Chapter 11

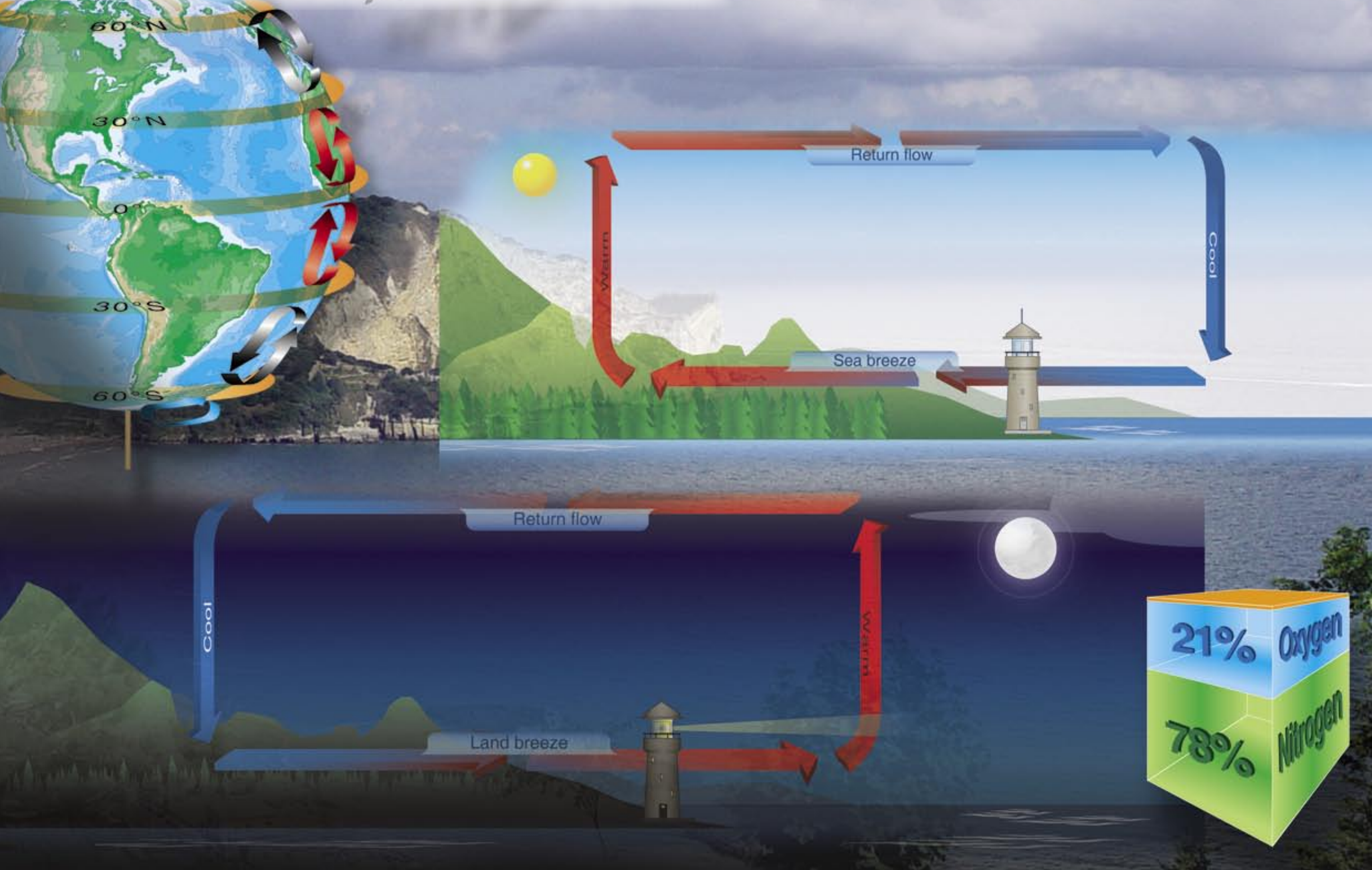
Weather Theory

Introduction

Weather is an important factor that influences aircraft performance and flying safety. It is the state of the atmosphere at a given time and place, with respect to variables such as temperature (heat or cold), moisture (wetness or dryness), wind velocity (calm or storm), visibility (clearness or cloudiness), and barometric pressure (high or low). The term weather can also apply to adverse or destructive atmospheric conditions, such as high winds.

This chapter explains basic weather theory and offers pilots background knowledge of weather principles. It is designed to help them gain a good understanding of how weather affects daily flying activities. Understanding the theories behind weather helps a pilot make sound weather decisions based on the reports and forecasts obtained from a Flight Service Station (FSS) weather specialist and other aviation weather services.

Be it a local flight or a long cross-country flight, decisions based on weather can dramatically affect the safety of the flight.



Atmosphere

The atmosphere is a blanket of air made up of a mixture of gases that surrounds the Earth and reaches almost 350 miles from the surface of the Earth. This mixture is in constant motion. If the atmosphere were visible, it might look like an ocean with swirls and eddies, rising and falling air, and waves that travel for great distances.

Life on Earth is supported by the atmosphere, solar energy, and the planet's magnetic fields. The atmosphere absorbs energy from the Sun, recycles water and other chemicals, and works with the electrical and magnetic forces to provide a moderate climate. The atmosphere also protects life on Earth from high energy radiation and the frigid vacuum of space.

Composition of the Atmosphere

In any given volume of air, 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 one percent. This cubic foot also contains some water vapor, varying from zero to about five percent by volume. This small amount of water vapor is responsible for major changes in the weather. *[Figure 11-1]*

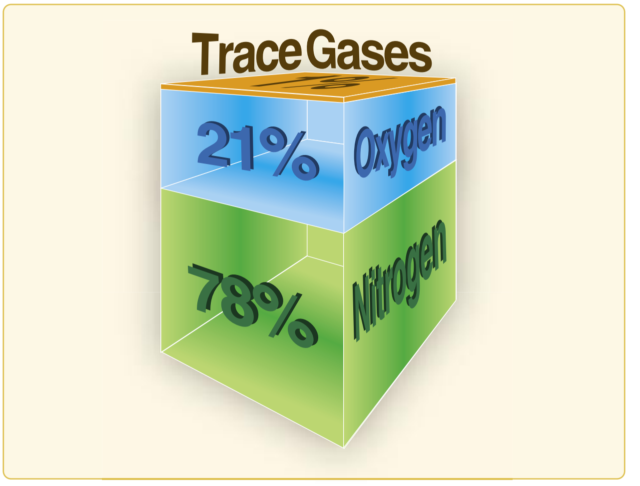


Figure 11-1. *Composition of the atmosphere.*

The envelope of gases surrounding the Earth changes from the ground up. Four distinct layers or spheres of the atmosphere have been identified using thermal characteristics (temperature changes), chemical composition, movement, and density. *[Figure 11-2]*

The first layer, known as the troposphere, extends from sea level up to 20,000 feet (8 kilometers (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 occur within this first layer of the atmosphere. Inside the troposphere, the temperature decreases at a rate of about 2 °Celsius (C) every 1,000 feet of altitude gain, and the pressure decreases at a rate of about one inch per 1,000 feet of altitude gain.

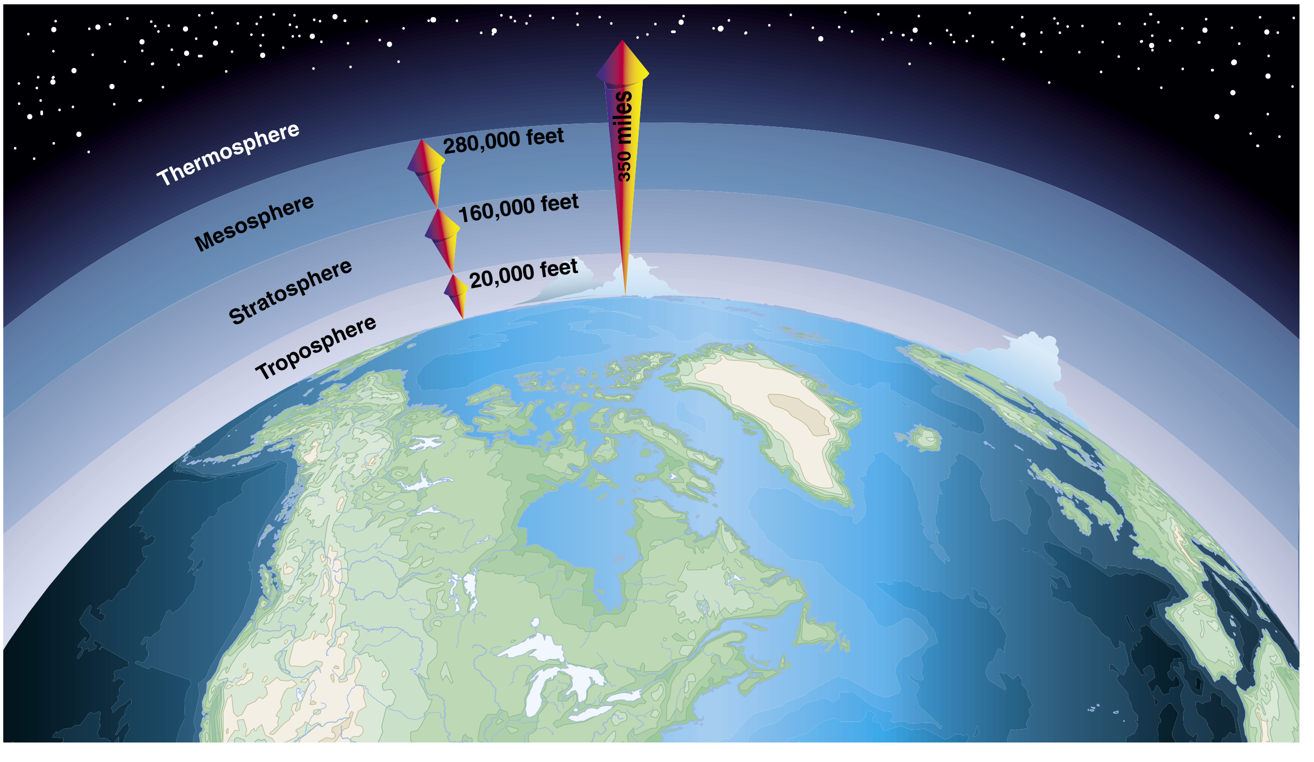


Figure 11-2. *Layers of the atmosphere.*

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 jet stream and possible clear air turbulence.

Above the tropopause are three more atmospheric levels. The first 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 although certain types of clouds occasionally extend in it. Above the stratosphere are the mesosphere and thermosphere which have little influence over weather.

Atmospheric Circulation

As noted earlier, the atmosphere is in constant motion. Certain factors combine to set the atmosphere in motion, but a major factor is the uneven heating of the Earth's surface. This heating upsets the equilibrium of the atmosphere, creating changes in air movement and atmospheric pressure. The movement of air around the surface of the Earth is called atmospheric circulation.

Heating of the Earth's surface is accomplished by several processes, but in the simple convection-only model used for this discussion, the Earth is warmed by energy radiating from the sun. The process causes a circular motion that results when warm air rises and is replaced by cooler air.

Warm air rises because heat causes air molecules to spread apart. As the air expands, it becomes less dense and lighter than the surrounding air. As air cools, the molecules pack together more closely, becoming denser and heavier than warm air. As a result, cool, heavy air tends to sink and replace warmer, rising air.

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 on the 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.

Solar heating causes higher temperatures in equatorial areas which causes the air to be less dense and rise. As the warm air flows toward the poles, it cools, becoming denser, and sinks back toward the surface. *[Figure 11-3]*

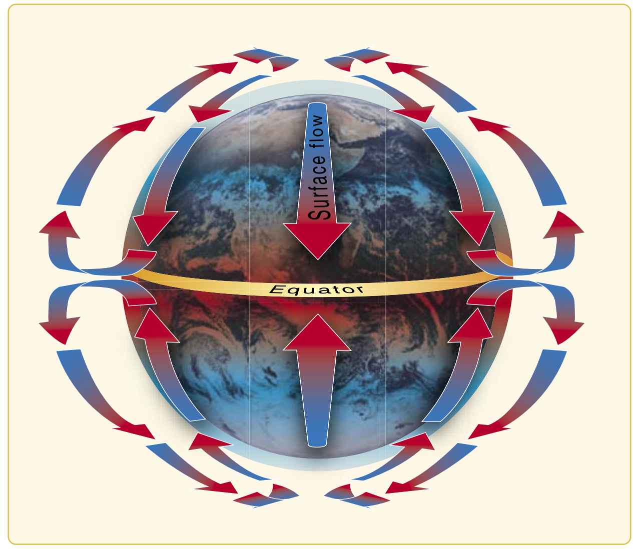


Figure 11-3. *Circulation pattern in a static environment.*

Atmospheric Pressure

The unequal heating of the Earth's surface not only modifies air density and creates circulation patterns; it also causes changes in air pressure or the force exerted by the weight of air molecules. Although air molecules are invisible, they still have weight and take up space.

Imagine a sealed column of air that has a footprint of one square inch and is 350 miles high. It would take 14.7 pounds of effort to lift that column. This represents the air's weight; if the column is shortened, the pressure exerted at the bottom (and its weight) would be less.

The weight of the shortened column of air at 18,000 feet is approximately 7.4 pounds; almost 50 percent that at sea level. For instance, if a bathroom scale (calibrated for sea level) were raised to 18,000 feet, the column of air weighing 14.7 pounds at sea level would be 18,000 feet shorter, and would weigh approximately 7.3 pounds (50 percent) less than at sea level. *[Figure 11-4]*

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

Coriolis Force

In general atmospheric 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. The resulting low pressure allows the high-pressure air at the poles to flow along the planet's surface

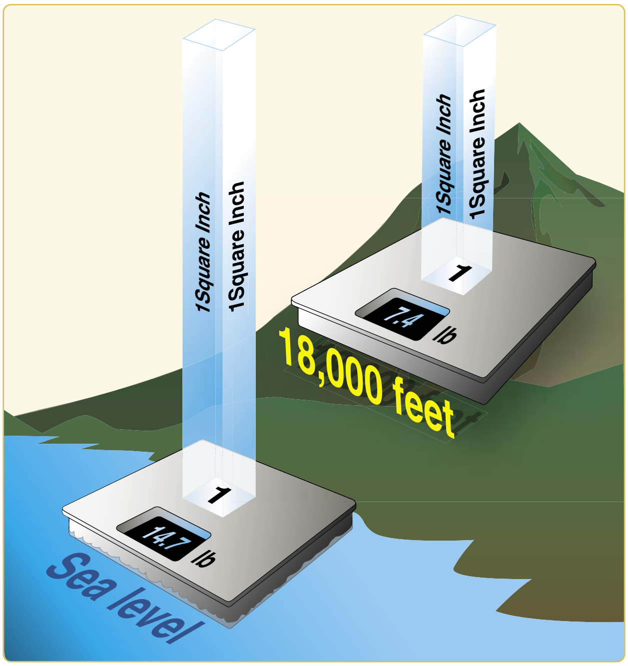


Figure 11-4. *Atmosphere weights.*

Figure 11-5. *Three-cell circulation pattern due to the rotation of the Earth.*

toward the equator. While this pattern of air circulation is correct in theory, the circulation of air is modified by several forces, the most important of which is the rotation of the Earth.

The force created by the rotation of the Earth is known as the Coriolis force. This force is not perceptible to humans as they walk around because humans move slowly and travel relatively short distances compared to the size and rotation rate of the Earth. However, the Coriolis force significantly affects bodies that move over great distances, such as an 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 greater 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 11-5]* 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 such as frictional forces caused by the topography of the Earth's surface which modify the movement of the air in the atmosphere. For example, 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. Thus, the wind direction at the surface varies somewhat from the wind direction just a few thousand feet above the Earth.

Measurement of Atmosphere Pressure

Atmospheric pressure is typically measured in inches of mercury ("Hg) by a mercurial barometer. *[Figure 11-6]* 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. When the pressure drops, mercury drains out of the tube, decreasing the height of the column. This type of barometer is typically used in a laboratory or weather observation station, is not easily transported, and difficult to read.

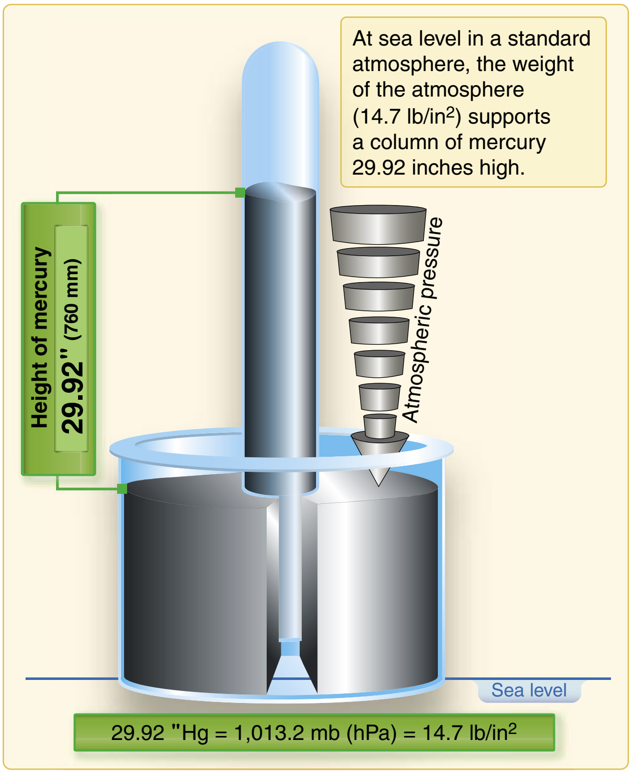


Figure 11-6. *Mercurial barometer.*

An aneroid barometer is an alternative to a mercurial barometer; it is easier to read and transport. *[Figure 11-7]* 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.

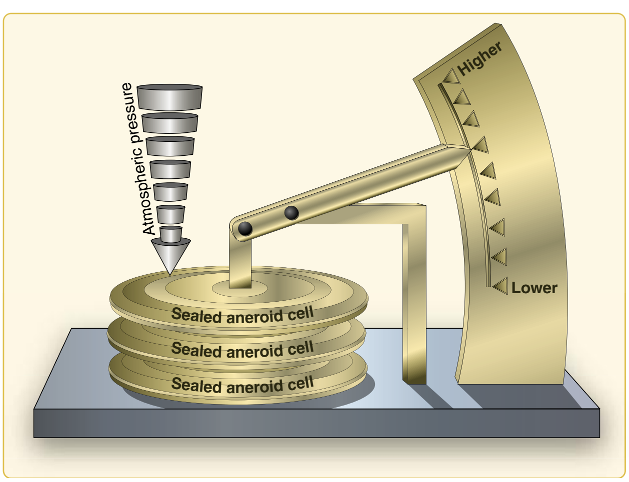


Figure 11-7. *Aneroid barometer.*

To provide a common reference, the International Standard Atmosphere (ISA) has been established. These standard conditions are the basis for certain flight instruments and most aircraft performance data. Standard sea level pressure is defined as 29.92 "Hg and a standard temperature of 59 °F (15 °C). Atmospheric pressure is also reported in millibars (mb), with 1 "Hg equal to approximately 34 mb. Standard sea level pressure is 1,013.2 mb. Typical mb pressure readings range from 950.0 to 1,040.0 mb. Constant pressure charts and hurricane pressure reports are written using mb.

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 "Hg for every 1,000 feet of elevation. For example, a station at 5,000 feet above sea level, with a reading of 24.92 "Hg, reports a sea level pressure reading of 29.92 "Hg. *[Figure 11-8]* 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.

Altitude and Atmospheric Pressure

As altitude increases, atmospheric pressure decreases. On average, with every 1,000 feet of increase in altitude, the atmospheric pressure decreases 1 "Hg. As pressure decreases, the air becomes less dense or "thinner." This is the equivalent of being at a higher altitude and is referred to as density altitude (DA). As pressure decreases, DA increases and has a pronounced effect on aircraft performance.

Differences in air density caused by changes in temperature result in a change in pressure. This, in turn, creates motion in the atmosphere, both vertically and horizontally, in the form of currents and wind. The atmosphere is almost constantly in motion as it strives to reach equilibrium. These never-ending air movements set up chain reactions which cause a continuing variety in the weather.

