahedrons can swing freely, and will align themselves with the wind direction. The wind tee and tetrahedron can also be manually set to align with the runway in use; therefore, a pilot should also look at the wind sock, if available.

## RADIO COMMUNICATIONS

Operating in and out of a controlled airport, as well as in a good portion of the airspace system, requires that an aircraft have two-way radio communication capability. For this reason, a pilot should be knowledgeable of radio station license requirements and radio communications equipment and procedures.

### RADIO LICENSE

There is no license requirement for a pilot operating in the United States; however, a pilot who operates internationally is required to hold a restricted radiotelephone permit issued by the Federal Communications Commission (FCC). There is also no station license requirement for most general aviation aircraft operating in the United States. A station license is required however for an aircraft which is operating internationally, which uses other than a very high frequency (VHF) radio, and which meets other criteria.

### RADIO EQUIPMENT

In general aviation, the most common types of radios are VHF. A VHF radio operates on frequencies between 118.0 and 136.975 and is classified as 720 or 760 depending on the number of channels it can accommodate. The 720 and 760 uses .025 spacing (118.025, 118.050) with the 720 having a frequency range up to 135.975 and the 760 going up to 136.975. VHF radios are limited to line of sight transmissions;

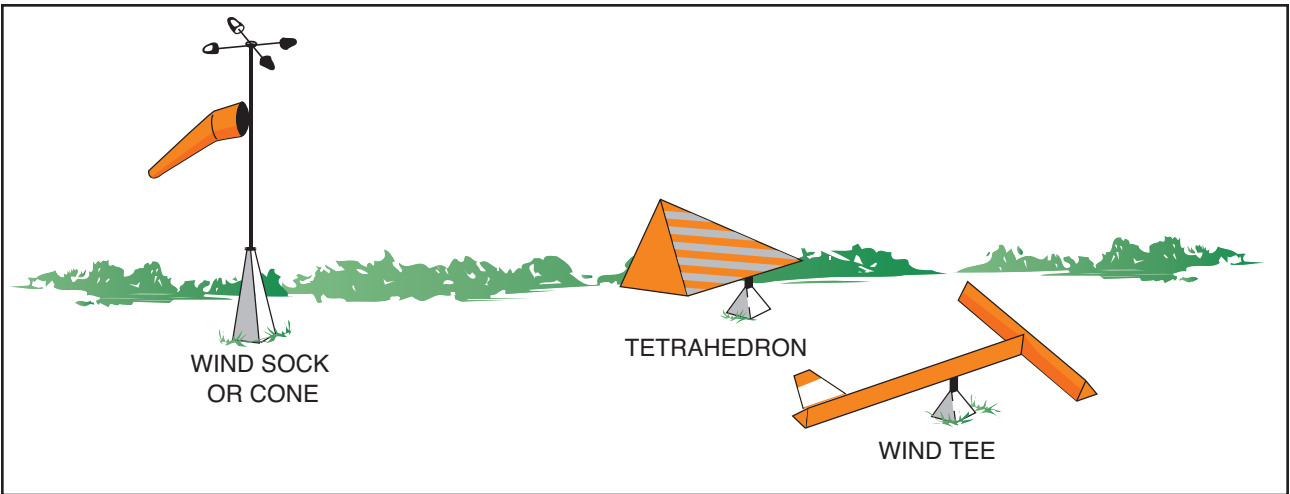
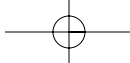


Figure 12-11. Wind direction indicators.