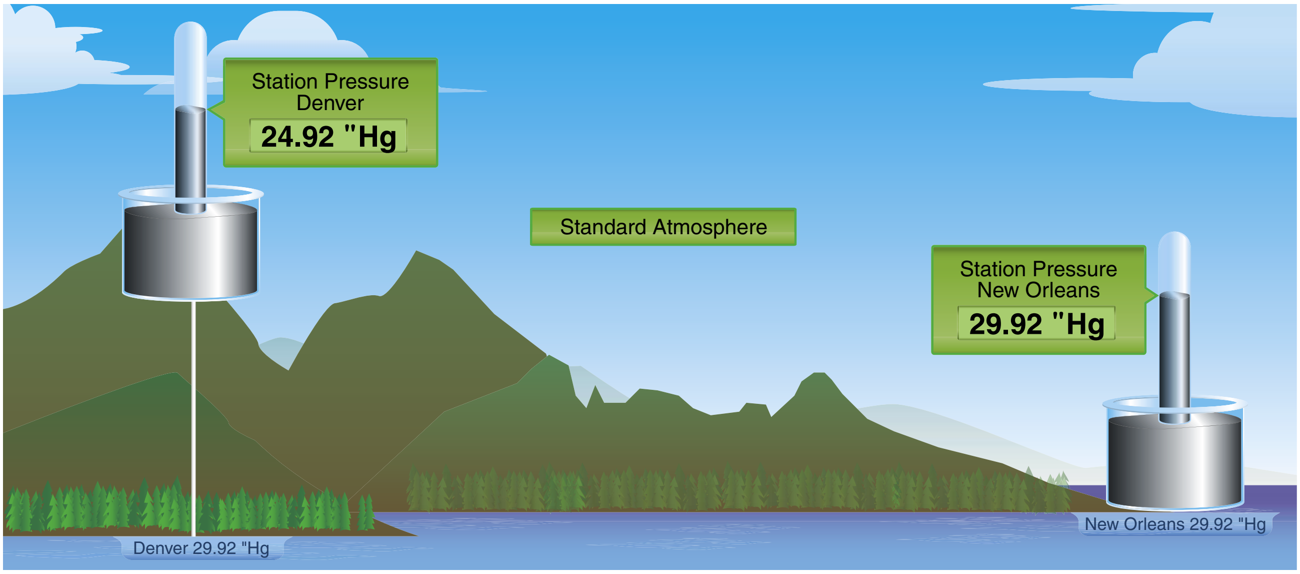


Figure 11-8. *Station pressure is converted to and reported in sea level pressure.*

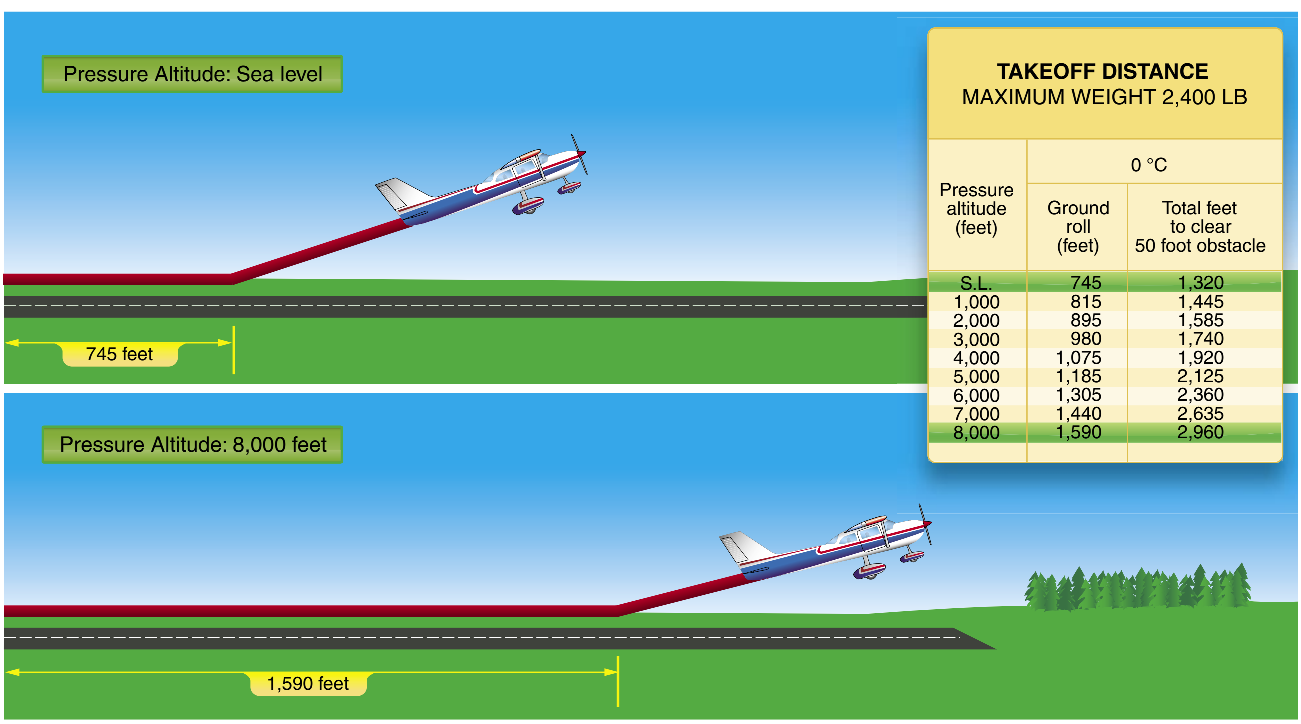
Altitude and Flight

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 745 feet of ground run at sea level requires more than double that at a pressure altitude of 8,000 feet. *[Figure 11-9]*. 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.

Altitude and the Human Body

As discussed earlier, nitrogen and other trace gases make up 79 percent of the atmosphere, while the remaining 21



TAKEOFF DISTANCE
MAXIMUM WEIGHT 2,400 LB

Pressure altitude (feet)	0 °C	
	Ground roll (feet)	Total feet to clear 50 foot obstacle
S.L.	745	1,320
1,000	815	1,445
2,000	895	1,585
3,000	980	1,740
4,000	1,075	1,920
5,000	1,185	2,125
6,000	1,305	2,360
7,000	1,440	2,635
8,000	1,590	2,960

Figure 11-9. *Takeoff distances increase with increased altitude.*

percent is life sustaining, atmospheric oxygen. At sea level, atmospheric pressure is great enough to support normal growth, activity, and life. By 18,000 feet, the partial pressure of oxygen is reduced and adversely affects the normal activities and functions of the human body.

The reactions of the average person become impaired at an altitude of about 10,000 feet, but for some people impairment can occur at an altitude as low as 5,000 feet. The physiological reactions to hypoxia or 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. Supplemental oxygen or cabin pressurization systems help pilots fly at higher altitudes and overcome the effects of oxygen deprivation.

Wind and Currents

Air flows from areas of high pressure into areas of low pressure because air always seeks out lower pressure. Air pressure, temperature changes, and the Coriolis force work in combination to create two kinds of motion in the atmosphere—vertical movement of ascending and descending currents, and horizontal movement in the form of wind. Currents and winds are important as they affect takeoff, landing, and cruise flight operations. Most importantly, currents and winds or atmospheric circulation cause weather changes.

Wind Patterns

In the Northern Hemisphere, the flow of air from areas of high to low pressure is deflected to the right and produces a clockwise circulation around an area of high pressure. This is known as anticyclonic circulation. The opposite is true of low-pressure areas; the air flows toward a low and is deflected to create a counterclockwise or cyclonic circulation. *[Figure 11-10]*

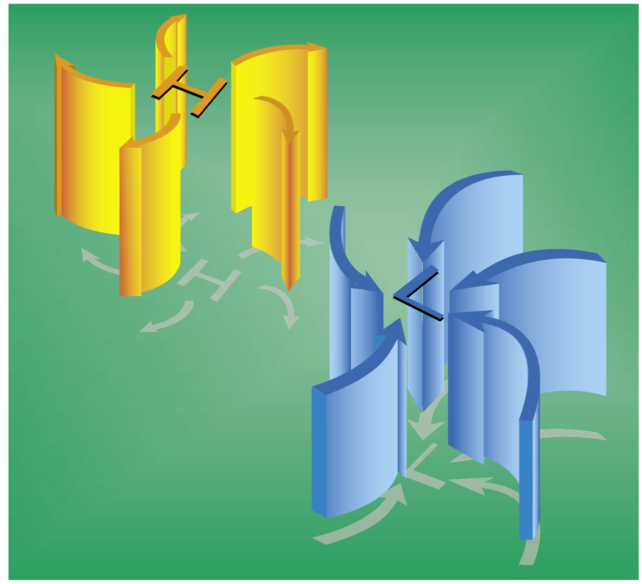


Figure 11-10. *Circulation pattern about areas of high and low pressure.*

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 11-11]* When planning a flight from west to east, favorable winds would be encountered 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.

While the theory of circulation and wind patterns is accurate for large scale atmospheric circulation, 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 11-12]*

Convective currents are particularly noticeable in areas with a land mass 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

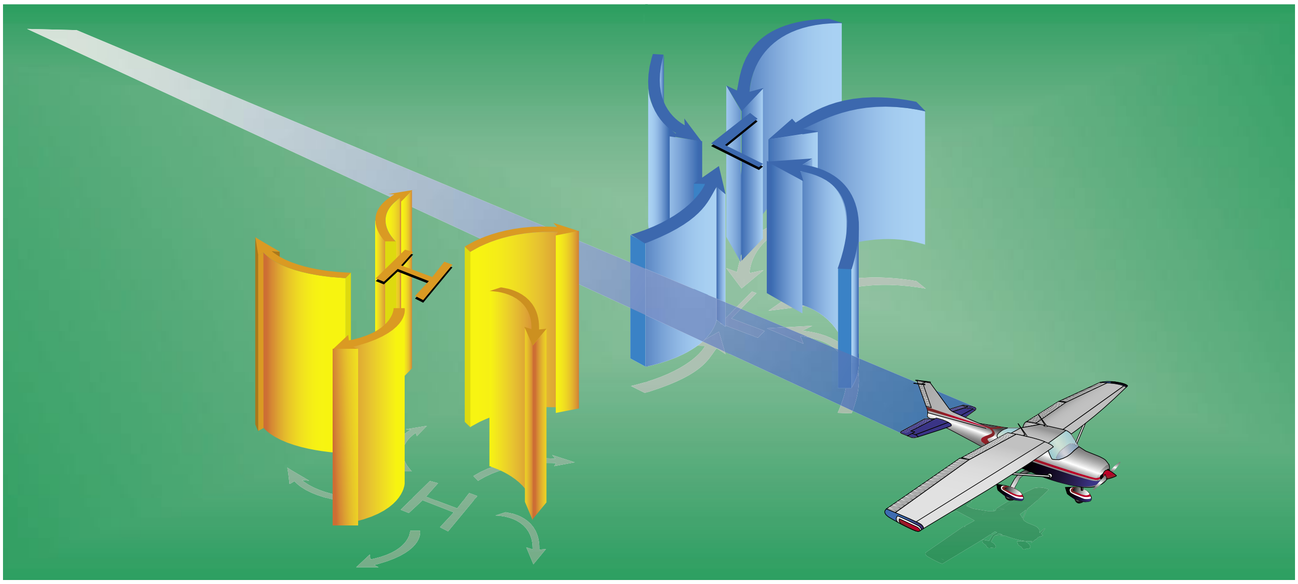


Figure 11-11. *Favorable winds near a high pressure system.*

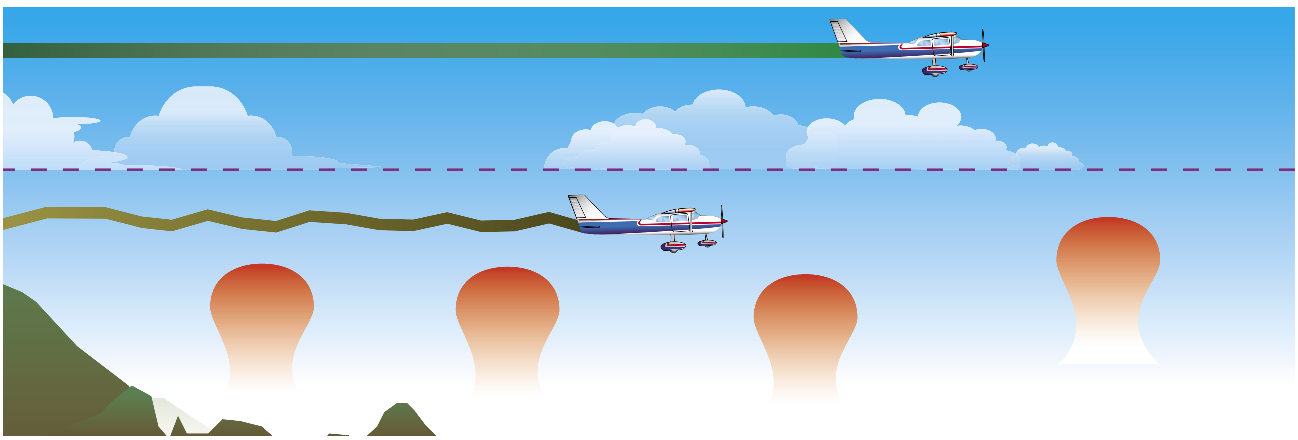


Figure 11-12. *Convective turbulence avoidance.*

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 11-13]*

Convective currents close to the ground can affect a pilot's ability to control the aircraft. For example, on final approach, 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 11-14]*

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 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 11-15]*

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

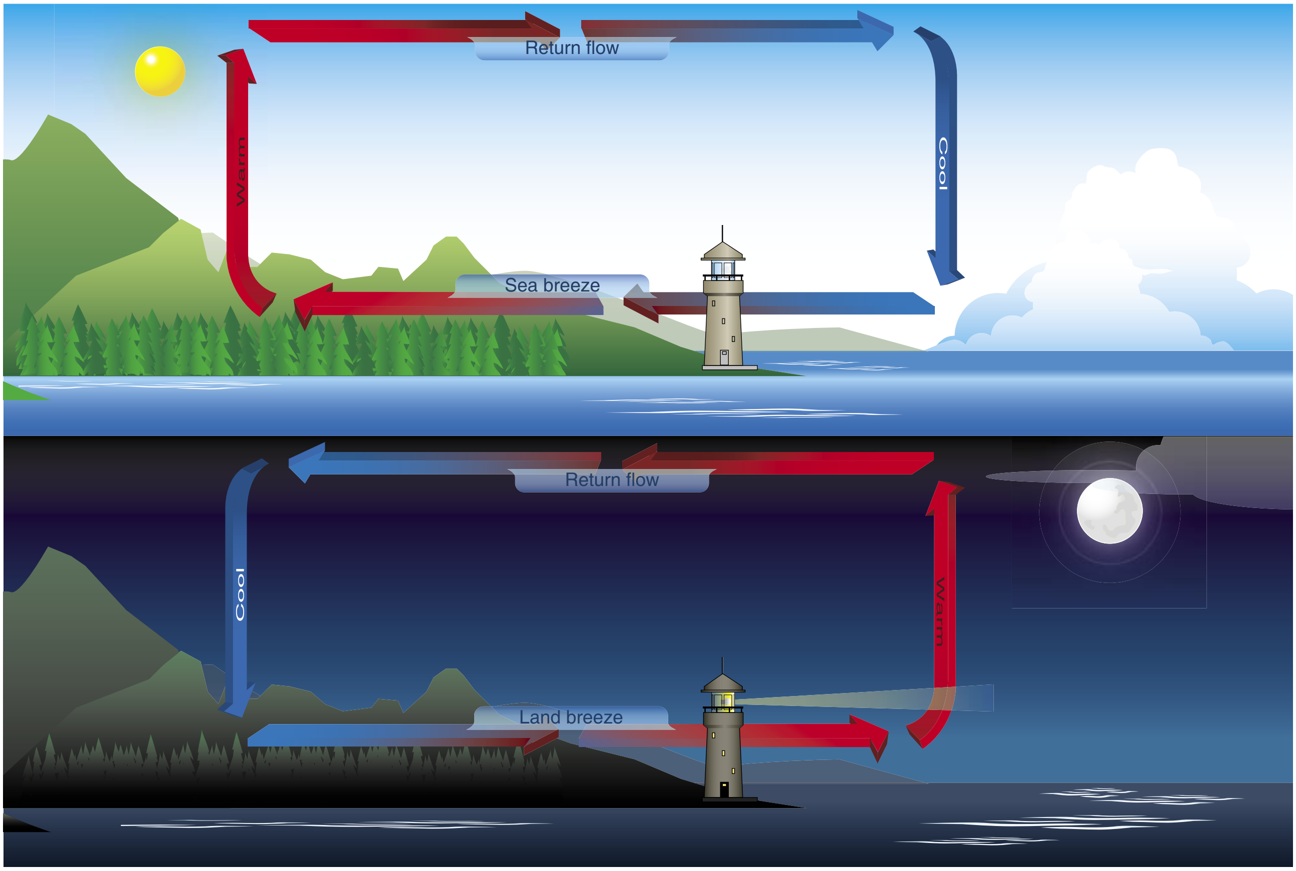


Figure 11-13. *Sea breeze and land breeze wind circulation patterns.*

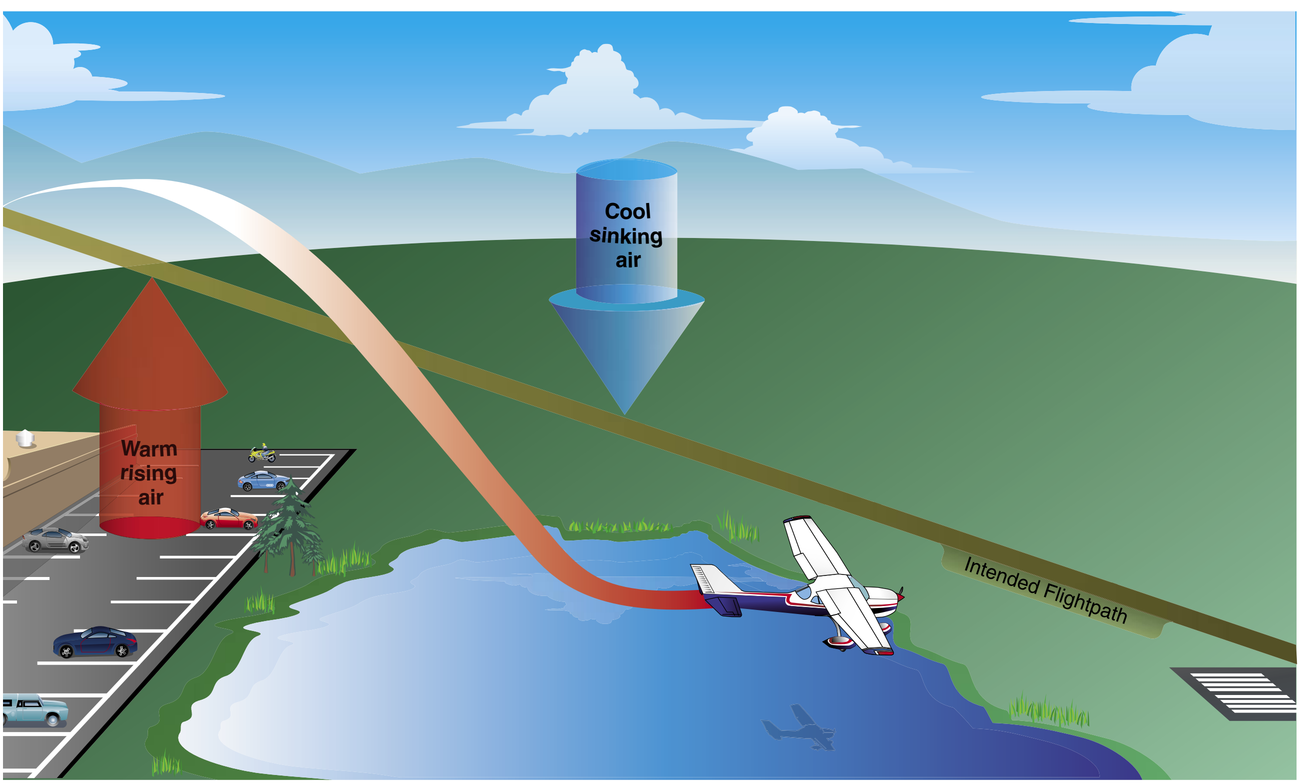


Figure 11-14. *Currents generated by varying surface conditions.*

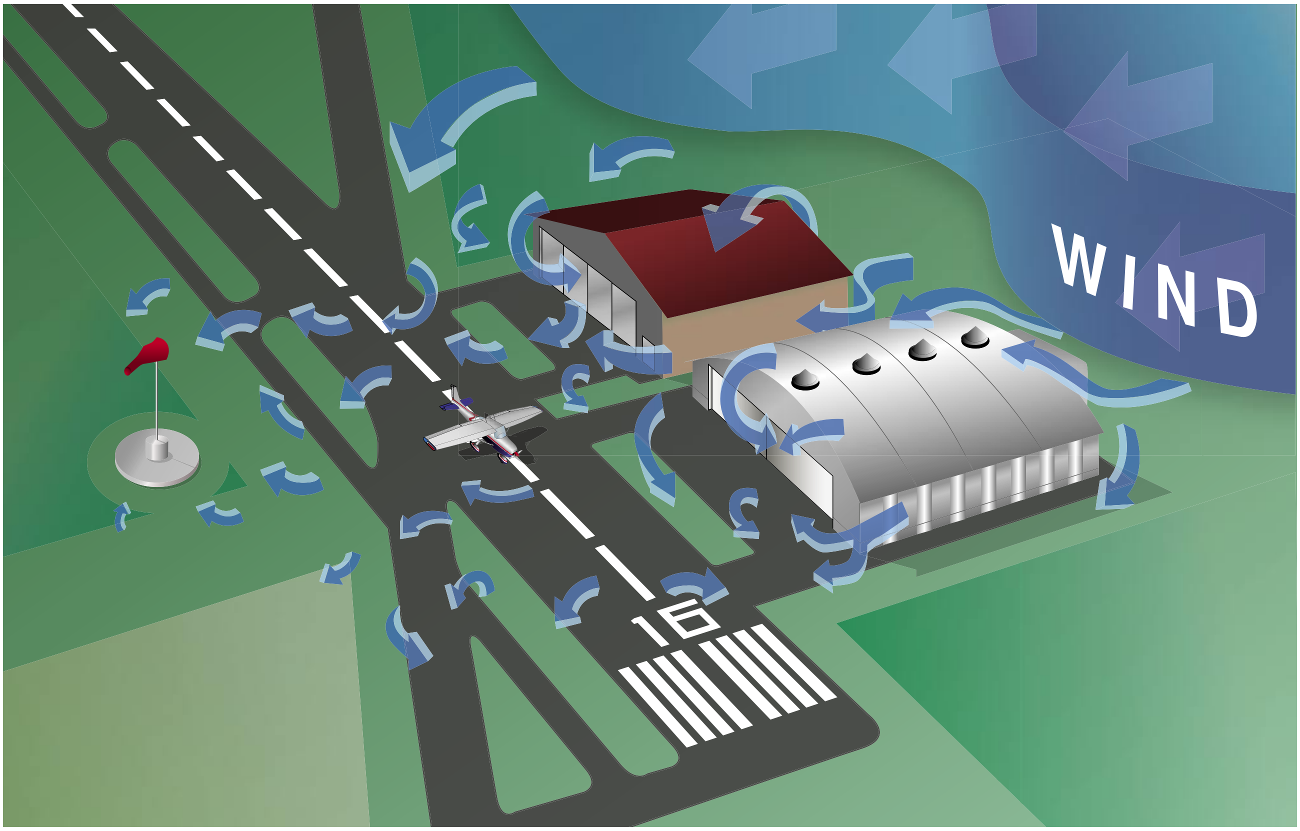


Figure 11-15. *Turbulence caused by manmade obstructions.*

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 11-16]* 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. Before conducting a flight in or near mountainous terrain, it is helpful for a pilot unfamiliar with a mountainous area to get a checkout with a mountain qualified flight instructor.

Figure 11-16. *Turbulence in mountainous regions.*

Low-Level Wind Shear

Wind shear is a sudden, drastic change in wind speed 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 change 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 wind speed and direction of change. For example, a tailwind that quickly changes to a headwind causes an increase in airspeed and performance. Conversely, when a headwind changes to a tailwind, the airspeed rapidly decreases and there is 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.

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 one 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 (fpm). It can also produce a hazardous wind direction change of 45 degrees 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 11-17]* 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).

Microbursts are often difficult to detect because they occur in relatively confined areas. 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 wind speeds. When wind speeds 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 (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

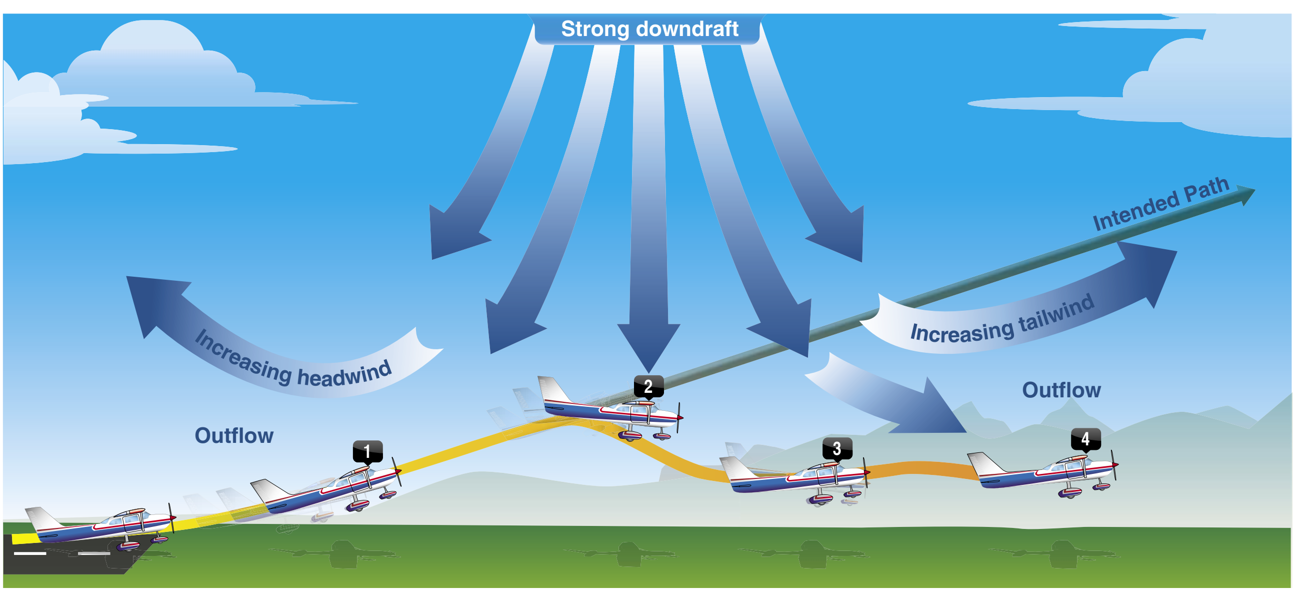


Figure 11-17. *Effects of a microburst wind.*

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 12, Weather Aviation Services.

Wind conditions are reported by an arrow attached to the station location circle. *[Figure 11-18]* 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 ten knots, while half a barb is equal to five knots, and a pennant is equal to 50 knots.

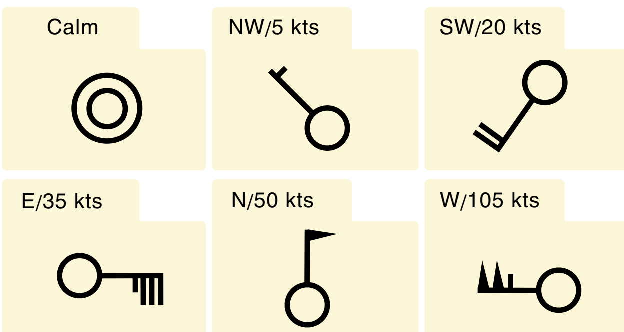


Figure 11-18. *Depiction of winds on a surface weather chart.*

The pressure for each station is recorded on the weather chart and is shown in mb. 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 11-19]* 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 cut-off lows (cols). A high is an area of high pressure 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 wind speed 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.

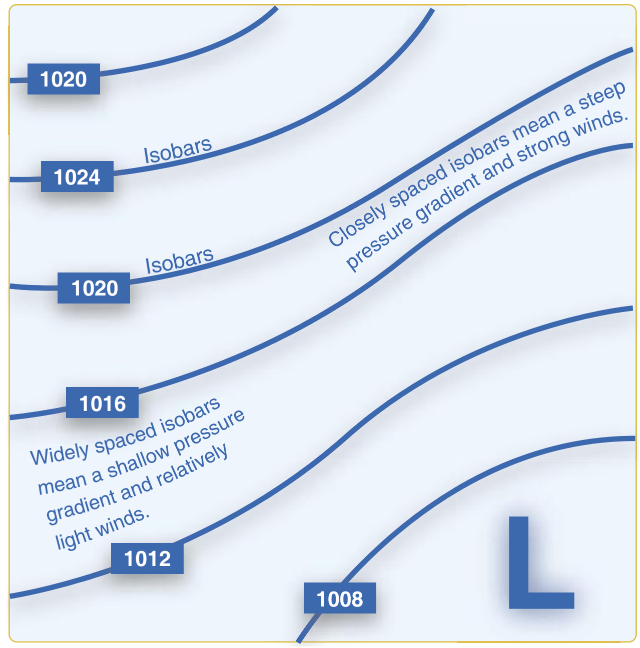


Figure 11-19. *Isobars reveal the pressure gradient of an area of high- or low-pressure areas.*

Generally, the wind 2,000 feet above ground level (AGL) is 20° to 40° to the right of surface winds, and the wind speed is 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 and adiabatic cooling are 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 °C (3.5 °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 °C (5.4 °F) per 1,000 feet. The moist adiabatic lapse rate varies from 1.1 °C to 2.8 °C (2 °F to 5 °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.

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 is the evaporation of human perspiration. 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 11-20]*

Temperature/Dew Point Relationship

The relationship between dew point and temperature defines the concept of relative humidity. The dew point, 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 dew point, 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.

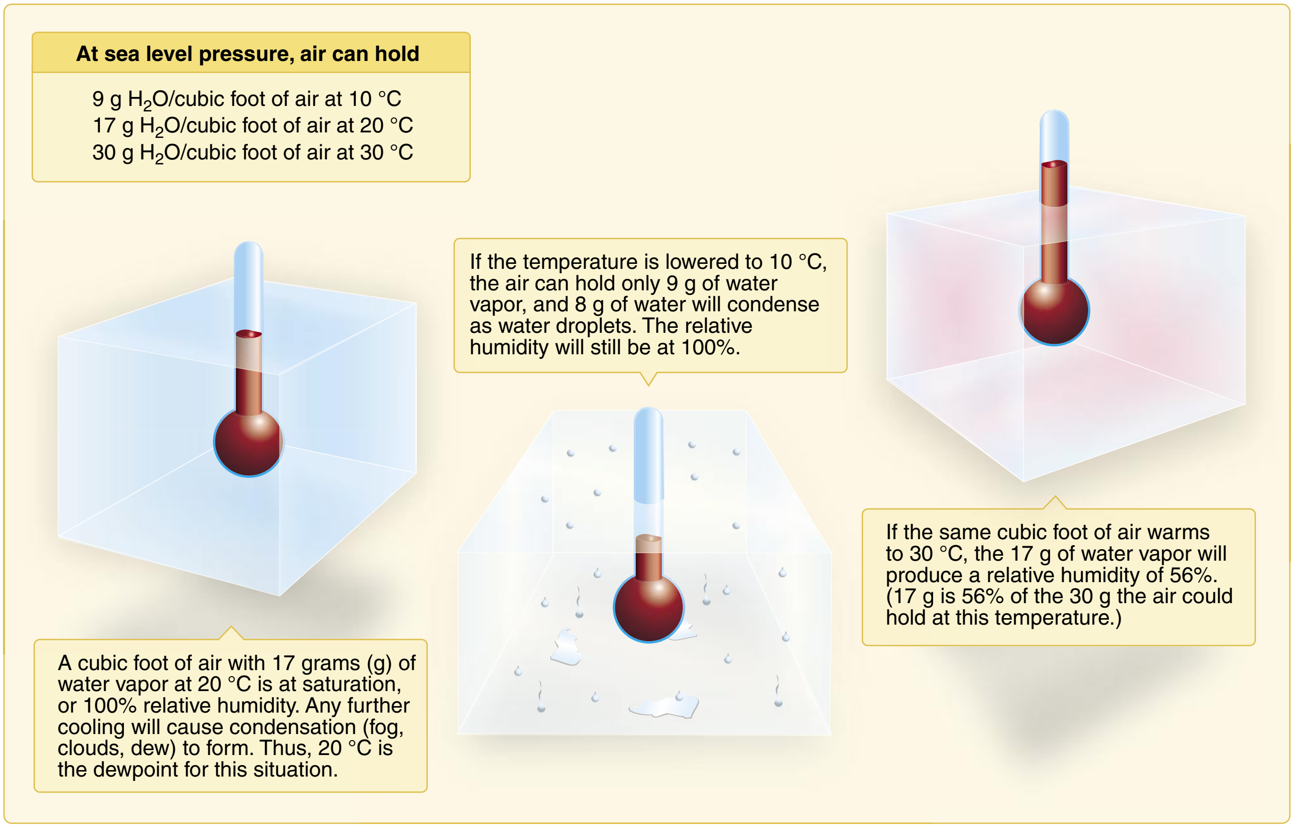


Figure 11-20. *Relationship between relative humidity, temperature, and dewpoint.*

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

Given:

Temperature (T) = 85 °F

Dew point (DP) = 71 °F

Convergence Rate (CR) = 4.4°

T – DP = Temperature Dew Point Spread (TDS)

TDS ÷ CR = X

X × 1,000 feet = height of cloud base AGL

Example:

85 °F–71 °F = 14 °F

14 °F ÷ 4.4 °F = 3.18

3.18 × 1,000 = 3,180 feet AGL

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

Explanation:

With an outside air temperature (OAT) of 85 °F at the surface, and dew point at the surface of 71 °F, the spread is 14°. Divide the temperature dew point 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 dew point 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 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 dew point. 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 is 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 adversely affect the ability to take off. An aircraft must be thoroughly cleaned and free of frost prior to beginning a flight.

Fog

Fog 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 dew point. 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 11-21]* 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 dew point. As the sun rises and the temperature increases, radiation fog lifts and eventually burns off. Any increase in wind also speeds the dissipation of radiation fog. If radiation fog is less than 20 feet thick, it is known as ground 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.

Figure 11-21. *Radiation fog.*

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 can also 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 °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 11-22]*

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 visual flight rules (VFR) flight impossible.

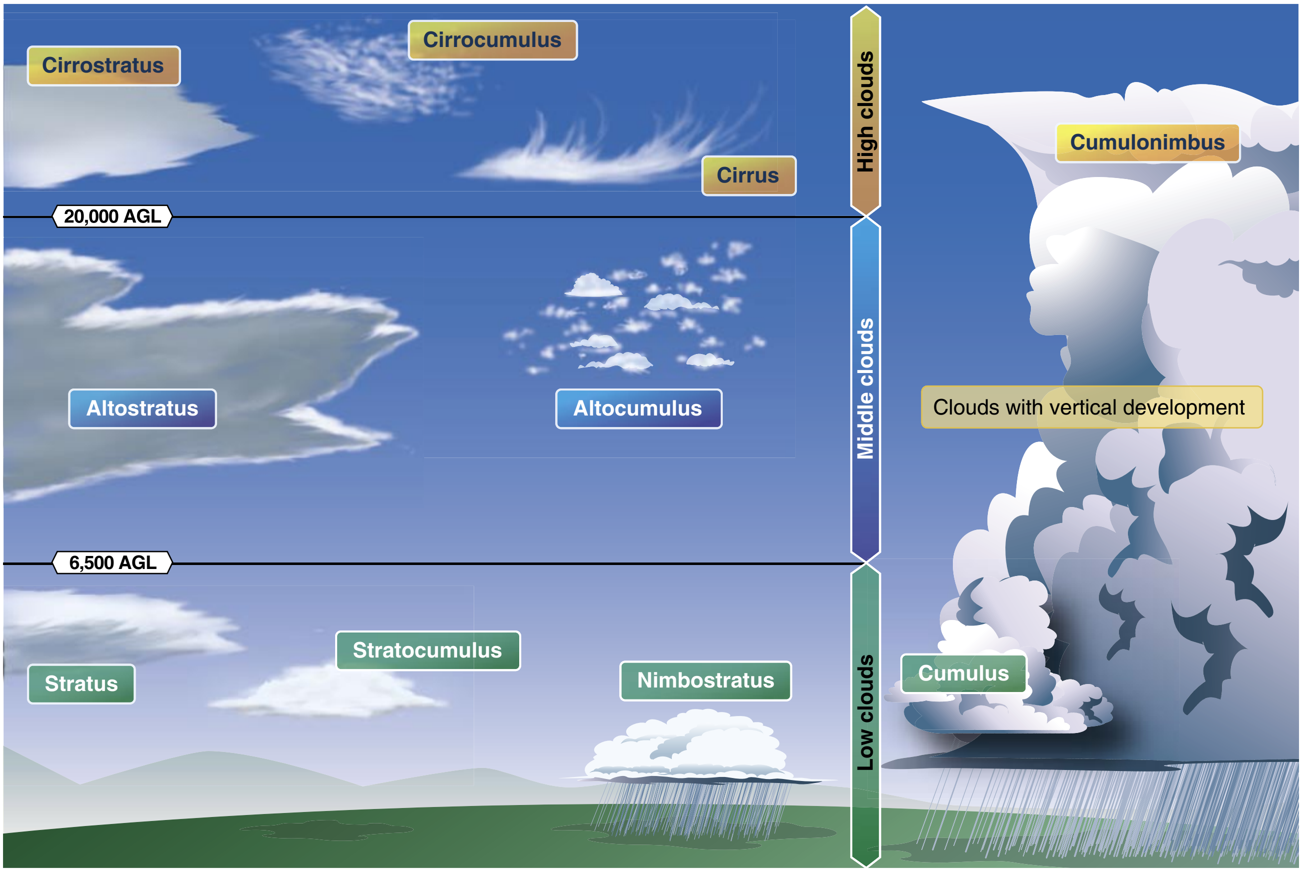


Figure 11-22. *Basic cloud types.*

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.

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.

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 fpm. 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 11-23]*

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 identified as severe or giving an intense radar echo by at least 20 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.

Cloud classification can be further broken down into specific cloud types according to the outward appearance and cloud composition. Knowing these terms can help a pilot 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

Ceiling

For aviation purposes, a ceiling 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

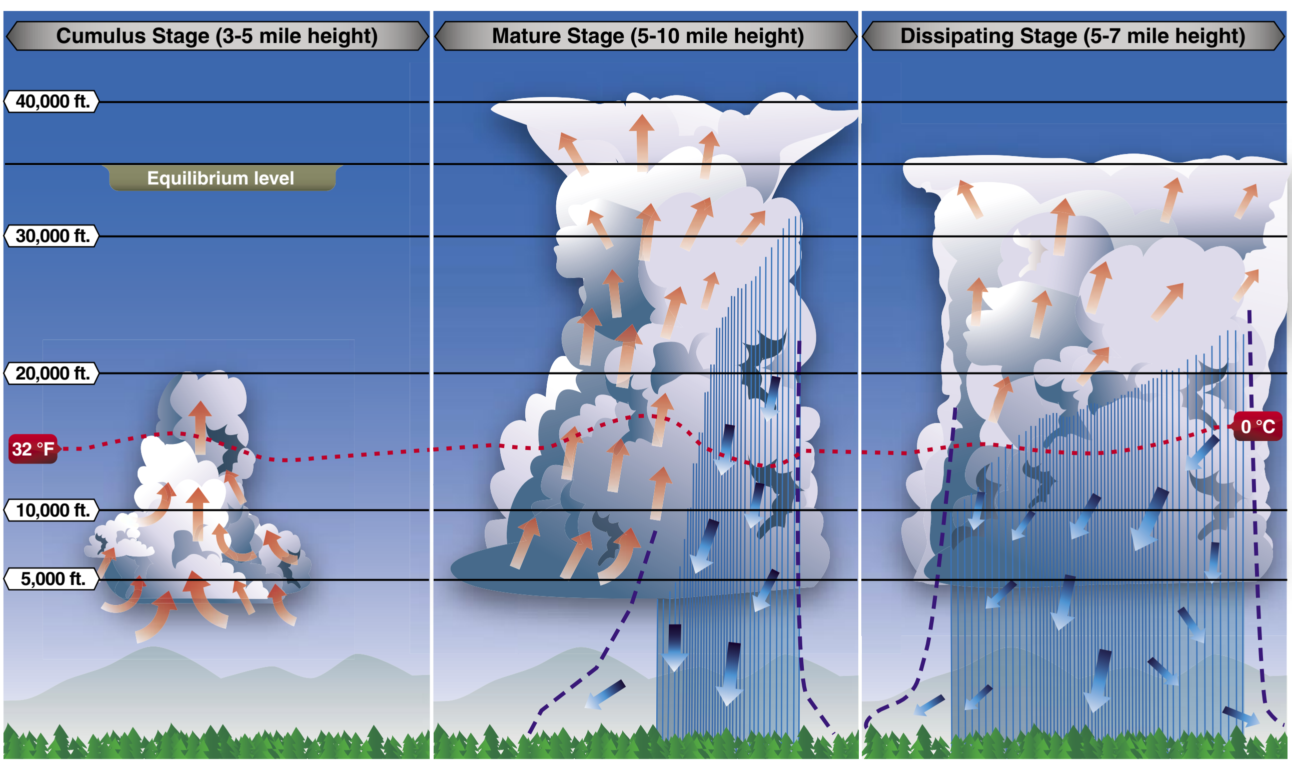


Figure 11-23. *Life cycle of a thunderstorm.*

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.

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 by automated weather systems. Visibility information, as predicted by meteorologists, is available for a pilot during a preflight weather briefing.

Precipitation

Precipitation refers to any type 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, snow, 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 five 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 classified according to the regions where they originate. They 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 generally identified as polar or tropical based on temperature characteristics and maritime or continental based on moisture content.

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 11-24]*

An air mass passing over a warmer surface is 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 an air mass moves across bodies of water and land, it eventually comes 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.