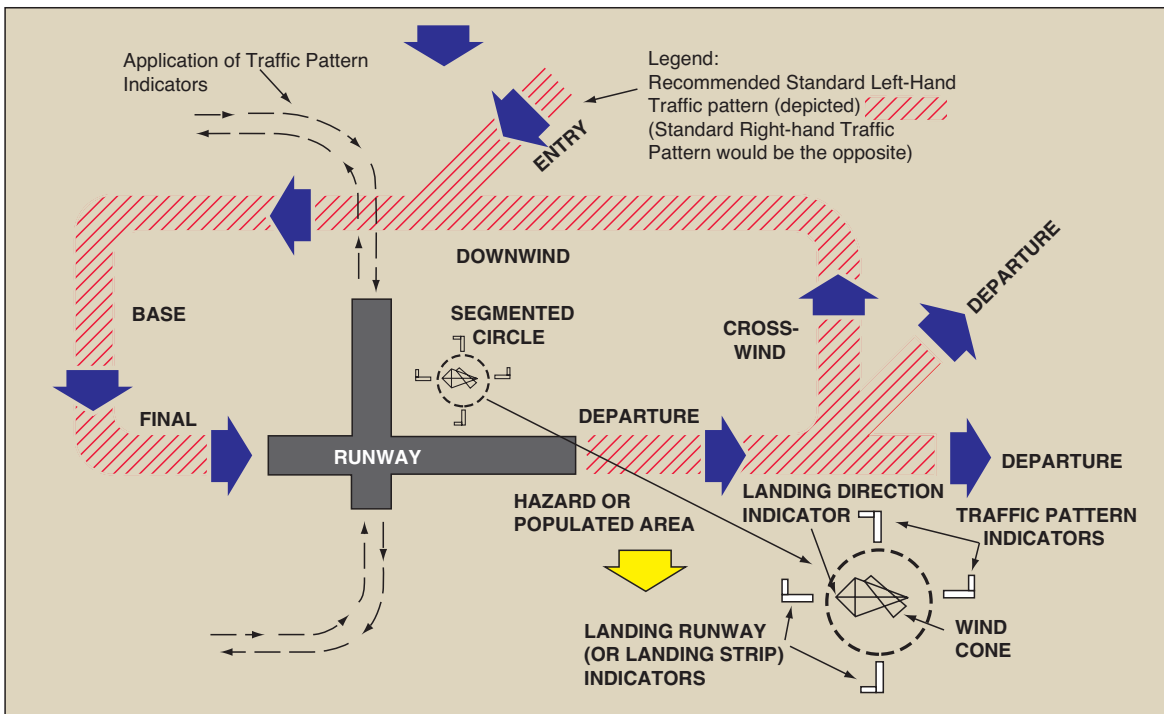


Figure 12-12. Segmented circle and airport traffic pattern.

therefore, aircraft at higher altitudes are able to transmit and receive at greater distances.

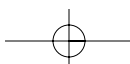
Using proper radio phraseology and procedures will contribute to a pilot's ability to operate safely and efficiently in the airspace system. A review of the Pilot/Controller Glossary contained in the *Aeronautical Information Manual (AIM)* will assist a pilot in the use and understanding of standard terminology. The AIM also contains many examples of radio communications, which should be helpful.

The International Civil Aviation Organization (ICAO) has adopted a phonetic alphabet, which should be used in radio communications. When communicating with

ATC, pilots should use this alphabet to identify their aircraft. [Figure 12-13]

### LOST COMMUNICATION PROCEDURES

It is possible that a pilot might experience a malfunction of the radio. This might cause the transmitter, receiver, or both to become inoperative. If a receiver becomes inoperative and a pilot needs to land at a controlled airport, it is advisable to remain outside or above Class D airspace until the direction and flow of traffic is determined. A pilot should then advise the tower of the aircraft type, position, altitude, and intention to land. The pilot should continue, enter the pattern, report a position as appropriate, and watch



CHARACTER	MORSE CODE	TELEPHONY	PHONIC (PRONUNCIATION)
A	•-	Alfa	(AL-FAH)
B	-•••	Bravo	(BRAH-VOH)
C	-••	Charlie	(CHAR-LEE) OR (SHAR-LEE)
D	-••	Delta	(DELL-TAH)
E	•	Echo	(ECK-OH)
F	••••	Foxtrot	(FOKS-TROT)
G	--•	Golf	(GOLF)
H	••••	Hotel	(HOH-TEL)
I	••	India	(IN-DEE-AH)
J	•---	Juliet	(JEW-LEE-ETT)
K	-•-	Kilo	(KEY-LOH)
L	•••	Lima	(LEE-MAH)
M	--	Mike	(MIKE)
N	-•	November	(NO-VEM-BER)
O	---	Oscar	(OSS-CAH)
P	•••	Papa	(PAH-PAH)
Q	--•-	Quebec	(KEH-BECK)
R	•••	Romeo	(ROW-ME-OH)
S	•••	Sierra	(SEE-AIR-RAH)
T	-•-	Tango	(TANG-GO)
U	••-	Uniform	(YOU-NEE-FORM) OR (OO-NEE-FORM)
V	•••-	Victor	(VIK-TAH)
W	••-	Whiskey	(WISS-KEY)
X	-••-	Xray	(ECKS-RAY)
Y	-••-	Yankee	(YANG-KEY)
Z	--••	Zulu	(ZOO-LOO)
1	•----	One	(WUN)
2	••---	Two	(TOO)
3	•••-	Three	(TREE)
4	••••-	Four	(FOW-ER)
5	•••••	Five	(FIFE)
6	-••••	Six	(SIX)
7	--•••	Seven	(SEV-EN)
8	---••	Eight	(AIT)
9	----•	Nine	(NIN-ER)
0	-----	Zero	(ZEE-RO)

Figure 12-13. Phonetic alphabet.

for light signals from the tower. Light signal colors and their meanings are contained in figure 12-14.