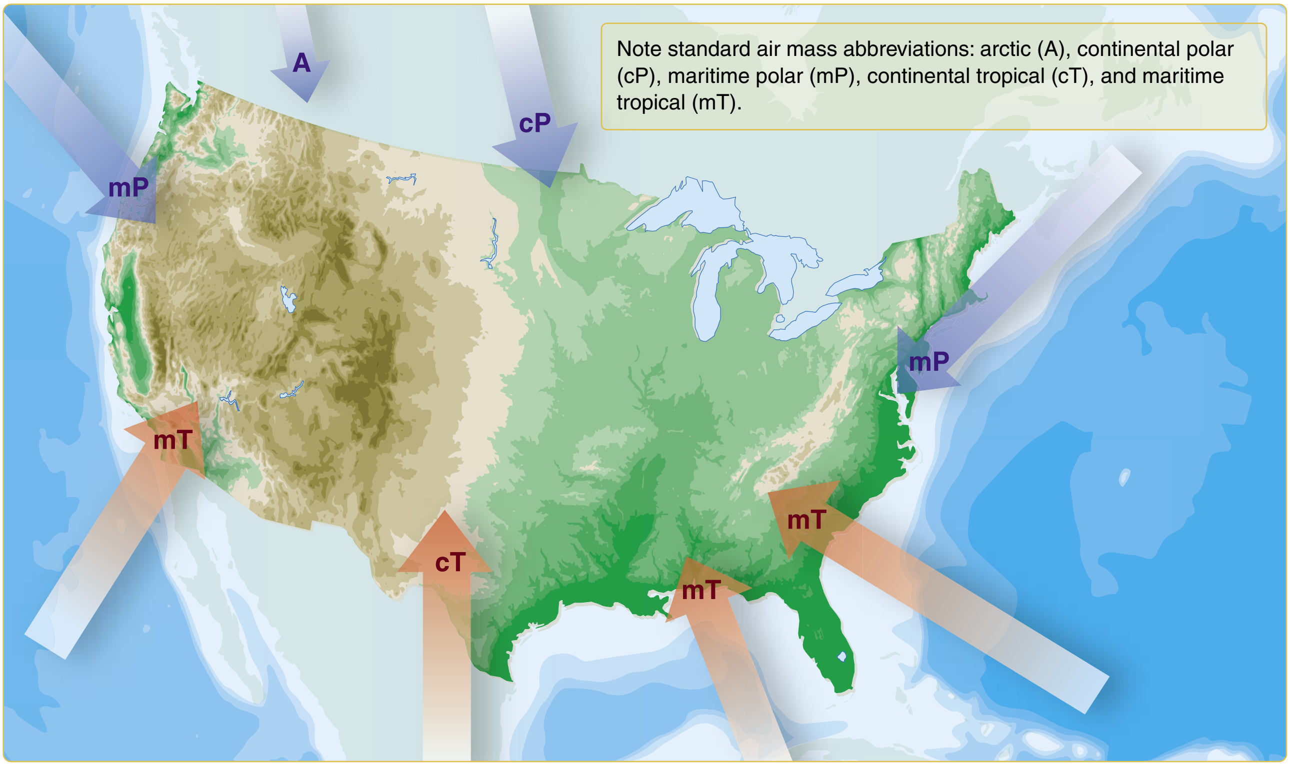


Figure 11-24. *North American air mass source regions.*

There are four types of fronts, which are named according to the temperature of the advancing air relative to the temperature of the air it is replacing: *[Figure 11-25]*

- Warm
- Cold
- Stationary
- Occluded

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.

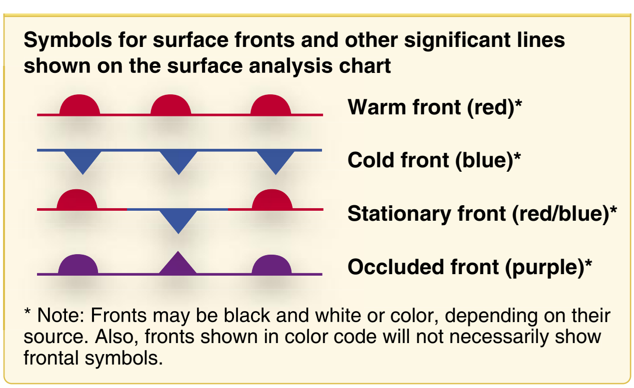


Figure 11-25. *Common chart symbology to depict weather front location.*

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 (mph). 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 have very high humidity. As the warm air is lifted, the temperature drops and condensation occurs.

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, accentuated by poor visibility. The wind blows from the south-southeast, and the outside temperature is cool or cold, with an increasing dew point. Finally, as the warm front approaches, the barometric pressure continues to fall until the front passes completely.

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 dew point 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 dew point 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 11-26* 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 six miles in haze with a falling barometric pressure. Approaching Indianapolis, the weather deteriorates to broken clouds at 2,000 feet with three miles visibility and rain. With the temperature and dew point the same, fog is likely. At St. Louis, the sky is overcast with low clouds and drizzle and the visibility is one 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 mph. However, extreme cold fronts have been recorded moving at speeds of up to 60 mph. A typical cold front moves in a manner opposite that of a warm front. 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 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.

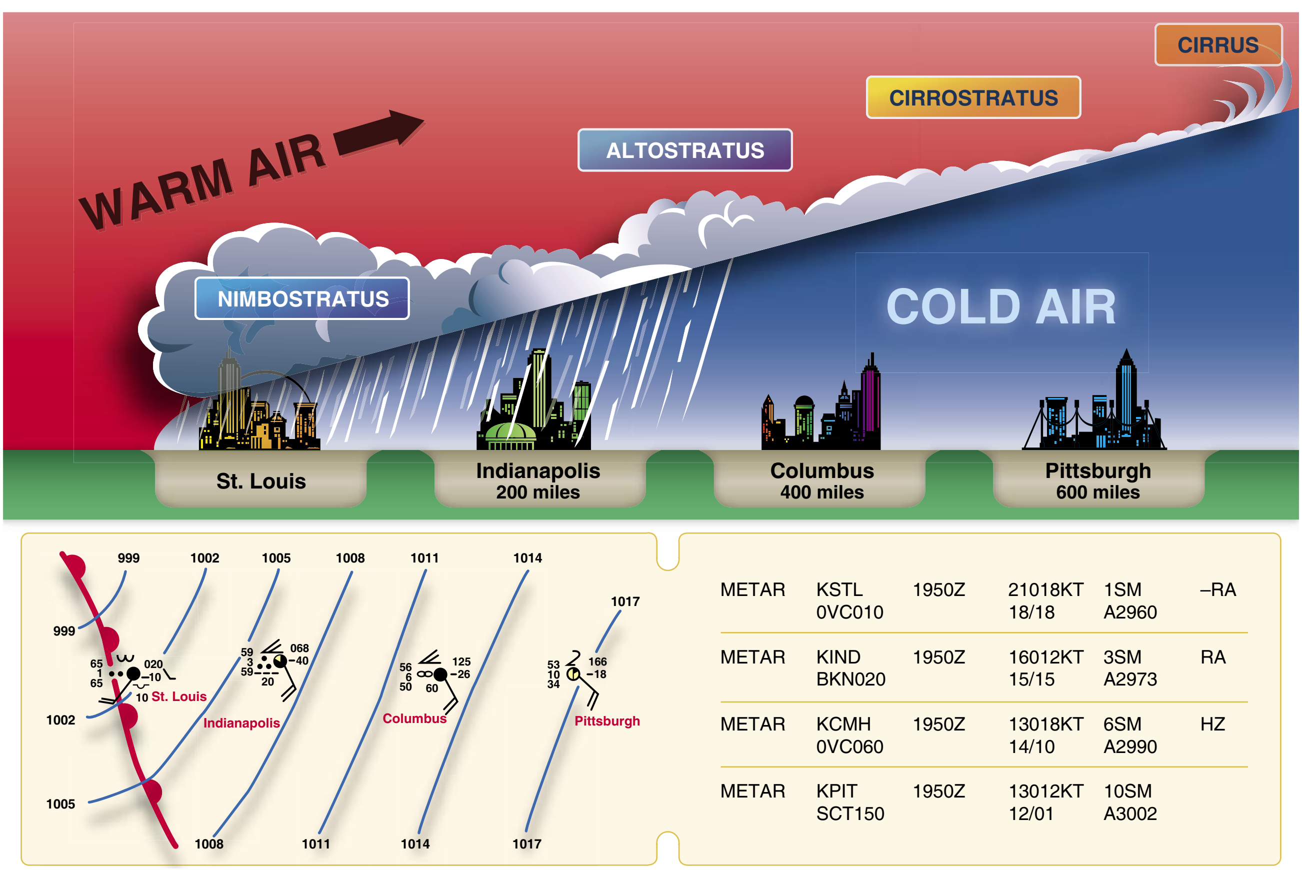


Figure 11-26. *Warm front cross-section with surface weather chart depiction and associated METAR.*

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 dew point 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 is poor, with winds variable and gusty, and the temperature and dew point 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 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 11-27* shows a flight from Pittsburgh, Pennsylvania, toward St. Louis, Missouri.

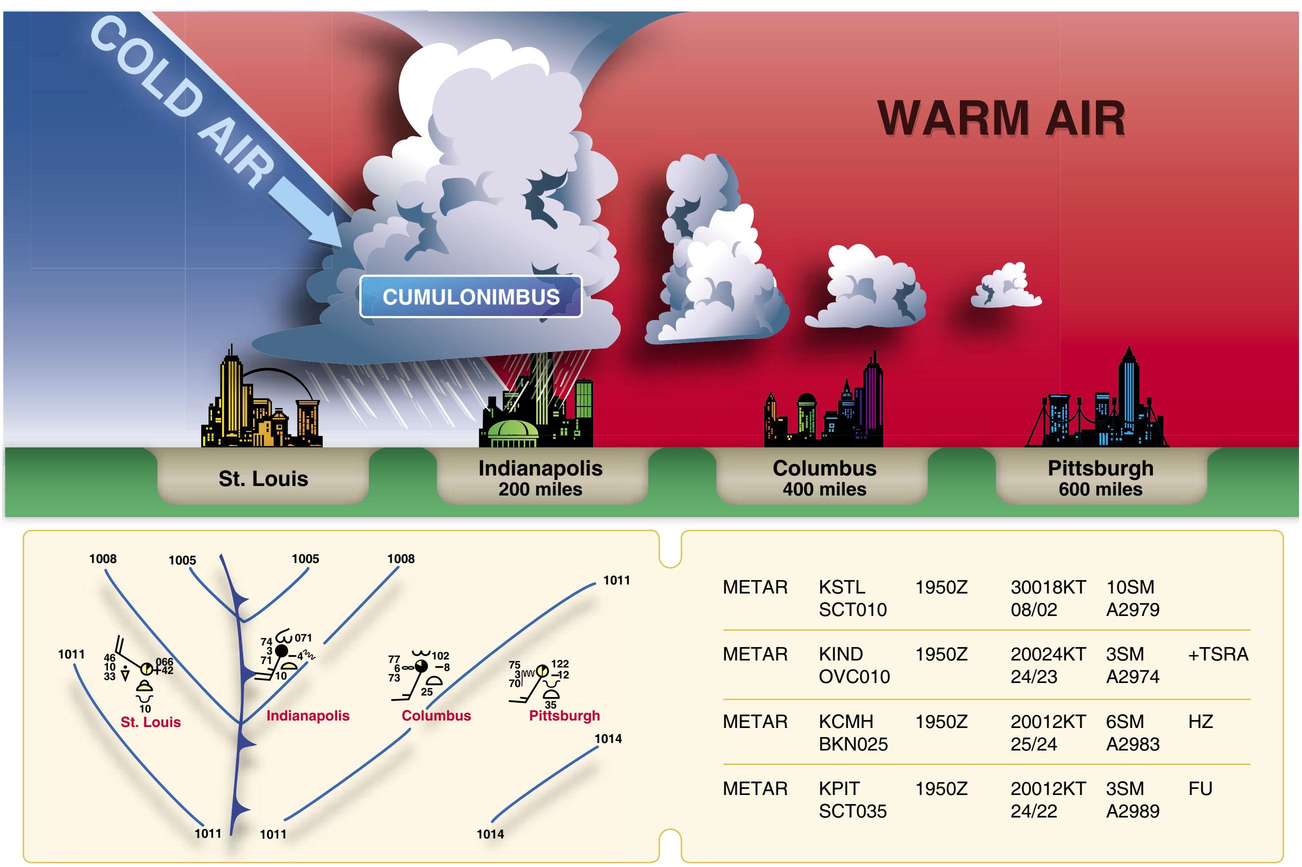


Figure 11-27. *Cold front cross-section with surface weather chart depiction and associated METAR.*

At the time of departure from Pittsburgh, the weather is VFR with three 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 six miles in haze with a falling barometric pressure. Approaching Indianapolis, the weather has deteriorated to overcast clouds at 1,000 feet, and three miles visibility with thunderstorms and heavy rain showers. At St. Louis, the weather gets better with scattered clouds at 1,000 feet and a ten 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 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 mph, move very quickly in comparison to warm fronts, which move at only 10 to 25 mph. 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 pressure systems are adjacent, the winds are almost in direct 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.

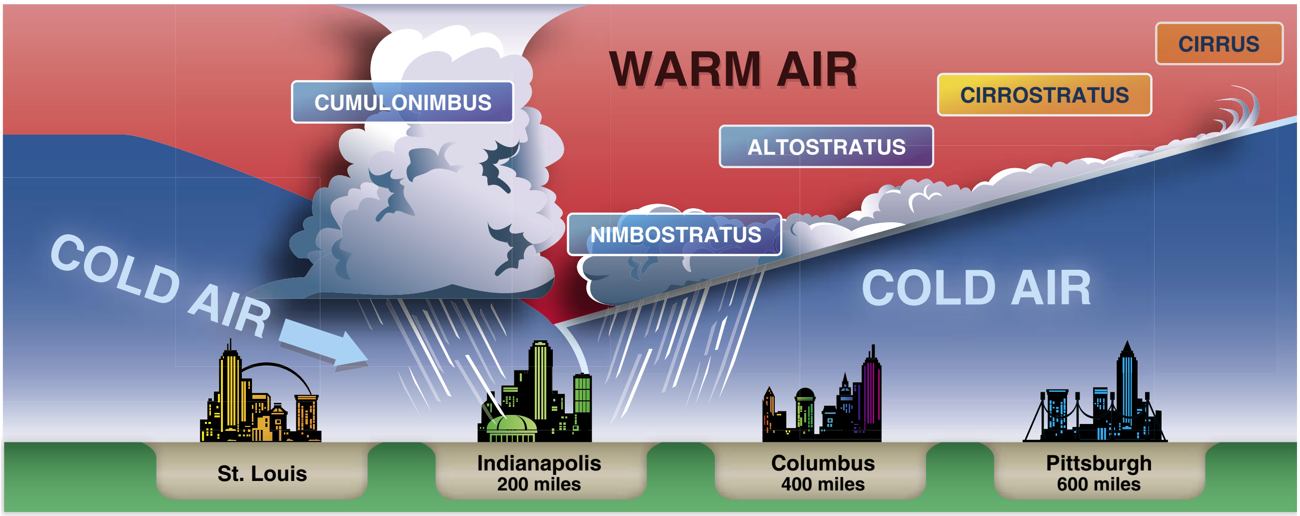
Occluded Front

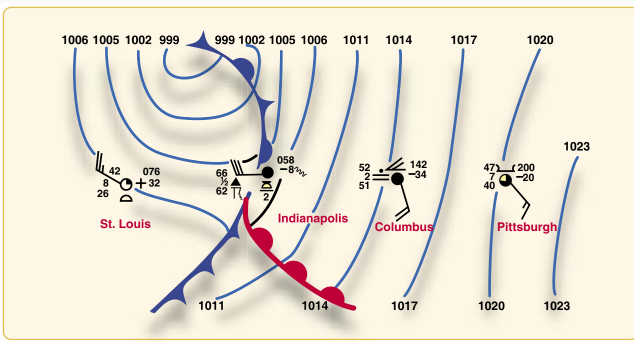
An occluded front occurs when a fast-moving cold front catches up with a slow-moving warm front. As the occluded front approaches, warm front weather prevails, but is immediately followed by cold front weather. There are two types of occluded fronts that can occur, and the temperatures of the colliding 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 is more severe than the weather found in a cold front occlusion. Embedded thunderstorms, rain, and fog are likely to occur.

Figure 11-28 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, dew point 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.

Thunderstorms

For a thunderstorm to form, the air must have sufficient water vapor, an unstable lapse rate, and an initial lifting action to start the storm process. Some storms occur at random in unstable air, last for only an hour or two, and produce only moderate wind gusts and rainfall. These are known as air





METAR	KSTL SCT035	1950Z	31023G40KT 05/M03	8SM A2976	
METAR	KIND VV005	1950Z	29028G45KT 18/16	1/2SM A2970	TSRAGR
METAR	KCMH OVC080	1950Z	16017KT 11/10	2SM A2970	BR
METAR	KPIT BKN130	1950Z	13012KT 08/04	75SM A3012	

Figure 11-28. *Occluded front cross-section with a weather chart depiction and associated METAR.*

mass thunderstorms and are generally a result of surface heating. Steady-state thunderstorms are associated with weather systems. Fronts, converging winds, and troughs aloft force upward motion spawning these storms which often form into squall lines. In the mature stage, updrafts become stronger and last much longer than in air mass storms, hence the name steady state. *[Figure 11-29]*

Knowledge of thunderstorms and the hazards associated with them is critical to the safety of flight.

Hazards

Weather can pose serious hazards to flight and a thunderstorm packs just about every weather hazard known to aviation into one vicious bundle. These hazards occur individually or in combinations and most can be found in a squall line.

Squall Line

A squall line is a narrow band of active thunderstorms. Often it develops on or ahead of a cold front in moist, unstable air, but it may develop in unstable air far removed from any front. The line may be too long to detour easily and too wide and severe to penetrate. It often contains steady-state thunderstorms and presents the single most intense weather hazard to aircraft. It usually forms rapidly, generally reaching maximum intensity during the late afternoon and the first few hours of darkness.

Tornadoes

The most violent thunderstorms draw air into their cloud bases with great vigor. If the incoming air has any initial rotating motion, it often forms an extremely concentrated vortex from the surface well into the cloud. Meteorologists have estimated that wind in such a vortex can exceed 200 knots with pressure inside the vortex quite low. The strong winds gather dust and debris and the low pressure generates a funnel-shaped cloud extending downward from the cumulonimbus base. If the cloud does not reach the surface, it is a funnel cloud; if it touches a land surface, it is a tornado.

Tornadoes occur with both isolated and squall line thunderstorms. Reports for forecasts of tornadoes indicate that atmospheric conditions are favorable for violent turbulence. An aircraft entering a tornado vortex is almost certain to suffer structural damage. Since the vortex extends well into the cloud, any pilot inadvertently caught on instruments in a severe thunderstorm could encounter a hidden vortex.

Families of tornadoes have been observed as appendages of the main cloud extending several miles outward from the area

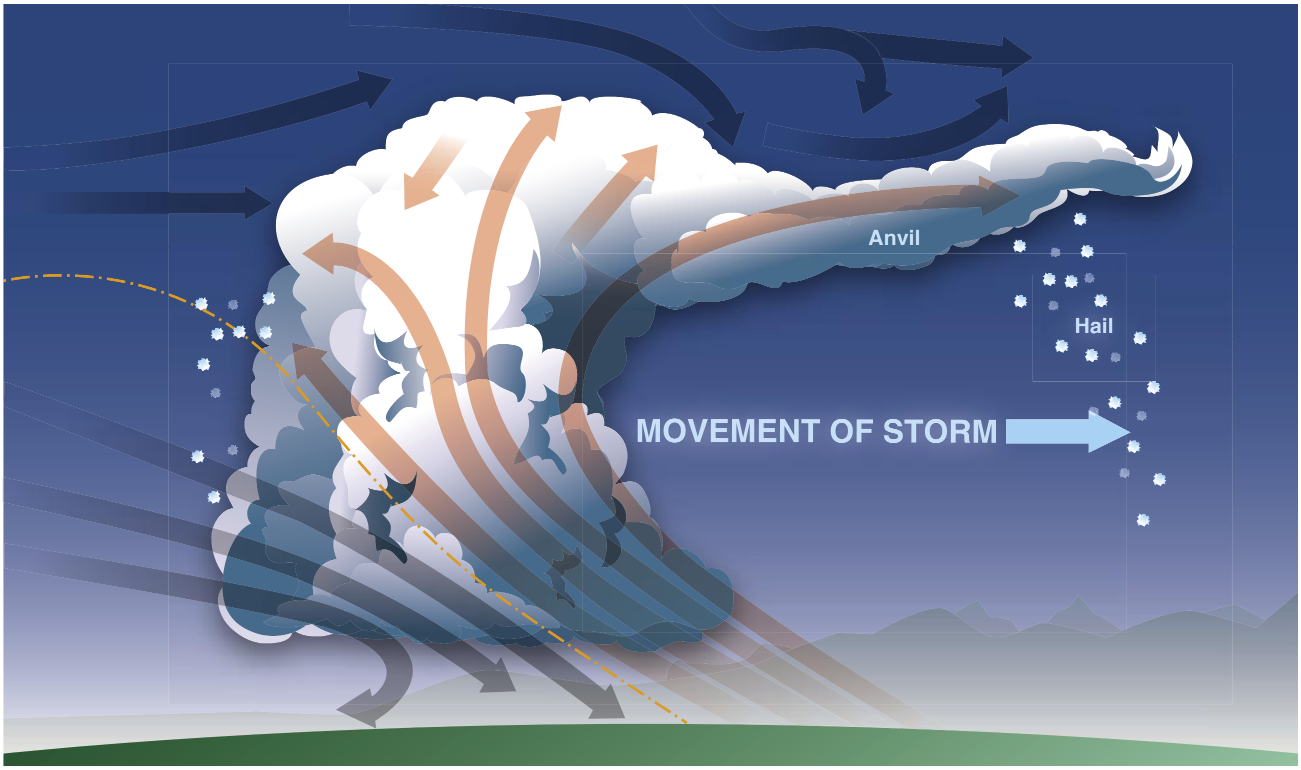


Figure 11-29. *Movement and turbulence of a maturing thunderstorm.*

of lightning and precipitation. Thus, any cloud connected to a severe thunderstorm carries a threat of violence.