If the transmitter becomes inoperative, a pilot should follow the previously stated procedures and also monitor the appropriate air traffic control frequency. During daylight hours air traffic control transmissions may be acknowledged by rocking the wings, and at night by blinking the landing light.

When both receiver and transmitter are inoperative, the pilot should remain outside of Class D airspace until the flow of traffic has been determined and then enter the pattern and watch for light signals.

If a radio malfunctions prior to departure, it is advisable to have it repaired, if possible. If this is not possible, a

call should be made to air traffic control and the pilot should request authorization to depart without two-way radio communications. If authorization is given to depart, the pilot will be advised to monitor the appropriate frequency and/or watch for light signals as appropriate.

## AIR TRAFFIC CONTROL SERVICES

Besides the services provided by FSS as discussed in Chapter 11, there are numerous other services provided by ATC. In many instances a pilot is required to have contact with air traffic control, but even when not required, a pilot will find it helpful to request their services.

## PRIMARY RADAR

Radar is a method whereby radio waves are transmitted into the air and are then received when they have been reflected by an object in the path of the beam. Range is







LIGHT GUN SIGNALS			
COLOR AND TYPE OF SIGNAL	MOVEMENT OF VEHICLES, EQUIPMENT AND PERSONNEL	AIRCRAFT ON THE GROUND	AIRCRAFT IN FLIGHT
<b>STEADY GREEN</b> 	Cleared to cross, proceed or go	Cleared for takeoff	Cleared to land
<b>FLASHING GREEN</b> 	Not applicable	Cleared for taxi	Return for landing (to be followed by steady green at the proper time)
<b>STEADY RED</b> 	STOP	STOP	Give way to other aircraft and continue circling
<b>FLASHING RED</b> 	Clear the taxiway/runway	Taxi clear of the runway in use	Airport unsafe, do not land
<b>FLASHING WHITE</b> 	Return to starting point on airport	Return to starting point on airport	Not applicable
<b>ALTERNATING RED AND GREEN</b> 	Exercise Extreme Caution!!!!	Exercise Extreme Caution!!!!	Exercise Extreme Caution!!!!

Figure 12-14. Light gun signals.

determined by measuring the time it takes (at the speed of light) for the radio wave to go out to the object and then return to the receiving antenna. The direction of a detected object from a radar site is determined by the position of the rotating antenna when the reflected portion of the radio wave is received.

Modern radar is very reliable and there are seldom outages. This is due to reliable maintenance and improved equipment. There are, however, some limitations which may affect air traffic control services and prevent a controller from issuing advisories concerning aircraft which are not under their control and cannot be seen on radar.

The characteristics of radio waves are such that they normally travel in a continuous straight line unless they are “bent” by atmospheric phenomena such as temperature inversions, reflected or attenuated by dense objects such as heavy clouds and precipitation, or screened by high terrain features.

### AIR TRAFFIC CONTROL RADAR BEACON SYSTEM

The air traffic control radar beacon system (ATCRBS) is often referred to as “secondary surveillance radar.” This system consists of three components and helps in alleviating some of the limitations associated with primary radar. The three components are an interrogator, transponder, and radarscope. The advantages of ATCRBS are the reinforcement of radar targets, rapid target identification, and a unique display of selected codes.

### TRANSPONDER

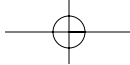
The transponder is the airborne portion of the secondary surveillance radar system and a system with which a pilot should be familiar. The ATCRBS cannot display the secondary information unless an aircraft is equipped with a transponder. A transponder is also required to operate in certain controlled airspace. Airspace is discussed in chapter 13.

A transponder code consists of four numbers from zero to seven (4,096 possible codes). There are some standard codes, or ATC may issue a four-digit code to an aircraft. When a controller requests a code or function on the transponder, the word “squawk” may be used. Figure 12-15 lists some standard transponder phraseology.