Turbulence

Potentially hazardous turbulence is present in all thunderstorms, and a severe thunderstorm can destroy an aircraft. Strongest turbulence within the cloud occurs with shear between updrafts and downdrafts. Outside the cloud, shear turbulence has been encountered several thousand feet above and 20 miles laterally from a severe storm. A low-level turbulent area is the shear zone associated with the gust front. Often, a "roll cloud" on the leading edge of a storm marks the top of the eddies in this shear and it signifies an extremely turbulent zone. Gust fronts often move far ahead (up to 15 miles) of associated precipitation. The gust front causes a rapid and sometimes drastic change in surface wind ahead of an approaching storm. Advisory Circular (AC) 00-50A, Low Level Wind Shear, explains in detail the hazards associated with gust fronts. Figure 1 in the AC shows a schematic truss section of a thunderstorm with areas outside the cloud where turbulence may be encountered.

Icing

Updrafts in a thunderstorm support abundant liquid water with relatively large droplet sizes. When carried above the freezing level, the water becomes supercooled. When temperature in the upward current cools to about –15 °C, much of the remaining water vapor sublimates as ice crystals. Above this level, at lower temperatures, the amount of supercooled water decreases.

Supercooled water freezes on impact with an aircraft. Clear icing can occur at any altitude above the freezing level, but at high levels, icing from smaller droplets may be rime or mixed rime and clear ice. The abundance of large, supercooled water droplets makes clear icing very rapid between 0 °C and –15 °C and encounters can be frequent in a cluster of cells. Thunderstorm icing can be extremely hazardous.

Thunderstorms are not the only area where pilots could encounter icing conditions. Pilots should be alert for icing anytime the temperature approaches 0 °C and visible moisture is present.

Hail

Hail competes with turbulence as the greatest thunderstorm hazard to aircraft. Supercooled drops above the freezing level begin to freeze. Once a drop has frozen, other drops latch on and freeze to it, so the hailstone grows—sometimes into a huge ice ball. Large hail occurs with severe thunderstorms with strong updrafts that have built to great heights. Eventually, the hailstones fall, possibly some distance from the storm core. Hail may be encountered in clear air several miles from thunderstorm clouds.

As hailstones fall through air whose temperature is above 0 °C, they begin to melt and precipitation may reach the ground as either hail or rain. Rain at the surface does not mean the absence of hail aloft. Possible hail should be anticipated with any thunderstorm, especially beneath the anvil of a large cumulonimbus. Hailstones larger than one-half inch in diameter can significantly damage an aircraft in a few seconds.

Ceiling and Visibility

Generally, visibility is near zero within a thunderstorm cloud. Ceiling and visibility also may be restricted in precipitation and dust between the cloud base and the ground. The restrictions create the same problem as all ceiling and visibility restrictions; but the hazards are multiplied when associated with the other thunderstorm hazards of turbulence, hail, and lightning.

Effect on Altimeters

Pressure usually falls rapidly with the approach of a thunderstorm, rises sharply with the onset of the first gust and arrival of the cold downdraft and heavy rain showers, and then falls back to normal as the storm moves on. This cycle of pressure change may occur in 15 minutes. If the pilot does not receive a corrected altimeter setting, the altimeter may be more than 100 feet in error.

Lightning

A lightning strike can puncture the skin of an aircraft and damage communications and electronic navigational equipment. Although lightning has been suspected of igniting fuel vapors and causing an explosion, serious accidents due to lightning strikes are rare. Nearby lightning can blind the pilot, rendering him or her momentarily unable to navigate either by instrument or by visual reference. Nearby lightning can also induce permanent errors in the magnetic compass. Lightning discharges, even distant ones, can disrupt radio communications on low and medium frequencies. Though lightning intensity and frequency have no simple relationship to other storm parameters, severe storms, as a rule, have a high frequency of lightning.

Engine Water Ingestion

Turbine engines have a limit on the amount of water they can ingest. Updrafts are present in many thunderstorms, particularly those in the developing stages. If the updraft velocity in the thunderstorm approaches or exceeds the terminal velocity of the falling raindrops, very high concentrations of water may occur. It is possible that these concentrations can be in excess of the quantity of water turbine engines are designed to ingest. Therefore, severe thunderstorms may contain areas of high water concentration which could result in flameout and/or structural failure of one or more engines.

Chapter Summary

Knowledge of the atmosphere and the forces acting within it to create weather is essential to understand how weather affects a flight. By understanding basic weather theories, a pilot can make sound decisions during flight planning after receiving weather briefings. For additional information on the topics discussed in this chapter, see AC 00-6, Aviation Weather For Pilots and Flight Operations Personnel; AC 00-24, Thunderstorms; AC 00-45, Aviation Weather Services; AC 91-74, Pilot Guide Flight in Icing Conditions; and chapter 7, section 2 of the Aeronautical Information Manual (AIM).

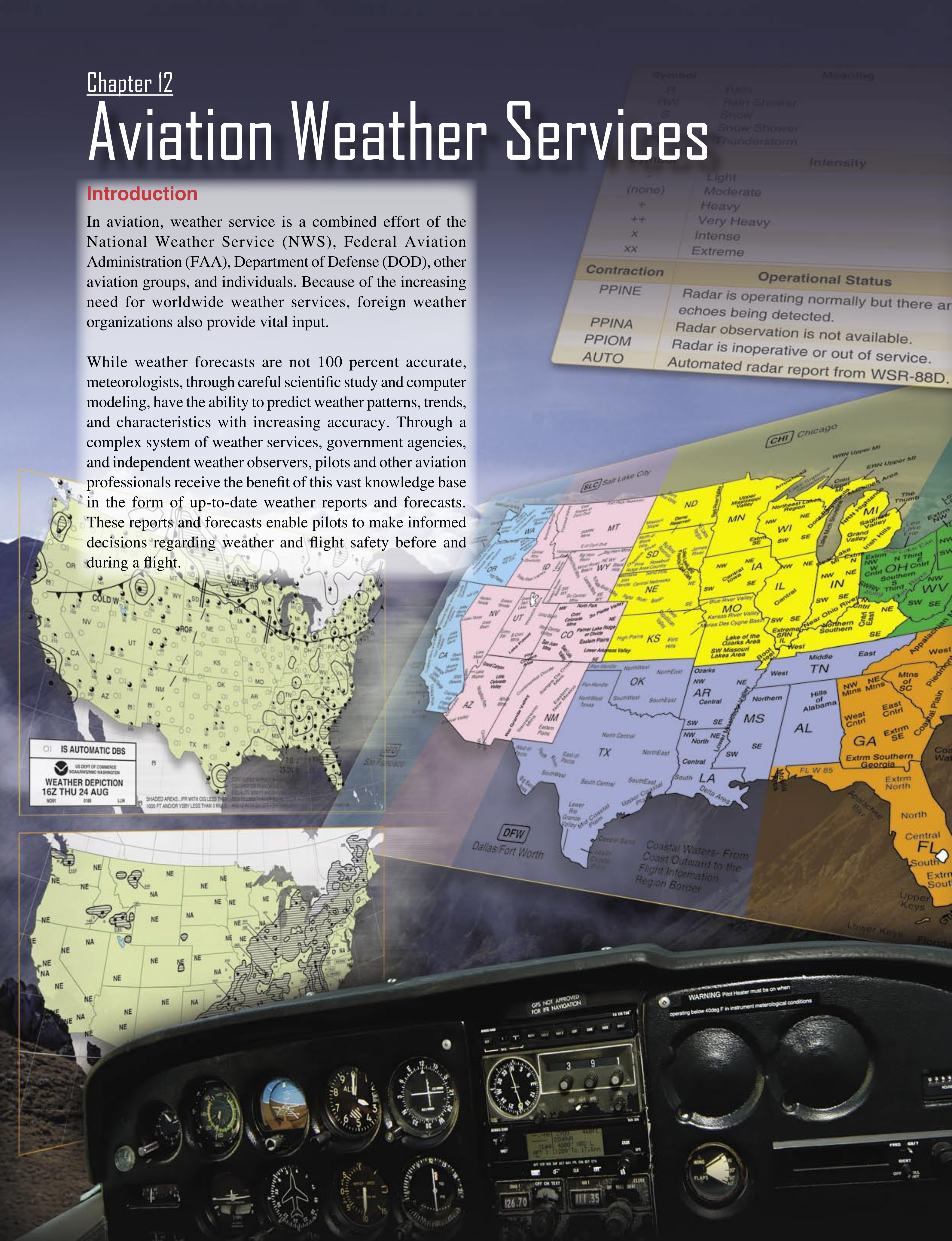
Chapter 12

Aviation Weather Services

Introduction

In aviation, weather service is a combined effort of the National Weather Service (NWS), Federal Aviation Administration (FAA), Department of Defense (DOD), 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 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 before and during a flight.



Observations

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

Surface Aviation Weather Observations

Surface aviation weather observations (METARs) are a compilation of elements of the current weather at individual ground stations across the United States. The network is made up of government and privately contracted facilities that provide continuous up-to-date weather information. Automated weather sources, such as the Automated Weather Observing Systems (AWOS), Automated Surface Observing Systems (ASOS), Air Route Traffic Control Center (ARTCC) facilities, 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 for a radius of five miles of a specific airport. 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/dew point, 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 individual airports around the country. Although the reports cover only a small radius, the pilot can generate a good picture of the weather over a wide area when many reporting stations are looked at together.

Air Route Traffic Control Center (ARTCC)

The ARTCC facilities are responsible for maintaining separation between flights conducted under instrument flight rules (IFR) in the en route structure. Center radars (Air Route Surveillance Radar (ARSR)) acquire and track transponder returns using the same basic technology as terminal radars. Earlier center radars displayed weather as an area of slashes (light precipitation) and Hs (moderate rainfall). Because the controller could not detect higher levels of precipitation, pilots had to be wary of areas showing moderate rainfall. Newer radar displays show weather as three shades of blue. Controllers can select the level of weather to be displayed. Weather displays of higher levels of intensity make it difficult for controllers to see aircraft data blocks, so pilots should not expect air traffic control (ATC) to keep weather displayed continuously.

Upper Air Observations

Observations of upper air weather are more challenging than surface observations. There are only two methods by which upper air weather phenomena can be observed: radiosonde observations and pilot weather reports (PIREPs). A radiosonde is a small cubic instrumentation package which is suspended below a six foot hydrogen or helium filled balloon. Once released, the balloon rises at a rate of approximately 1,000 feet per minute (fpm). As it ascends, the instrumentation gathers various pieces of data such as air temperature and pressure, as well as wind speed and direction. Once the information is gathered, it is relayed to ground stations via a 300 milliwatt radio transmitter.

The balloon flight can last as long as 2 hours or more and can ascend to altitudes as high as 115,000 feet and drift as far as 125 miles. The temperatures and pressures experienced during the flight can be as low as -130 °F and pressures as low as a few thousandths of what is experienced at sea level.

Since the pressure decreases as the balloon rises in the atmosphere, the balloon expands until it reaches the limits of its elasticity. This point is reached when the diameter has increased to over 20 feet. At this point, the balloon pops and the radiosonde falls back to Earth. The descent is slowed by means of a parachute. The parachute aids in protecting people and objects on the ground. Each year over 75,000 balloons are launched. Of that number, 20 percent are recovered and returned for reconditioning. Return instructions are printed on the side of each radiosonde.

Pilots also provide vital information regarding upper air weather observations and remain the only real-time source of information regarding turbulence, icing, and cloud heights. This information is gathered and filed by pilots in flight. Together, PIREPs and radiosonde observations provide information on upper air conditions important for flight planning. Many domestic and international airlines have equipped their aircraft with instrumentation that automatically transmits inflight weather observations through the DataLink system to the airline dispatcher who disseminates the data to appropriate weather forecasting authorities.

Radar Observations

Weather observers use four types of radar to provide information about precipitation, wind, and weather systems.

1. The WSR-88D NEXRAD radar, commonly called Doppler radar, provides in-depth observations that inform surrounding communities of impending weather. Doppler radar has two operational modes: clear air and precipitation. In clear air mode, the radar is in its most sensitive operational mode because a slow antenna rotation allows the radar to sample the atmosphere longer. Images are updated about every 10 minutes in this mode.

Precipitation targets provide stronger return signals therefore the radar is operated in the Precipitation mode when precipitation is present. A faster antenna rotation in this mode allows images to update at a faster rate, approximately every 4 to 6 minutes. Intensity values in both modes are measured in dBZ (decibels of Z) and depicted in color on the radar image. *[Figure 12-1]* Intensities are correlated to intensity terminology (phraseology) for air traffic control purposes. *[Figure 12-2* and *12-3]*

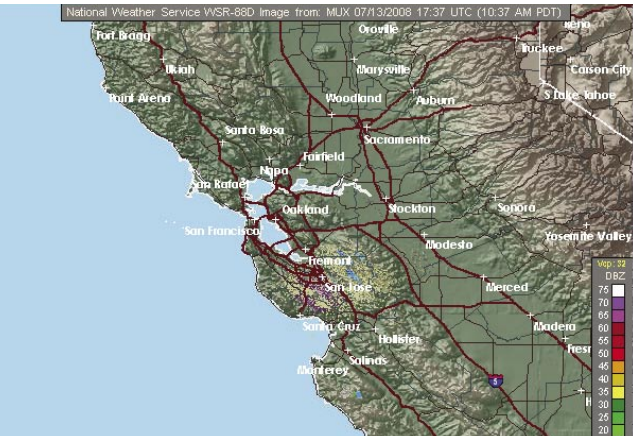


Figure 12-1. *Example of a weather radar scope.*

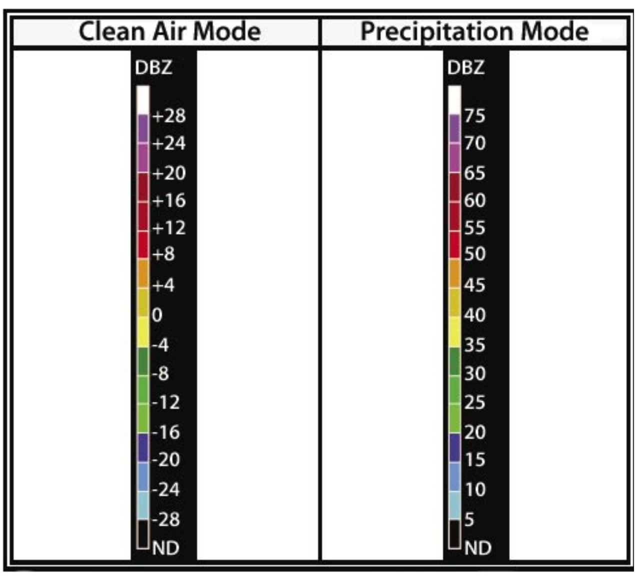


Figure 12-2. *WSR-88D Weather Radar Echo Intensity Legend.*

2. FAA terminal doppler weather radar (TDWR), installed at some major airports around the country, also aids in providing severe weather alerts and warnings to ATC. Terminal radar ensures pilots are aware of wind shear, gust fronts, and heavy precipitation, all of which are dangerous to arriving and departing aircraft.

Reflectivity (dBZ) Ranges	Weather Radar Echo Intensity
<30 dBZ	Light
30–40 dBZ	Moderate
>40–50	Heavy
50+ dBZ	Extreme

Figure 12-3. *WSR-88D Weather Radar Precipitation Intensity Terminology.*

3. 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, but it also detects the location and intensity of precipitation which is used to route aircraft traffic around severe weather in an airport environment.

4. Airborne radar is equipment carried by aircraft to locate weather disturbances. The airborne radars generally operate in the C or X bands (around 6 GHz or around 10 GHz, respectively) permitting both penetration of heavy precipitation, required for determining the extent of thunderstorms, and sufficient reflection from less intense precipitation.

Satellite

Advancement in satellite technologies has recently allowed for commercial use to include weather uplinks. Through the use of satellite subscription services, individuals are now able to receive satellite transmitted signals that provide near real-time weather information for the North American continent.

Satellite Weather

Recently private enterprise and satellite technology have expanded the realm of weather services. Pilots now have the capability of receiving continuously updated weather across the entire country at any altitude. No longer are pilots restricted by radio range or geographic isolations such as mountains or valleys.

In addition, pilots no longer have to request specific information from weather briefing personnel directly. When the weather becomes questionable, radio congestion often increases, delaying the timely exchange of valuable inflight weather updates for a pilot's specific route of flight. Flight Service Station (FSS) personnel can communicate with only one pilot at a time, which leaves other pilots waiting and flying in uncertain weather conditions. Satellite weather provides the pilot with a powerful resource for enhanced situational awareness at any time. Due to continuous satellite broadcasts, pilots can obtain a weather briefing by looking at a display screen. Pilots have a choice between FAA-certified devices or portable receivers as a source of weather data.

Satellite Weather Products

Significant Meteorological Information (SIGMET)

SIGMETs are weather advisories issued concerning weather significant to the safety of all aircraft. SIGMET advisories can cover an area of at least 3,000 square miles and provide data regarding severe and extreme turbulence, severe icing, and widespread dust or sandstorms that reduce visibility to less than three miles. *[Figure 12-4]*

Figure 12-4. *Satellite SIGMET.*

Airmen's Meteorological Information (AIRMET)

AIRMETs are weather advisories issued only to amend the area forecast concerning weather phenomena which are of operational interest to all aircraft and potentially hazardous to aircraft having limited capability because of lack of equipment, instrumentation, or pilot qualifications. AIRMETs concern weather of less severity than that covered by SIGMETs or convective SIGMETs. AIRMETs cover moderate icing, moderate turbulence, sustained winds of 30 knots or more at the surface, widespread areas of ceilings less than 1,000 feet and/or visibility less than three miles, and extensive mountain obscurement. *[Figure 12-5]*

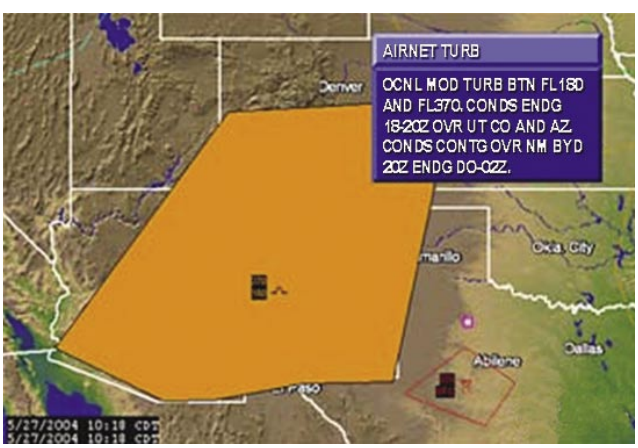


Figure 12-5. *Satellite AIRMET.*

Service Outlets

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

Automated Flight Service Station (AFSS)

The AFSS is the primary source for preflight weather information. A preflight weather briefing from an AFSS can be obtained 24 hours a day by calling 1-800-WX BRIEF from almost anywhere in the United States. In areas not served by an AFSS, NWS facilities may provide pilot weather briefings. Telephone numbers for NWS facilities and additional numbers for AFSS can be found in the Airport/Facility Directory (A/FD) or in the United States Government section of the telephone book.

The AFSS also provides inflight weather briefing services, as well as scheduled and unscheduled weather broadcasts. An AFSS may also furnish weather advisories to flights within the AFSS region of authority.

Transcribed Information Briefing Service (TIBS)

The Transcribed Information Briefing Service (TIBS) is a service prepared and disseminated by selected AFSS. 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 a 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 touchtone 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 (DUATS), 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 via the Internet at http://www.duats.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, Safety of Flight, of the Aeronautical Information Manual (AIM).

En Route Flight Advisory Service (EFAS)

A service specifically designed to provide timely en route weather information upon pilot request is known as the en route 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 United States and Puerto Rico. The common EFAS frequency, 122.0 MHz, is established for pilots of aircraft flying between 5,000 feet above ground level (AGL) and 17,500 feet mean sea level (MSL).

Hazardous Inflight Weather Advisory (HIWAS)

Hazardous Inflight Weather Advisory (HIWAS) is a national program for broadcasting hazardous weather information continuously over selected navigation aids (NAVAIDs). 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 a FSS or EFAS for detailed information. NAVAIDs that have HIWAS capability are depicted on sectional charts with an "H" in the upper right corner of the identification box. *[Figure 12-6]*

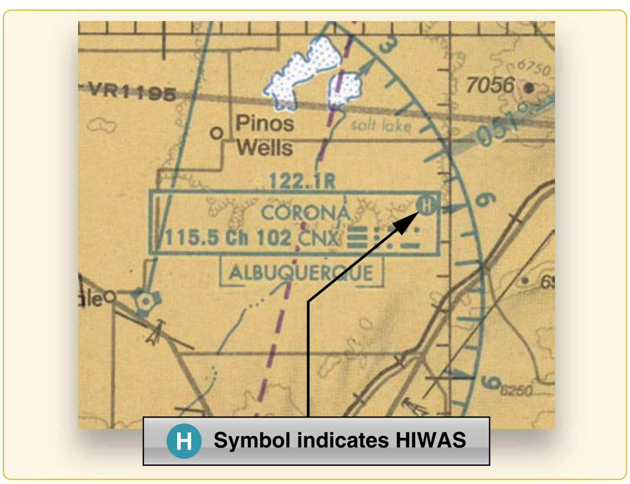


Figure 12-6. *HIWAS availability is shown on sectional chart.*

Transcribed Weather Broadcast (TWEB) (Alaska Only)

Equipment is provided in Alaska by which meteorological and aeronautical data are recorded on tapes and broadcast continuously over selected low or medium frequency (L/MF) and very high frequency (VHF) omnidirectional radio range navigation system (VOR) facilities. Broadcasts are made from a series of individual tape recordings, and changes, as they occur, are transcribed onto the tapes. The information provided varies depending on the type equipment available. Generally, the broadcast contains a summary of adverse conditions, surface weather observations, PIREPS, and a density altitude statement (if applicable). At the discretion of the broadcast facility, recordings may also include a synopsis, winds aloft forecast, en route and terminal forecast data, and radar reports. At selected locations, telephone access to the TWEB has been provided (TEL-TWEB). Telephone numbers for this service are found in the Supplement Alaska A/FD. These broadcasts are made available primarily for preflight and inflight planning, and as such, should not be considered as a substitute for specialist-provided preflight briefings.

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 a 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—standard, abbreviated, or outlook. Other helpful information is whether the flight is visual flight rules (VFR) or 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 include 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—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 are not included in the briefing.
5. En route forecast—a summary of the weather forecast for the proposed route of flight.
6. Destination forecast—a summary of the expected weather for the destination airport at the estimated time of arrival (ETA).
7. Winds and temperatures aloft—a report of the winds at specific altitudes for the route of flight. The temperature information is provided only on request.
8. Notices to Airmen (NOTAM)—information pertinent to the route of flight which has not been published in the NOTAM publication. Published NOTAM information is provided during the briefing only when requested.
9. ATC delays—an advisory of any known ATC delays that may affect the flight.
10. Other information—at the end of the standard briefing, the FSS specialist provides the radio frequencies needed to open a flight plan and to contact 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 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. It is always a good idea to update weather whenever a pilot has additional time.

Outlook Briefing

An outlook briefing should be requested when a planned departure is 6 hours or more 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 prudent pilot requests a follow-up briefing prior to departure since an outlook briefing generally only contains information based on weather trends and existing weather in geographical areas at or near the departure airport. A standard briefing near the time of departure ensures that the pilot has the latest information available prior to their flight.

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 METAR, PIREPs, and radar weather reports (SDs).

Aviation Routine Weather Report (METAR)

A 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.

Metars are issued hourly unless significant weather changes have occurred. A special METAR (SPECI) can be issued at any interval between routine METAR reports.

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 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—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—depicted in a six-digit group (161753Z). The first two digits 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—denotes 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 (for example: METAR KGGG 161753Z COR).

5. Wind—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 true 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 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 wind speed (G26). After the letter “G,” the peak gust recorded is provided. If the wind varies more than 60° and the wind speed is greater than six knots, a separate group of numbers, separated by a “V,” will indicate the extremes of the wind directions. *Figure 12-7* shows how the TDWR/Weather System Processor (WSP) determines the true wind, as well as gust front/wind shear location.

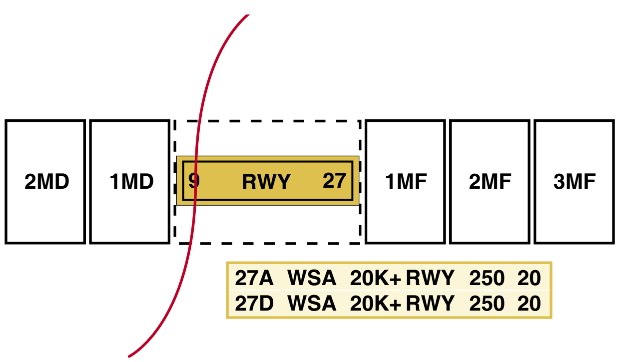


Figure 12-7. *Example of what the controller sees on the ribbon display in the tower cab.*

6. Visibility—the prevailing visibility (¾ SM) is reported in statute miles as denoted by the letters “SM.” It is reported in both miles and fractions of miles. At times, runway visual range (RVR) is reported following the 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—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 five to ten 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 12-8]*

8. Sky condition—always reported in the sequence of amount, height, and type or indefinite ceiling/height (vertical visibility) (BKN008 OVC012CB). The heights of the cloud bases are reported with a three-digit number in hundreds of feet AGL. 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 12-9]*

9. Temperature and dew point—the air temperature and dew point are always given in degrees Celsius (C) or (°C 18/17). Temperatures below 0 °C are preceded by the letter “M” to indicate minus.

10. Altimeter setting—reported as inches of mercury ("Hg) 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.

11. Zulu time—a term used in aviation for UTC which places the entire world on one time standard.

Qualifier		Weather Phenomena		
Intensity or Proximity 1	Descriptor 2	Precipitation 3	Obscuration 4	Other 5
– Light	**MI** Shallow	**DZ** Drizzle	**BR** Mist	**PO** Dust/sand whirls
Moderate (no qualifier)	**BC** Patches	**RA** Rain	**FG** Fog	**SQ** Squalls
+ Heavy	**DR** Low drifting	**SN** Snow	**FU** Smoke	**FC** Funnel cloud
VC in the vicinity	**BL** Blowing	**SG** Snow grains	**DU** Dust	**+FC** Tornado or waterspout
	SH Showers	**IC** Ice crystals (diamond dust)	**SA** Sand	**SS** Sandstorm
	TS Thunderstorms	**PL** Ice pellets	**HZ** Haze	**DS** Dust storm
	FZ Freezing	**GR** Hail	**PY** Spray	
	PR Partial	**GS** Small hail or snow pellets	**VA** Volcanic ash	
		UP *Unknown precipitation		

The weather groups are constructed by considering columns 1–5 in this table in sequence:
intensity, followed by descriptor, followed by weather phenomena (e.g., heavy rain showers(s) is coded as +SHRA).
* Automated stations only

Figure 12-8. *Descriptors and weather phenomena used in a typical METAR.*

Sky Cover	Contraction
Less than ⅛ (Clear)	SKC, CLR, FEW
⅛-⅜ (Few)	FEW
⅜-⅝ (Scattered)	SCT
⅝-⅞ (Broken)	BKN
⁸⁄₈ or (Overcast)	OVC

Figure 12-9. *Reportable contractions for sky condition.*

12. Remarks—the remarks section always begins with the letters "RMK." 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.

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

Explanation:
Routine METAR for Gregg County Airport for the 16th day of the month at 1753Z automated source. Winds are 140 at 21 knots gusting to 26. Visibility is ¾ statute mile. Thunderstorms with heavy rain and mist. Ceiling is broken at 800 feet, overcast at 1,200 feet with cumulonimbus clouds. Temperature 18 °C and dew point 17 °C. Barometric pressure is 29.70 "Hg and falling rapidly.

Pilot Weather Reports (PIREPs)

PIREPs provide valuable information regarding the conditions as they actually exist in the air, which cannot be gathered from any other source. Pilots can confirm the height of bases and tops of clouds, locations of wind shear and turbulence, and the location of inflight icing. If the ceiling is below 5,000 feet, or visibility is at or below five miles, ATC facilities are required to solicit PIREPs from pilots in the area. When unexpected weather conditions are encountered, pilots are encouraged to make a report to a FSS or ATC. When a pilot weather report is filed, the ATC facility or FSS will add it to the distribution system to brief other pilots and provide inflight advisories.

PIREPs are easy to file and a standard reporting form outlines the manner in which they should be filed. *Figure 12-10* shows the elements of a PIREP form. Item numbers 1 through 5 are required information when making a report, as well as at least one weather phenomenon encountered. A PIREP is normally transmitted as an individual report, but may be appended to a surface report. Pilot reports are easily decoded and most contractions used in the reports are self-explanatory.

Encoding Pilot Weather Reports (PIREPS)			
1	XXX	3-letter station identifier	Nearest weather reporting location to the reported phenomenon
2	UA	Routine PIREP, UUA-Urgent PIREP.	
3	/OV	Location	Use 3-letter NAVAID idents only. a. Fix: /OV ABC, /OV ABC 090025. b. Fix: /OV ABC 045020-DEF, /OV ABC-DEF-GHI
4	/TM	Time	4 digits in UTC: /TM 0915.
5	/FL	Altitude/Flight level	3 digits for hundreds of feet. If not known, use UNKN: /FL095, /FL310, /FLUNKN.
6	/TP	Type Aircraft	4 digits maximum. If not known, use UNKN: /TP L329, /TP B727, /TP UNKN.
7	/SK	Sky cover/Cloud layers	Describe as follows: a. Height of cloud base in hundreds of feet. If unknown, use UNKN. b. Cloud cover symbol. c. Height of cloud tops in hundreds of feet.
8	/WX	Weather	Flight visibility reported first: Use standard weather symbols; intensity is not reported: /WX FV02 R H, /WX FV01 TRW.
9	/TA	Air temperature in Celsius (C)	If below zero, prefix with a hyphen: /TA 15, /TA -06.
10	/WV	Wind	Direction in degrees magnetic north and speed in six digits: /WV 270045, WV 280110.
11	/TB	Turbulence	Use standard contractions for intensity and type (use CAT or CHOP when appropriate). Include altitude only if different from /FL, /TB EXTREME, /TB LGT-MDT BLO 090.
12	/IC	Icing	Describe using standard intensity and type contractions. Include altitude only if different than /FL: /IC LGT-MDT RIME, /IC SVR CLR 028-045.
13	/RM	Remarks	Use free from to clarify the report and type hazardous elements first: /RM LLWS -15KT SFC-030 DURC RNWY 22 JFK.

Figure 12-10. *PIREP encoding and decoding.*

Example:
UA/OV GGG 090025/TM 1450/FL 060/TP C182/SK 080 OVC/WX FV 04R/TA 05/WV 270030/TB LGT/RM HVY RAIN

Explanation:
Type: ....Routine pilot report
Location: .... 25 NM out on the 090° radial, Gregg County VOR
Time: .... 1450 Zulu
Altitude or Flight Level: 6,000 feet
Aircraft Type: ....Cessna 182
Sky Cover: ....8,000 overcast
Visibility/Weather: ....4 miles in rain
Temperature: ....5 °Celsius
Wind: ....270° at 30 knots
Turbulence: ....Light
Icing: .... None reported
Remarks: .... Rain is heavy

Radar Weather Reports (RAREP)

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

RAREPs provide information on the type, intensity, and location of the echo top of the precipitation. *[Figure 12-11]* 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

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 12-11. *Radar weather report codes.*

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
- 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—given when the azimuth and range define only the center line of the pattern.
- Cell movement—movement is coded only 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 contraction "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 8⁄10 of the area. Thunderstorms and very heavy rain showers are indicated. The next set of numbers indicates the azimuth that defines the echo (86° at 40 NM and 199° at 115 NM). The dimension of this echo is given as 20 NM wide (10 NM 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), inflight weather advisories (SIGMET, AIRMET), and the winds and temperatures aloft forecast (FD).

Terminal Aerodrome Forecasts (TAF)

A TAF is a report established for the five statute mile radius around an airport. TAF reports are usually given for larger airports. Each TAF is valid for a 30-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 TAF 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—given in statute miles and may be in whole numbers or fractions. If the forecast is greater than six miles, it will be coded as "P6SM."
7. Forecast significant weather—weather phenomena are 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" is included in the "becoming" or "temporary" weather groups.
8. Forecast sky condition—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). "FM" is used when a rapid and significant change, usually within an hour, is expected. "BECMG" is used when a gradual change in the weather is expected over a period of no more than 2 hours. "TEMPO" is used for temporary fluctuations of weather, expected to last less than one hour.
10. Probability forecast—a 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 11th day of the month, at 1130Z…valid for 24 hours from 1200Z on the 11th to 1200Z on the 12th…wind from 150° at 12 knots…visibility greater than 6 sm…broken clouds at 9,000 feet…temporarily, between 1200Z and 1400Z, visibility 5 sm in mist…from 1500Z winds from 160° at 15 knots, gusting to 25 knots visibility greater than 6 sm…clouds scattered at 4,000 feet and broken at 25,000 feet…from 0000Z wind from 140° at 12 knots…visibility greater than 6 sm…clouds broken at 8,000 feet, overcast at 15,000 feet…between 0000Z and 0400Z, there is 40 percent probability of visibility 3 sm…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 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—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.

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 12th day of the month at 0945. The synopsis is valid from the time of issuance until 0400 hours on the 13th. VFR clouds and weather information on this area forecast are valid until 2200 hours on the 12th and the outlook is valid until 0400 hours on the 13th.

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 ceiling (CIG) 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 BYAGL 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 occurrences 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 MSL. Those that are not MSL will be AGL or CIG.

3. 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 1000Z, there is a low pressure trough over the Oklahoma and Texas panhandle area, which is forecast to move eastward into central southwestern Oklahoma by 0400Z. A warm front located over central Oklahoma, southern Arkansas, and northern Mississippi at 1000Z is forecast to lift northwestward into northeastern Oklahoma, northern Arkansas, and extreme northern Mississippi by 0400Z.

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
PNDLAND 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 sm in mist. Between 1400Z and 1600Z, the cloud bases are expected to increase to 3,000 feet AGL. After 1900Z, 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 Z, the lowest cloud base is expected to increase to 4,000 feet AGL with a scattered layer at 10,000 feet AGL. After 2000Z, the forecast calls for scattered thunderstorms with rain developing and a few becoming severe; the CB 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 12-12* shows an area forecast chart with six regions of forecast, states, regional areas, and common geographical features.

Inflight Weather Advisories

Inflight 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 inflight weather advisory is issued in the form of either an AIRMET, SIGMET, or convective SIGMET.

AIRMET

AIRMETs (WAs) are examples of inflight 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 three miles, and extensive mountain obscurement.

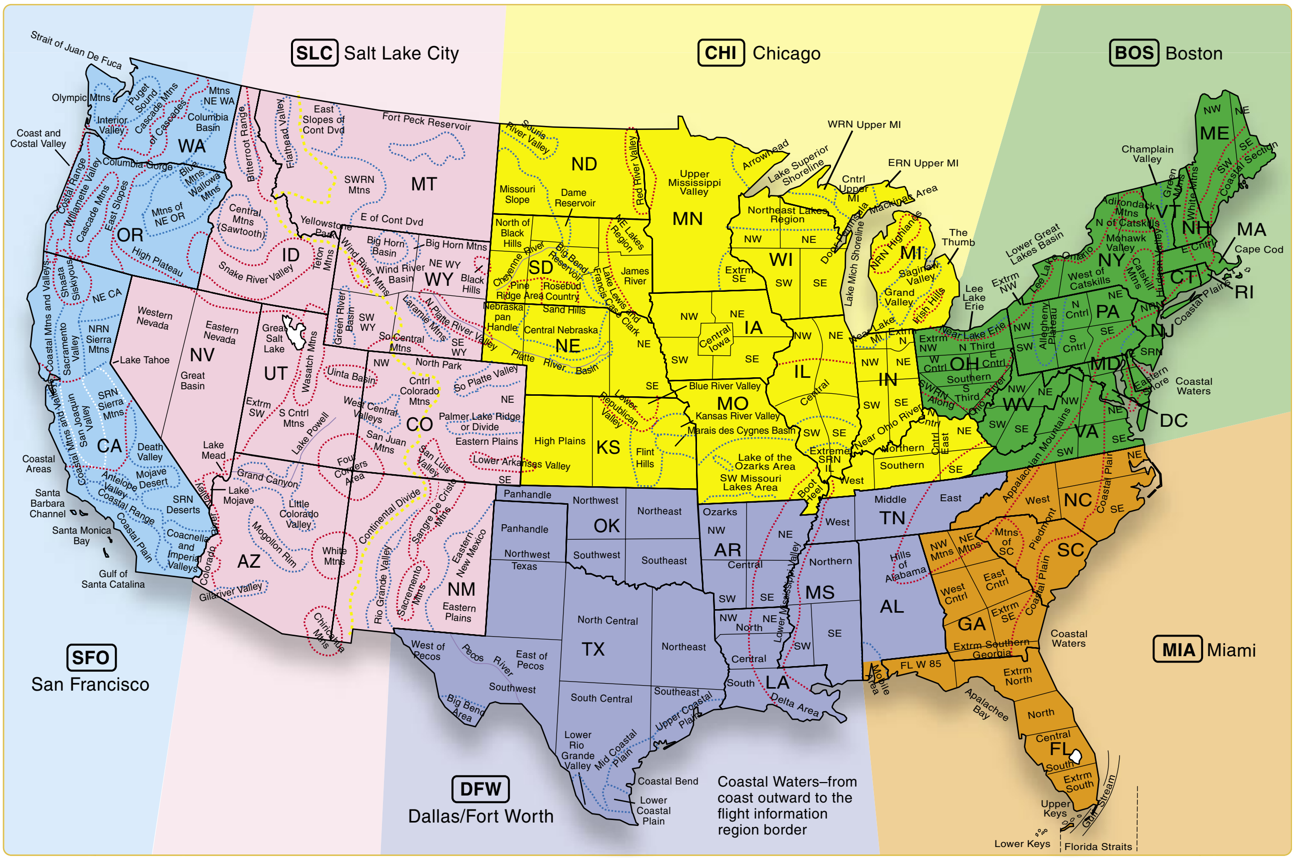


Figure 12-12. *Area forecast region map.*

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 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:
DFWTWA 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 24th day of the month, at 1650Z time. On this third update, the AIRMET Tango is issued for turbulence, strong surface winds, and low-level wind shear until 2000Z 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 2000Z.

SIGMET

SIGMETs (WSs) are inflight 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 inflight visibilities to below three 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 an Urgent Weather SIGMET (UWS). Reissued 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 BGNG 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 0530Z 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 jet stream. These conditions will be beginning after 0200Z and will continue beyond the forecast scope of this SIGMET of 0530Z.

Convective Significant Meteorological Information (WST)

A convective SIGMET (WST) is an inflight 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 ¾ 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 00Z time. If no hazardous weather exists, the convective SIGMET is still issued; however, it states "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 DVLPG BY 1955Z WILL MOV EWD
30-35 KT THRU 2055Z
HAIL TO 2 IN PSBL

Explanation:
The WST indicates this report is a convective SIGMET. The current date is the 22nd of the month and it was issued at 1855Z. 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 2055Z 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 2055Z. Hail up to 2 inches in size is possible with the developing thunderstorms.

Winds and Temperature Aloft Forecast (FD)

Winds and temperatures aloft forecasts (FD) 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 wind speed 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 wind speed 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 wind speed 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 wind speed is calm or less than 5 knots, the data group is coded "9900," which means light and variable. *[Figure 12-13]*

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 12-13. *Winds and temperature aloft report.*

Explanation of *Figure 12-13:*
The heading indicates that this FD was transmitted on the 15th of the month at 1640Z and is based on the 1200Z radiosonde. The valid time is 1800Z 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 four-digit data group shows the wind direction in reference to true north and the wind speed in knots. The elevation at Amarillo, Texas (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 six-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 12-14]* 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, dew points, 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 12-15]* A station model includes:

- 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 is shown as clear, scattered, broken, overcast, or obscured/partially obscured.
- Clouds—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.