### RADAR TRAFFIC INFORMATION SERVICE

Radar equipped air traffic control facilities provide radar assistance to VFR aircraft provided the aircraft can communicate with the facility and are within radar coverage. This basic service includes safety alerts, traffic advisories, limited vectoring when requested, and sequencing at locations where this procedure has been established. In addition to basic radar service, terminal radar service area (TRSA) has been implemented at certain terminal locations. The purpose of this service is to provide separation between all participating VFR aircraft and all IFR aircraft operating within the TRSA. Class C service provides approved separation between IFR and VFR aircraft, and sequencing of VFR aircraft to the primary airport. Class B service provides approved separation of aircraft based on IFR, VFR,





<b>RADAR BEACON PHRASEOLOGY</b>	
SQUAWK (number)	Operate radar beacon transponder on designated code in MODE A/3
IDENT	Engage the "IDENT" feature (military I/P) of the transponder.
SQUAWK (number) and IDENT	Operate transponder on specified code in MODE A/3 and engage the "IDENT" (military I/P) feature.
SQUAWK STANDBY	Switch transponder to standby position.
SQUAWK LOW/NORMAL	Operate transponder on low or normal sensitivity as specified. Transponder is operated in "NORMAL" position unless ATC specifies "LOW" ("ON" is used instead of "NORMAL" as a master control label on some types of transponders).
SQUAWK ALTITUDE	Activate MODE C with automatic altitude reporting.
STOP ALTITUDE SQUAWK	Turn off altitude reporting switch and continue transmitting MODE C framing pulses. If your equipment does not have this capability, turn off MODE C.
STOP SQUAWK (mode in use)	Switch off specified mode. (Used for military aircraft when the controller is unaware of military service requirements for the aircraft to continue operation on another MODE.)
STOP SQUAWK	Switch off transponder.
SQUAWK MAYDAY	Operate transponder in the emergency position (MODE A Code 7700 for civil transponder. MODE 3 Code 7700 and emergency feature for military transponder.)
SQUAWK VFR	Operate radar beacon transponder on Code 1200 in the MODE A/3, or other appropriate VFR code.

**Figure 12-15. Transponder phraseology.**

and/or weight, and sequencing of VFR arrivals to the primary airport(s).

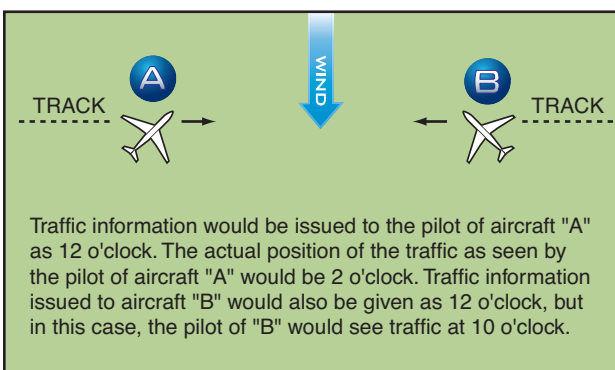
ATC issues traffic information based on observed radar targets. The traffic is referenced by azimuth from the aircraft in terms of the 12-hour clock. Also the distance in nautical miles, direction in which the target is moving, and the type and altitude of the aircraft, if known, are given. An example would be: "Traffic 10 o'clock 5 miles east bound, Cessna 152, 3,000 feet." The pilot should note that traffic position is based on the aircraft track, and that wind correction can affect the clock position at which a pilot locates traffic. [Figure 12-16]

## WAKE TURBULENCE

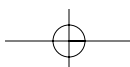
All aircraft generate a wake while in flight. This disturbance is caused by a pair of counter-rotating vortices trailing from the wingtips. The vortices from larger aircraft pose problems to encountering aircraft. The wake of these aircraft can impose rolling moments exceeding the roll-control authority of the encountering aircraft. Also, the turbulence generated within the vortices can damage

aircraft components and equipment if encountered at close range. For this reason, a pilot must envision the location of the vortex wake and adjust the flightpath accordingly.

During ground operations and during takeoff, jet-engine blast (thrust stream turbulence) can cause damage and upsets at close range. For this reason, pilots of small aircraft should consider the effects of



**Figure 12-16. Traffic advisories.**



jet-engine blast and maintain adequate separation. Also, pilots of larger aircraft should consider the effects of their aircraft's jet-engine blast on other aircraft and equipment on the ground.

### VORTEX GENERATION

Lift is generated by the creation of a pressure differential over the wing surface. The lowest pressure occurs over the upper wing surface, and the highest pressure under the wing. This pressure differential triggers the rollup of the airflow aft of the wing resulting in swirling air masses trailing downstream of the wingtips. After the rollup is completed, the wake consists of two counter-rotating cylindrical vortices. Most of the energy is within a few feet of the center of each vortex, but pilots should avoid a region within about 100 feet of the vortex core. [Figure 12-17]

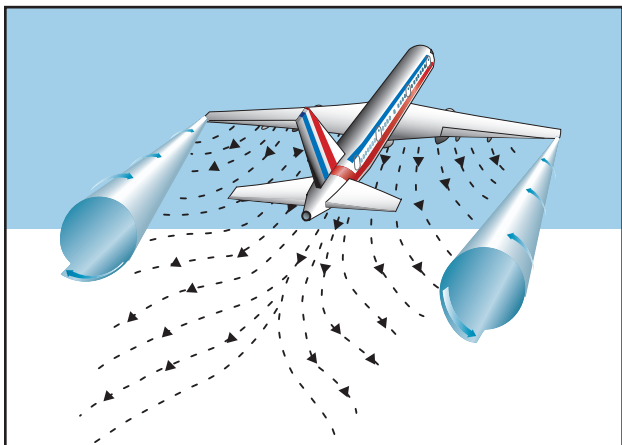


Figure 12-17. Vortex generation.

### VORTEX STRENGTH

The strength of the vortex is governed by the weight, speed, and shape of the wing of the generating aircraft. The vortex characteristics of any given aircraft can also be changed by the extension of flaps or other wing configuration devices as well as by a change in speed. The greatest vortex strength occurs when the generating aircraft is heavy, clean, and slow.

### VORTEX BEHAVIOR

Trailing vortices have certain behavioral characteristics that can help a pilot visualize the wake location and take avoidance precautions.

Vortices are generated from the moment an aircraft leaves the ground, since trailing vortices are the by-product of wing lift. The vortex circulation is outward, upward, and around the wingtips when viewed from either ahead or behind the aircraft. Tests have shown that vortices remain spaced a bit less than a wingspan apart, drifting with the wind, at altitudes greater than a wingspan from the ground. Tests have also shown that the vortices sink at a rate of several hundred feet per minute, slowing their descent and diminishing in strength with time and distance behind the generating aircraft. [Figure 12-18]

When the vortices of larger aircraft sink close to the ground (within 100 to 200 feet), they tend to move laterally over the ground at a speed of 2 or 3 knots. A crosswind will decrease the lateral movement of the upwind vortex and increase the movement of the downwind vortex. A tailwind condition can move the vortices of the preceding aircraft forward into the touchdown zone.

### VORTEX AVOIDANCE PROCEDURES

- Landing behind a larger aircraft on the same runway—stay at or above the larger aircraft's approach flightpath and land beyond its touchdown point.
- Landing behind a larger aircraft on a parallel runway closer than 2,500 feet—consider the possibility of drift and stay at or above the larger aircraft's final approach flightpath and note its touchdown point.
- Landing behind a larger aircraft on crossing runway—cross above the larger aircraft's flightpath.

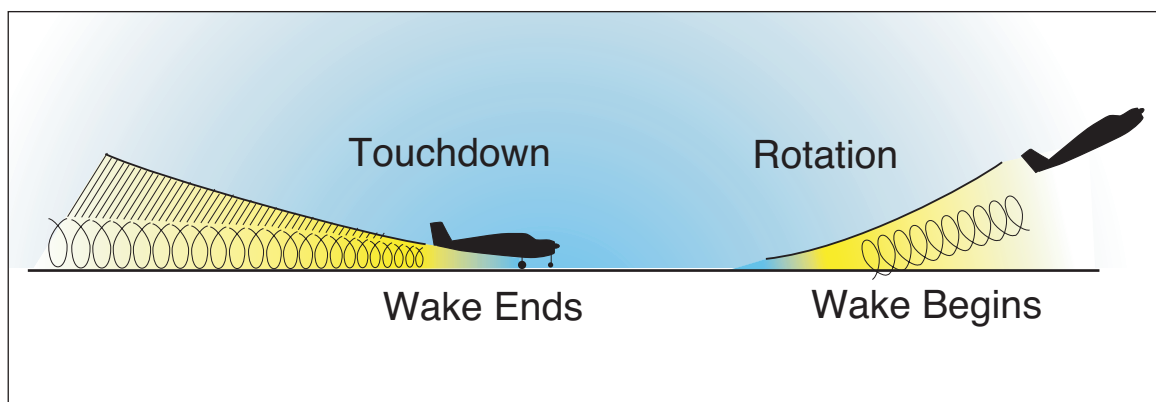
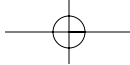


Figure 12-18. Vortex behavior.