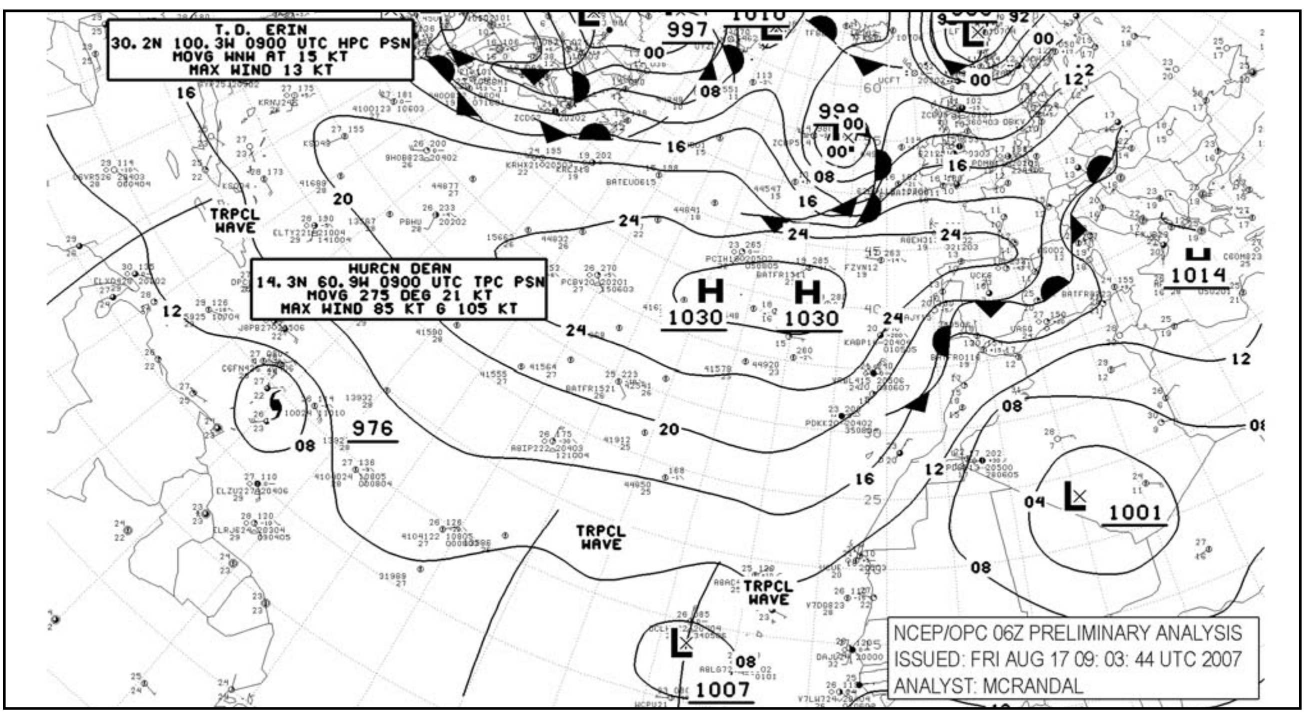
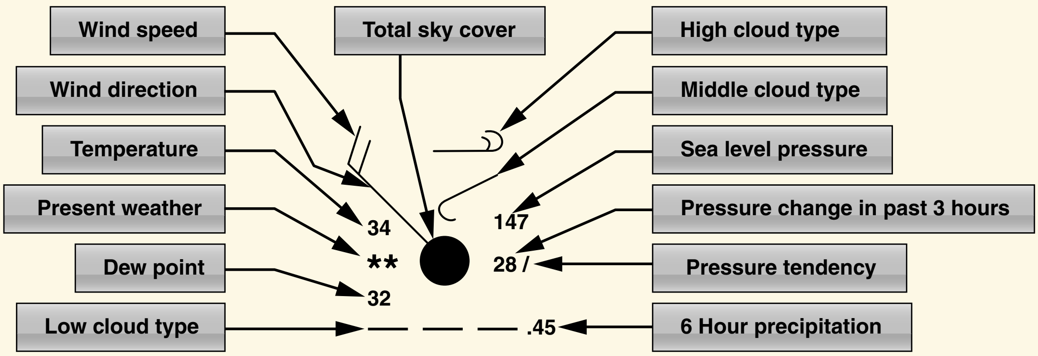


Figure 12-14. *Surface analysis chart.*



1. Total sky cover:	**Overcast**
2. Temperature/Dew point:	**34 °F/32 °F**
3. Wind:	**From the northwest at 20 knots** (relative to true north)
4. Present weather:	**Continuous light snow**
5. Predominant low, middle, high cloud reported:	**Strato fractus or cumulus, fractus of bad weather, altocumulus in patches and dense cirrus**
6. Sea level pressure:	**1014.7 millibars** (mb) Note: Pressure is always shown in 3 digits to the nearest tenth of a millibar. For 1,000 mb or greater, prefix a "10" to the 3 digits For less than 1,000 mb, prefix a "9" to the 3 digits
7. Pressure change in past 3 hours:	**Increased steadily or unsteadily by 2.8 mb**
8. 6-hour precipitation:	**45 hundredths of an inch.** The amount is given to the nearest hundredth of an inch.

Examples of Wind Speed and Direction Plots

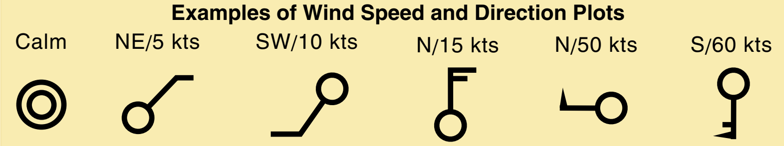


Figure 12-15. *Sample station model and weather chart symbols.*

- Sea level pressure—given in three digits to the nearest tenth of a millibar (mb). For 1,000 mbs or greater, prefix a 10 to the three digits. For less than 1,000 mbs, prefix a 9 to the three digits.
- Pressure change/tendency—pressure change in tenths of mb 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.
- Dew point—given in degrees Fahrenheit.
- Present weather—over 100 different weather symbols are used to describe the current weather.
- Temperature—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 0100Z 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 12-16]*

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 three 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 nonhatched area outlined by a smooth line. Areas of VFR (no ceiling or ceiling greater than 3,000 feet and visibility greater than five miles) are not outlined.

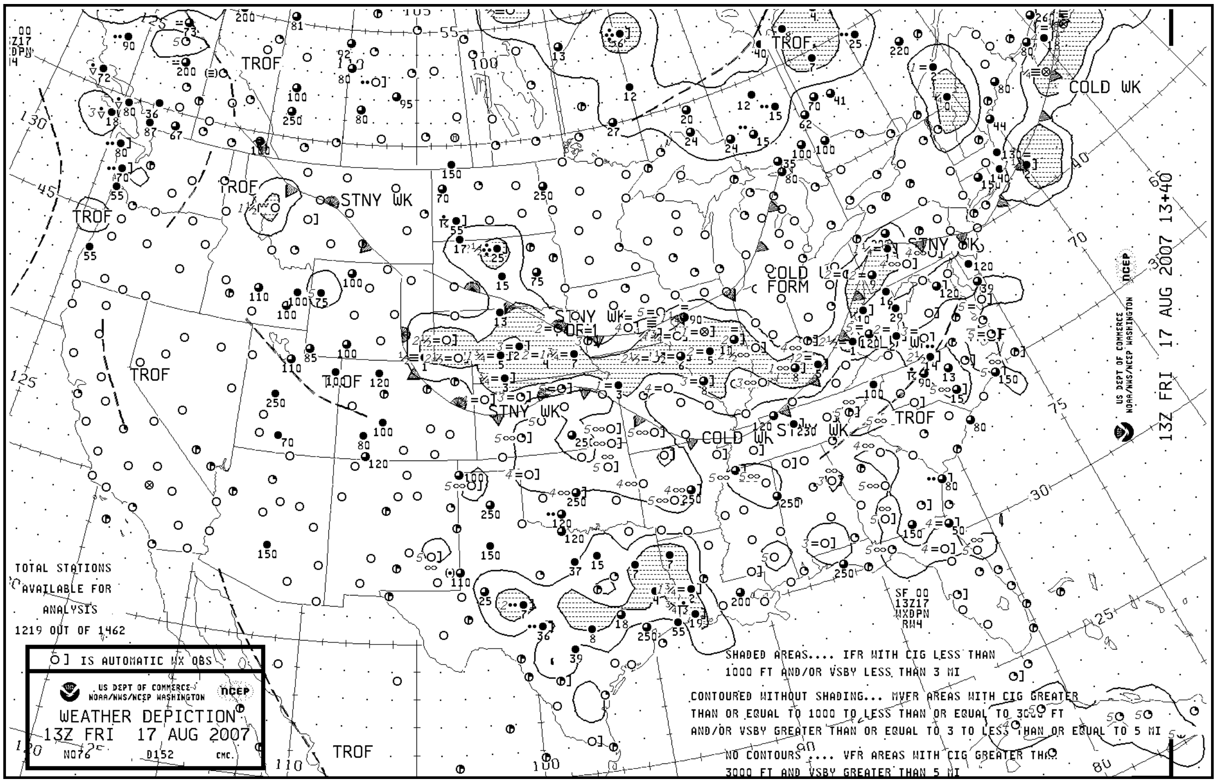


Figure 12-16. *Weather depiction chart.*

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 12-17]* 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 12-18]* 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.

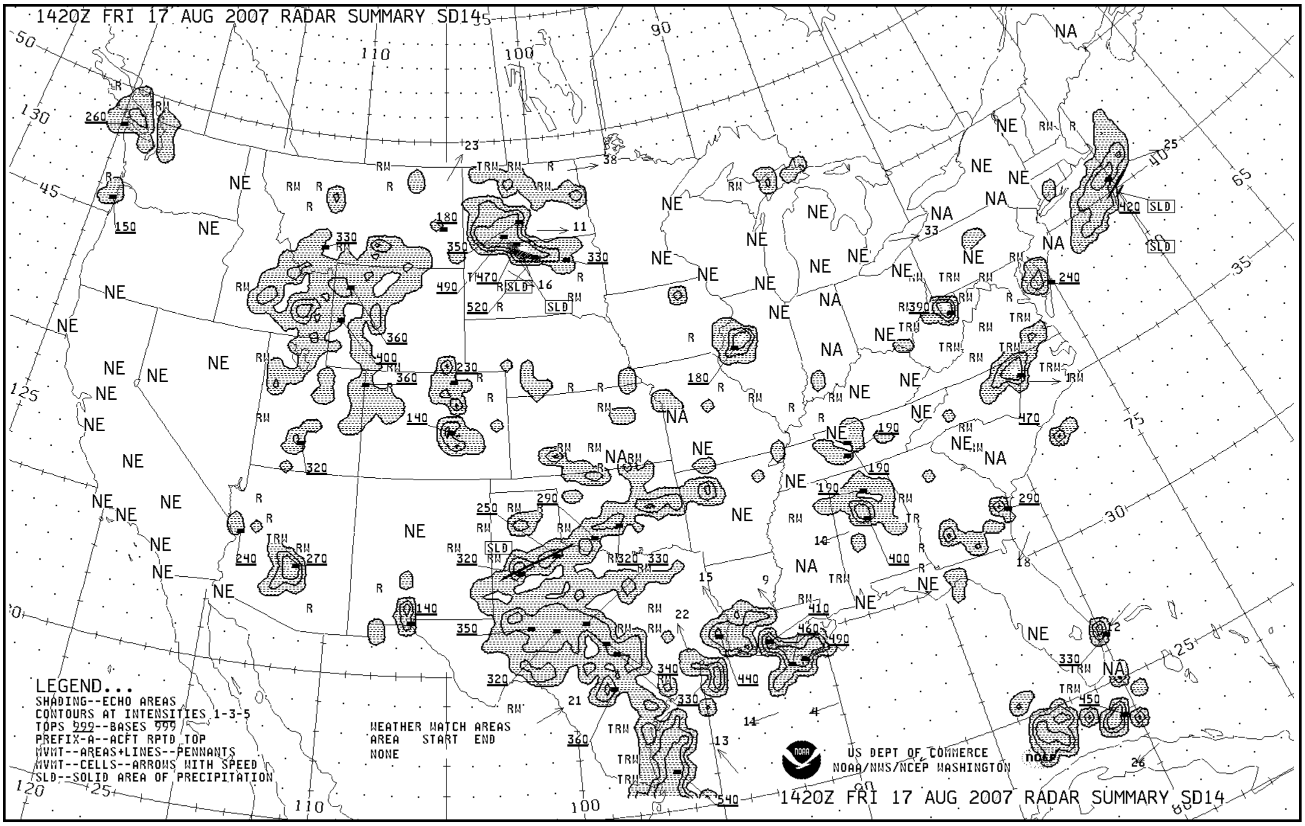


Figure 12-17. *Radar summary chart.*

Symbol	Meaning
R	Rain
RW	Rain shower
S	Snow
SW	Snow shower
T	Thunderstorm
NA	Not available
NE	No echoes
OM	Out for maintenance
↗ 35	Cell movement to the northeast at 35 knots
LM	Little movement
$\boxed{\text{WS999}}$	Severe thunderstorm watch number 999
$\boxed{\text{WT210}}$	Tornado watch number 210
$\boxed{\text{SLD}}$	8/10 or greater coverage in a line
	Line of echoes

Figure 12-18. *Intensity levels, contours, and precipitation type symbols.*

Significant Weather Prognostic Charts

Significant weather prognostic charts are available for low-level significant weather from the surface to FL 240 (24,000 feet), also referred to as the 400 mb level, and high-level significant weather from FL 250 to FL 600 (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-hour surface 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 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 12-19 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 surface weather forecasts and includes a discussion of the forecast. This chart is issued twice 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 12-20*.

ATC Radar Weather Displays

Although ATC systems cannot always detect the presence or absence of clouds, they can often determine the intensity of a precipitation area, but the specific character of that area (snow, rain, hail, VIRGA, etc.) cannot be determined. For this reason, ATC refers to all weather areas displayed on ATC radar scopes as "precipitation."

ARTCC facilities normally use a Weather and Radar Processor (WARP) to display a mosaic of data obtained from multiple NEXRAD sites. There is a time delay between actual conditions and those displayed to the controller. The precipitation data on the ARTCC controller's display could be up to 6 minutes old. The WARP processor is only used in ARTCC facilities. All ATC facilities using radar weather processors with the ability to determine precipitation intensity, describe the intensity to pilots as:

- Light,
- Moderate,
- Heavy, or
- Extreme.

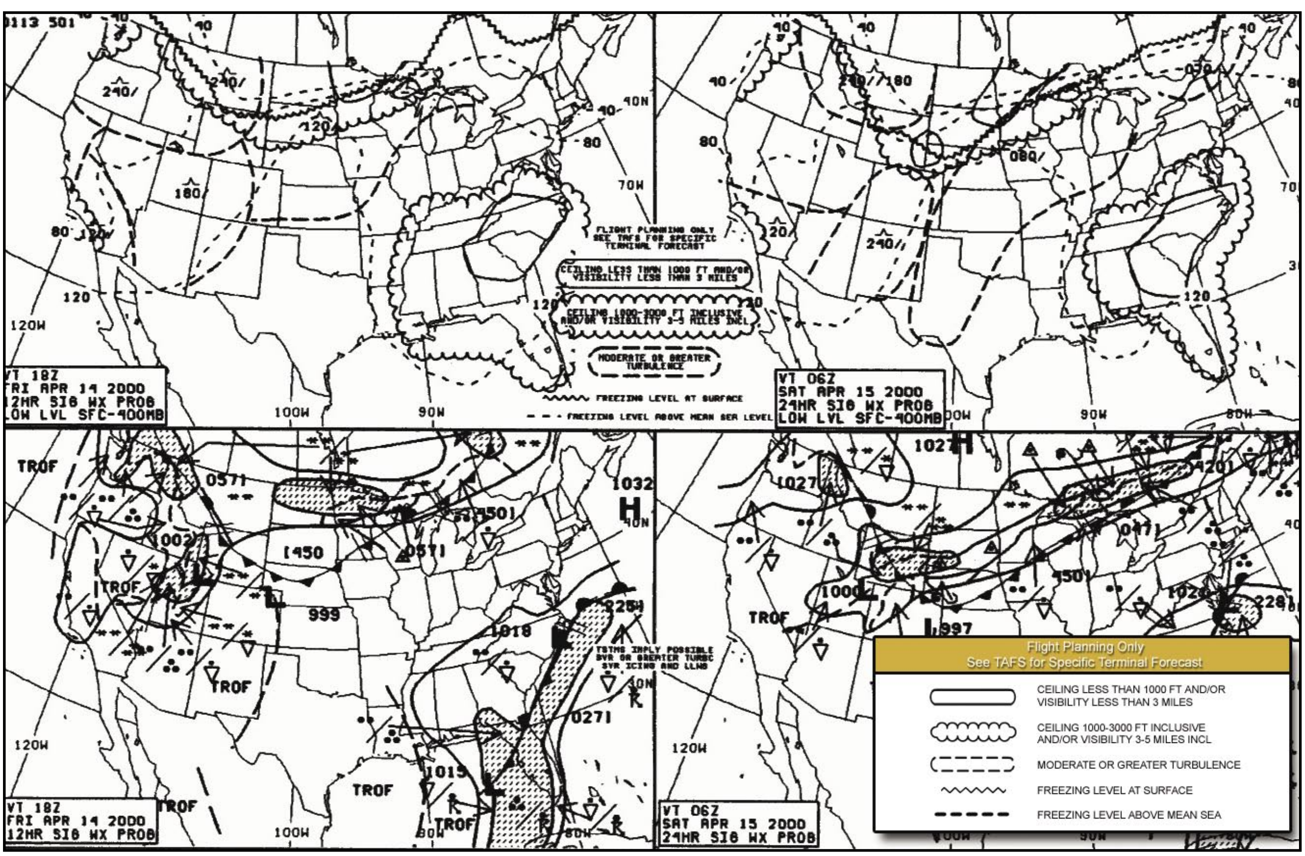


Figure 12-19. *Significant weather prognostic chart and legend (inset).*

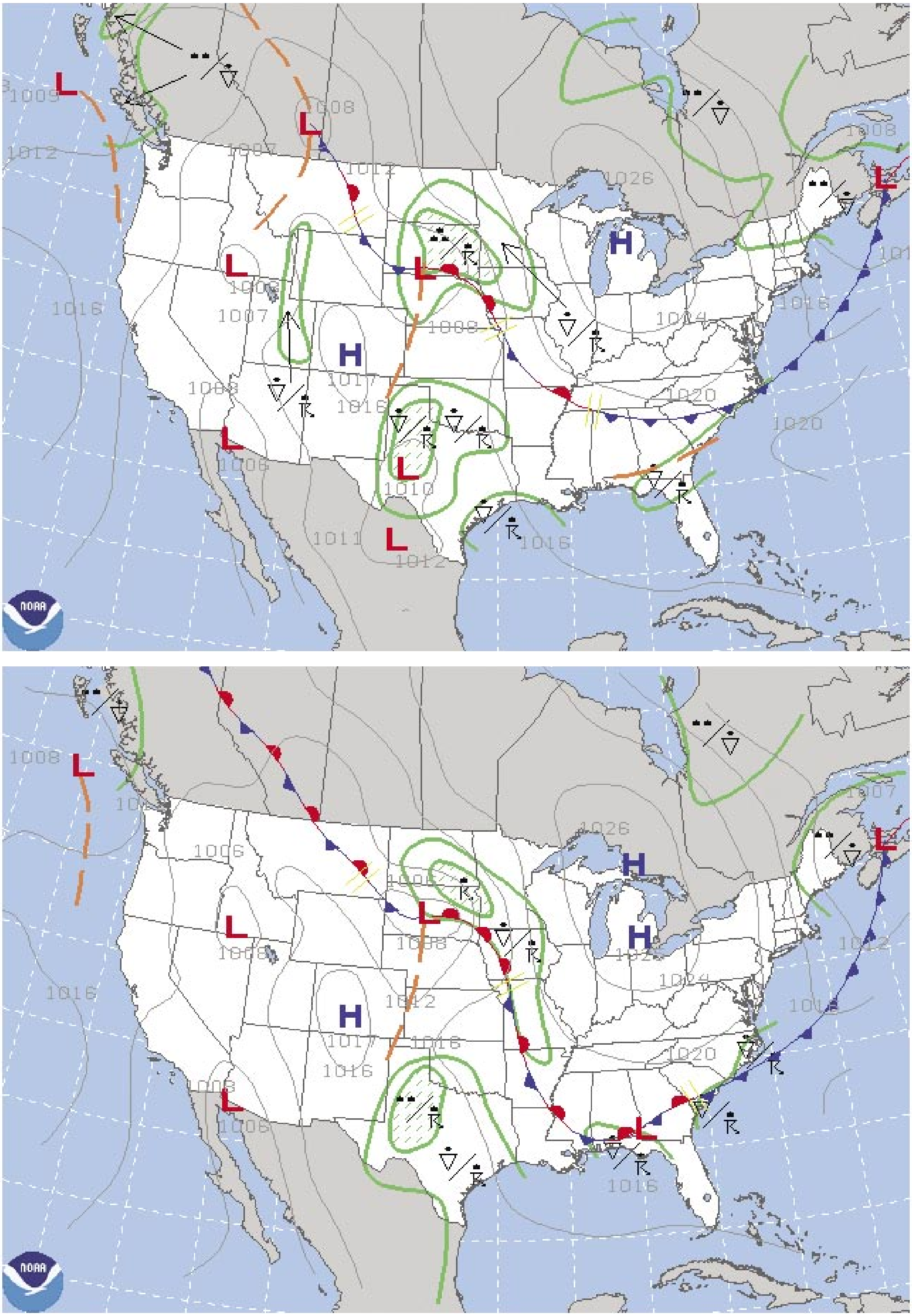


Figure 12-20. *36- (top) and 48-hour (bottom) surface prognostic chart.*

When the WARP is not available, a second system, the narrowband Air Route Surveillance Radar (ARSR) can display two distinct levels of precipitation intensity that will be described to pilots as "MODERATE and "HEAVY TO EXTREME."

ATC facilities that cannot display the intensity levels of precipitation due to equipment limitations will describe the location of the precipitation area by geographic position, or position relative to the aircraft. Since the intensity level is not available, the controller will state "INTENSITY UNKNOWN."