- Landing behind a departing aircraft on the same runway—land prior to the departing aircraft’s rotating point.
- Landing behind a larger aircraft on a crossing runway—note the aircraft’s rotation point and if past the intersection, continue and land prior to the intersection. If the larger aircraft rotates prior to the intersection, avoid flight below its flight-path. Abandon the approach unless a landing is ensured well before reaching the intersection.
- Departing behind a large aircraft, rotate prior to the large aircraft’s rotation point and climb above its climb path until turning clear of the wake.
- For intersection takeoffs on the same runway, be alert to adjacent larger aircraft operations, particularly upwind of the runway of intended use. If an intersection takeoff clearance is received, avoid headings that will cross below the larger aircraft’s path.
- If departing or landing after a large aircraft executing a low approach, missed approach, or touch and go landing (since vortices settle and move laterally near the ground, the vortex hazard may exist along the runway and in the flightpath, particularly in a quartering tailwind), it is prudent to wait 2 minutes prior to a takeoff or landing.
- En route it is advisable to avoid a path below and behind a large aircraft, and if a large aircraft is observed above on the same track, change the aircraft position laterally and preferably upwind.

## COLLISION AVOIDANCE

Title 14 of the Code of Federal Regulations (14 CFR) part 91 has established right-of-way rules, minimum safe altitudes, and VFR cruising altitudes to enhance flight safety. The pilot can contribute to collision avoidance by being alert and scanning for other aircraft. This is particularly important in the vicinity of an airport.

Effective scanning is accomplished with a series of short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10°, and each should be observed for at least 1 second to enable detection. Although back and forth eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable and then adhere to it to assure optimum scanning.

Even if entitled to the right-of-way, a pilot should give way if it is felt another aircraft is too close.

## CLEARING PROCEDURES

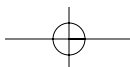
The following procedures and considerations should assist a pilot in collision avoidance under various situations.

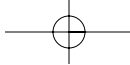
- **Before Takeoff**—Prior to taxiing onto a runway or landing area in preparation for takeoff, pilots should scan the approach area for possible landing traffic, executing appropriate maneuvers to provide a clear view of the approach areas.
- **Climbs and Descents**—During climbs and descents in flight conditions which permit visual detection of other traffic, pilots should execute gentle banks left and right at a frequency which permits continuous visual scanning of the airspace.
- **Straight and Level**—During sustained periods of straight-and-level flight, a pilot should execute appropriate clearing procedures at periodic intervals.
- **Traffic Patterns**—Entries into traffic patterns while descending should be avoided.
- **Traffic at VOR Sites**—Due to converging traffic, sustained vigilance should be maintained in the vicinity of VORs and intersections.
- **Training Operations**—Vigilance should be maintained and clearing turns should be made prior to a practice maneuver. During instruction, the pilot should be asked to verbalize the clearing procedures (call out “clear left, right, above, and below”).

High-wing and low-wing aircraft have their respective blind spots. High-wing aircraft should momentarily raise their wing in the direction of the intended turn and look for traffic prior to commencing the turn. Low-wing aircraft should momentarily lower the wing.

## RUNWAY INCURSION AVOIDANCE

It is important to give the same attention to operating on the surface as in other phases of flights. Proper planning can prevent runway incursions and the possibility of a ground collision. A pilot should be aware of the airplane’s position on the surface at all times and be aware of other aircraft and vehicle operations on the airport. At times controlled airports can be busy and taxi instructions complex. In





this situation it may be advisable to write down taxi instructions. The following are some practices to help prevent a runway incursion.

- Read back all runway crossing and/or hold instructions.
- Review airport layouts as part of preflight planning and before descending to land, and while taxiing as needed.
- Know airport signage.
- Review Notices to Airmen (NOTAM) for information on runway/taxiway closures and construction areas.
- Request progressive taxi instructions from ATC when unsure of the taxi route.
- Check for traffic before crossing any Runway Hold Line and before entering a taxiway.
- Turn on aircraft lights and the rotating beacon or strobe lights while taxiing.
- When landing, clear the active runway as soon as possible, then wait for taxi instructions before further movement.
- Study and use proper phraseology in order to understand and respond to ground control instructions.
- Write down complex taxi instructions at unfamiliar airports.

For more detailed information, refer to Advisory Circular (AC) 91-73, Part 91 Pilot and Flightcrew Procedures During Taxi Operations and Part 135 Single-Pilot Operations.