ATC radar is not able to detect turbulence. Generally, turbulence can be expected to occur as the rate of rainfall or intensity of precipitation increases. Turbulence associated with greater rates of rainfall/precipitation will normally be more severe than any associated with lesser rates of rainfall/precipitation. Turbulence should be expected to occur near convective activity, even in clear air. Thunderstorms are a form of convective activity that imply severe or greater turbulence. Operation within 20 miles of thunderstorms should be approached with great caution, as the severity of turbulence can be much greater than the precipitation intensity might indicate.

Weather Avoidance Assistance

To the extent possible, controllers will issue pertinent information on weather and assist pilots in avoiding such areas when requested. Pilots should respond to a weather advisory by either acknowledging the advisory or by acknowledging the advisory and requesting an alternative course of action as follows:

- Request to deviate off course by stating the number of miles and the direction of the requested deviation.
- Request a new route to avoid the affected area.
- Request a change of altitude.
- Request radar vectors around the affected areas.

It should be remembered that the controller's primary function is to provide safe separation between aircraft. Any additional service, such as weather avoidance assistance, can only be provided to the extent that it does not detract from the primary function. It's also worth noting that the separation workload is generally greater than normal when weather disrupts the usual flow of traffic. ATC radar limitations and frequency congestion may also be a factor in limiting the controller's capability to provide additional service.

Electronic Flight Displays (EFD) /Multi-Function Display (MFD) Weather

Many aircraft manufacturers now include satellite weather services with new electronic flight display (EFD) systems. EFDs give a pilot access to many of the satellite weather services available.

Products available to a pilot on the display pictured in *Figure 12-21* are listed as follows. The letters in parentheses indicate the soft key to press in order to access the data.

Figure 12-21. *Information page.*

- Graphical NEXRAD data (NEXRAD)
- Graphical METAR data (METAR)
- Textual METAR data
- Textual terminal aerodrome forecasts (TAF)
- City forecast data
- Graphical wind data (WIND)
- Graphical echo tops (ECHO TOPS)
- Graphical cloud tops (CLD TOPS)
- Graphical lightning strikes (LTNG)
- Graphical storm cell movement (CELL MOV)
- NEXRAD radar coverage (information displayed with the NEXRAD data)
- SIGMETs/AIRMETs (SIG/AIR)
- Surface analysis to include city forecasts (SFC)
- County warnings (COUNTY)
- Freezing levels (FRZ LVL)
- Hurricane track (CYCLONE)
- Temporary flight restrictions (TFR)

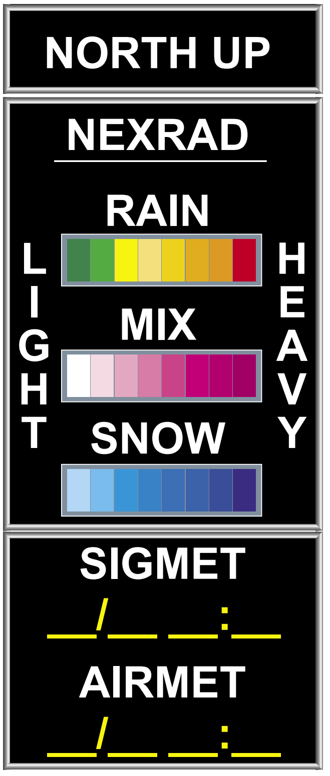


Figure 12-22. *List of weather products and the expiration times of each.*

Pilots must be familiar with any EFD or MFD used and the satellite weather products available on the display.

Weather Products Age and Expiration

The information displayed using a satellite weather link is near real time but should not be thought of as instantaneous up-to-date information. Each type of weather display is stamped with the age information on the MFD. The time is referenced from Zulu when the information was assembled at the ground station. The age should not be assumed to be the time when the FIS received the information from the satellite.

Two types of weather are displayed on the screen: "current" weather and forecast data. Current information is displayed by an age while the forecast data has a data stamp in the form of "__ / __ __ : __". *[Figure 12-22]*

The Next Generation Weather Radar System (NEXRAD)

The NEXRAD system is comprised of a series of 159 Weather Surveillance Radar–1988 Doppler (WSR-88D) sites situated throughout the United States as well as selected oversees sites. The NEXRAD system is a joint venture between the United States Department of Commerce (DOC), the United States Department of Defense, (DOD) as well as the United States Department of Transportation (DOT). The individual agencies that have control over the system are the NWS, Air Force Weather Agency (AFWA) and the FAA. *[Figure 12-23]*

NEXRAD radar produces two levels of products: level II and level III.

Level II Data Products

All NEXRAD level-II data products are available through the National Climatic Data Center (NCDC). Level II data consists of the three meteorological base data quantities: reflectivity, mean radial velocity, and spectrum width.

Level III Data Products

There are 41 products routinely available through the NCDC. Level III graphic products are available as digital images, color hard copy, gray scale hard copy, or acetate overlay copies. This information is then encoded and disseminated through the satellite weather system as well as other sources.

NEXRAD level III data for up to a 2,000 mile range can be displayed. It is important to realize that the radar image is not real time and can be up to 5 minutes old. At no time should the images be used as storm penetrating radar nor to navigate through a line of storms. The images display should only be used as a reference.

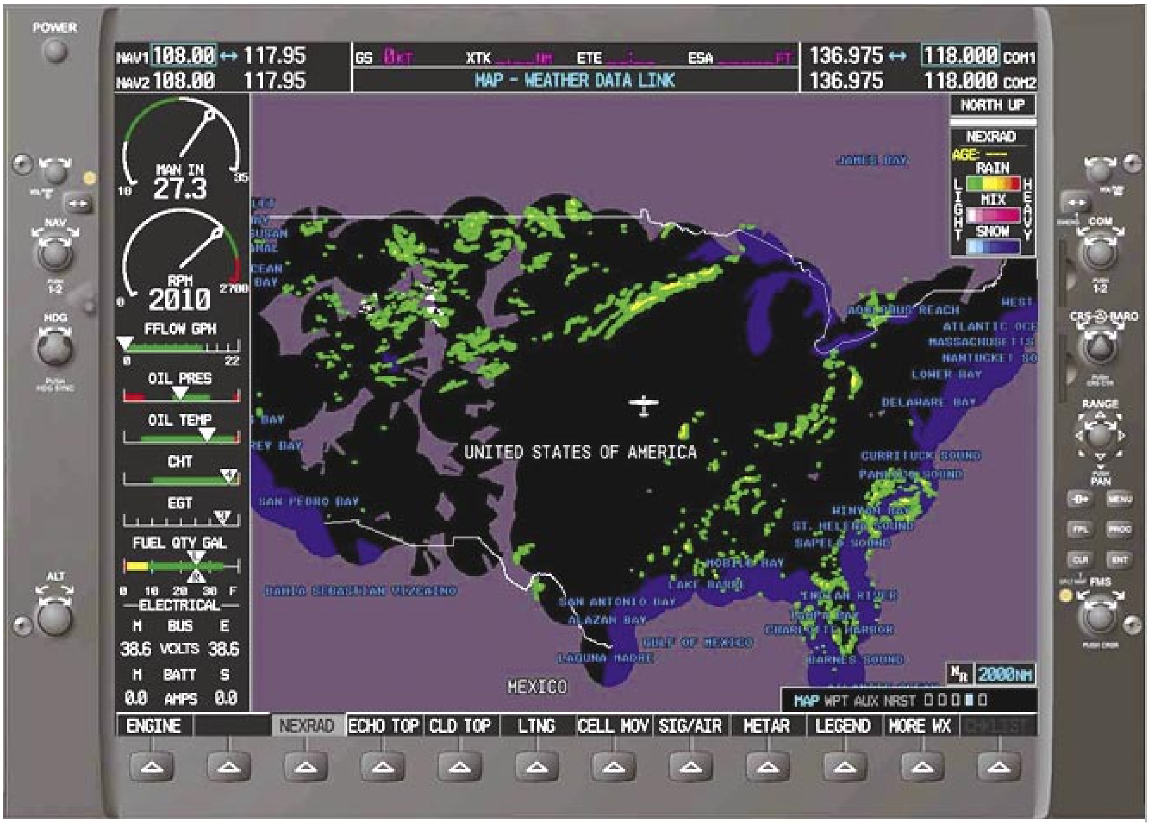


Figure 12-23. *NEXRAD radar display.*

NEXRAD radar is mutually exclusive of Topographic (TOPO), TERRAIN and STORMSCOPE. When NEXRAD is turned on, TOPO, TERRAIN, and STORMSCOPE are turned off because the colors used to display intensities are very similar.

Lightning information is available to assist when NEXRAD is enabled. This presents a more vivid picture of the weather in the surrounding area.

In addition to utilizing the soft keys to activate the NEXRAD display, the pilot also has the option of setting the desired range. It is possible to zoom in on a specific area of the display in order to gain a more detailed picture of the radar display. *[Figure 12-24]*

NEXRAD Abnormalities

Although NEXRAD is a compilation of stations across the country, there can be abnormalities associated with the system. Some of the abnormalities are listed below.

- Ground clutter
- Strobes and spurious radar data
- Sun strobes, when the radar antenna points directly at the sun
- Interference from buildings or mountains, which may cause shadows
- Military aircraft which deploy metallic dust and may reflect the radar signature

NEXRAD Limitations

In addition to the abnormalities listed, the NEXRAD system does have some specific limitations.

Base Reflectivity

The NEXRAD base reflectivity does not provide adequate information from which to determine cloud layers or type of precipitation with respect to hail versus rain. Therefore, a pilot may mistake rain for hail.

In addition, the base reflectivity is sampled at the minimum antenna elevation angle. With this minimum angle, an individual site cannot depict high altitude storms directly over the station. This will leave an area of null coverage if an adjacent site does not also cover the affected area.

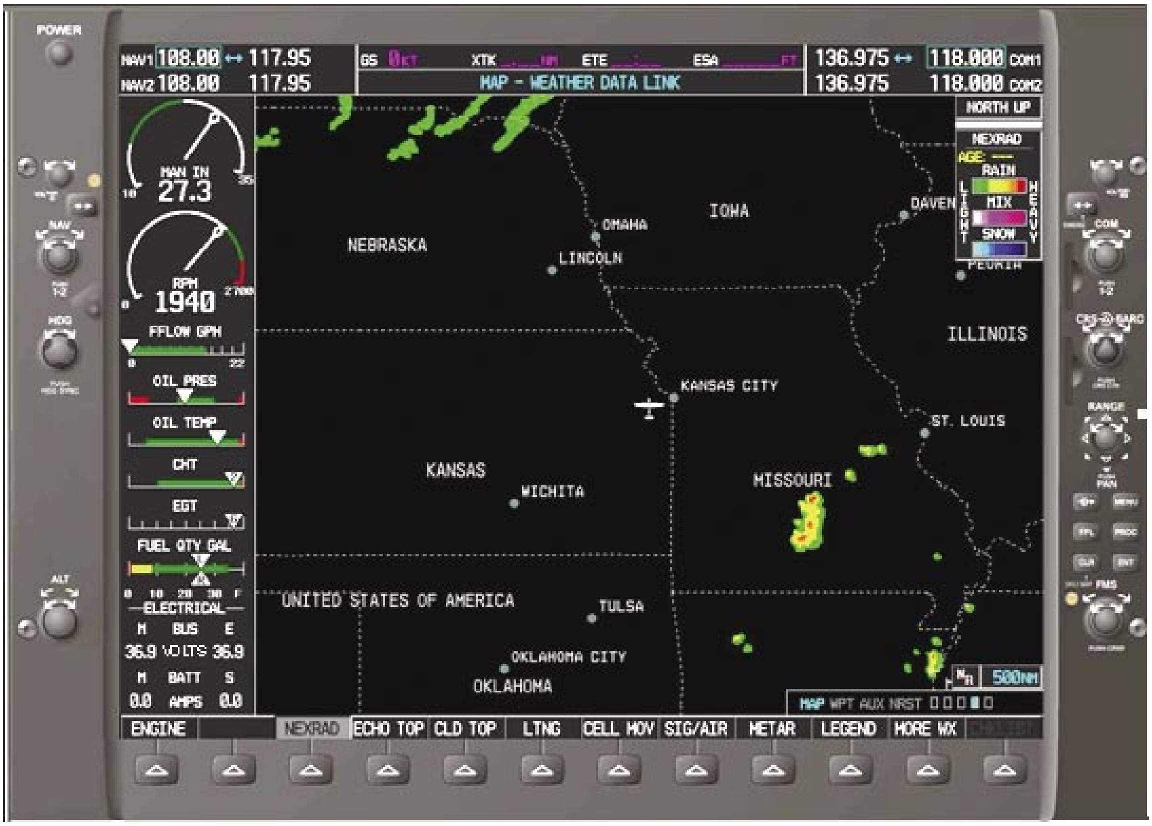


Figure 12-24. *NEXRAD radar display (500 mile range). The individual color gradients can be easily discerned and interpreted via the legend in the upper right corner of the screen. Additional information can be gained by pressing the LEGEND soft key, which displays the legend page.*

Resolution Display

The resolution of the displayed data will pose additional concerns when the range is decreased. The minimum resolution for NEXRAD returns is two kilometers. This means that when the display range is zoomed in to approximately ten miles, the individual square return boxes will be more prevalent. Each square will indicate the strongest display return within that two kilometer square area.

AIRMET/SIGMET Display

AIRMET/SIGMET information is available for the displayed viewing range on the MFD. Some displays are capable of displaying weather information for a 2,000 mile range. AIRMETS/SIGMETS are displayed by dashed lines on the map. *[Figure 12-25]*

The legend box denotes the various colors used to depict the AIRMETs such as icing, turbulence, IFR weather, mountain obscuration as well as surface winds. *[Figure 12-26]* The great advantage of the graphically displayed AIRMET/SIGMET boundary box is the pilot can see the extent of the area that the report covers. The pilot does not need to manually plot the points to determine the full extent of the coverage area.

Graphical METARs

METARs can be displayed on the multi-function display. Each reporting station that has a METAR/TAF available is depicted by a flag from the center of the airport symbol. Each flag is color coded to depict the type of weather that is currently reported at that station. A legend is available to assist users in determining what each flag color represents. *[Figure 12-27]*

The graphical METAR display shows all available reporting stations within the set viewing range. By setting the range knob up to a 2,000 mile range, pilots can pan around the display map to check the current conditions of various airports along the route of flight.

By understanding what each colored flag indicates, a pilot can quickly determine where weather patterns display marginal weather, IFR, or areas of VFR. These flags make it easy to determine weather at a specific airport should the need arise to divert from the intended airport of landing.

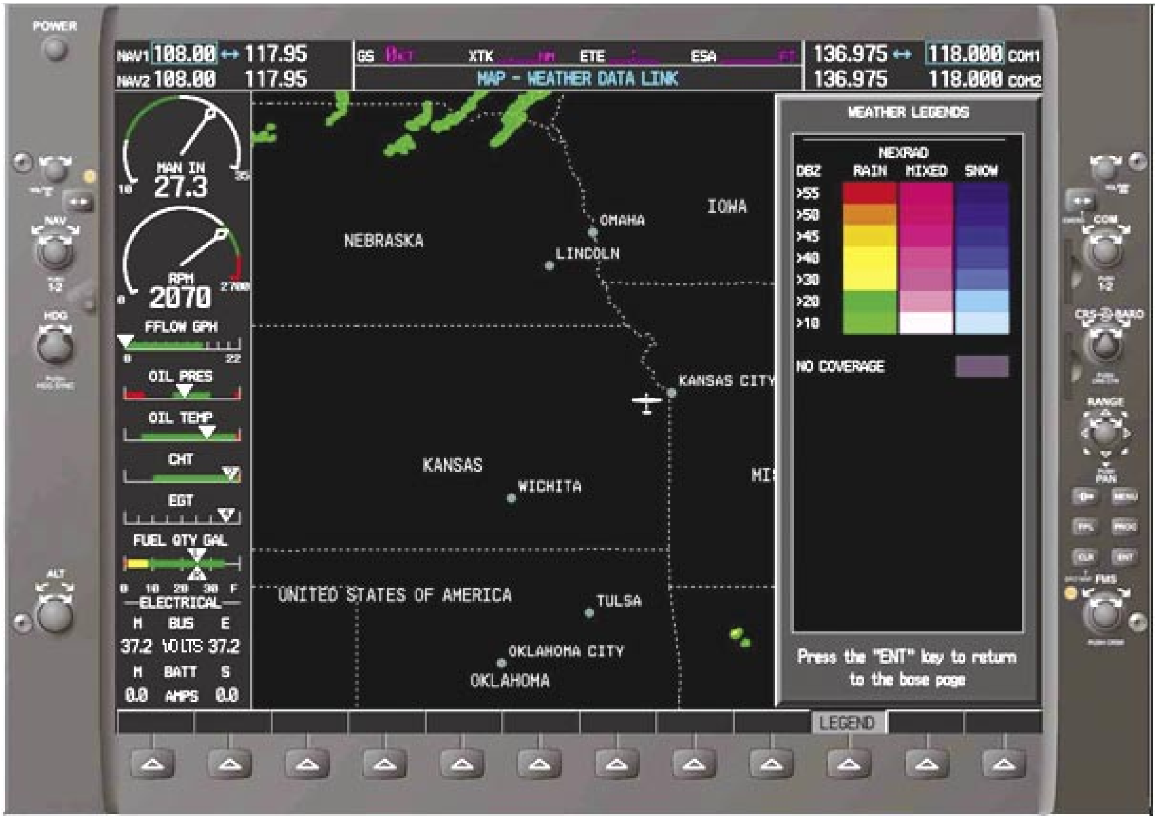


Figure 12-25. *The AIRMET information box instructs the pilot to press the enter button to gain additional information on the selected area of weather. Once the enter soft key (ENT) is depressed, the specific textual information is displayed on the right side of the screen.*

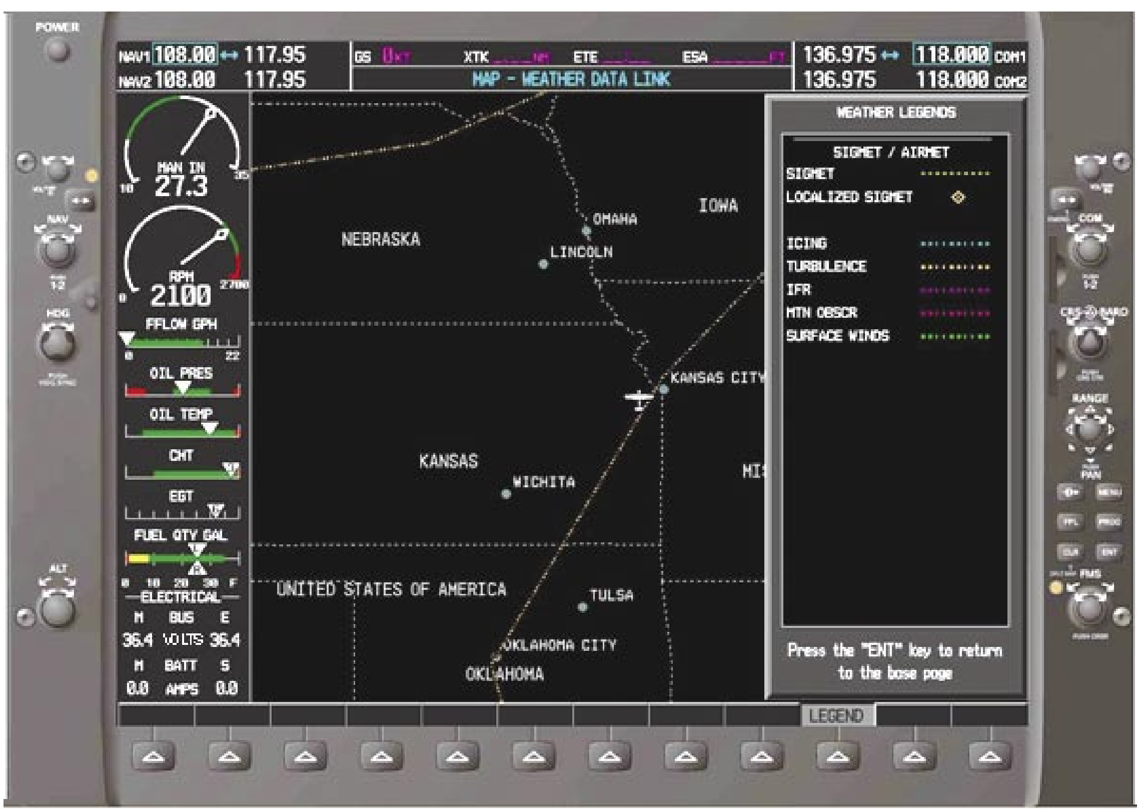


Figure 12-26. *SIGMET/AIRMET legend display.*

Figure 12-27. *Graphical METAR legend display.*

Chapter Summary

While no weather forecast is guaranteed to be 100 percent accurate, pilots have access to a myriad of weather information on which to base flight decisions. Weather products available for preflight planning to en route information received over the radio or via satellite link provide the pilot with the most accurate and up-to-date information available. Each report provides a piece of the weather puzzle. Pilots must use several reports to get an overall picture and gain an understanding of the weather that will affect the safe completion of a flight.