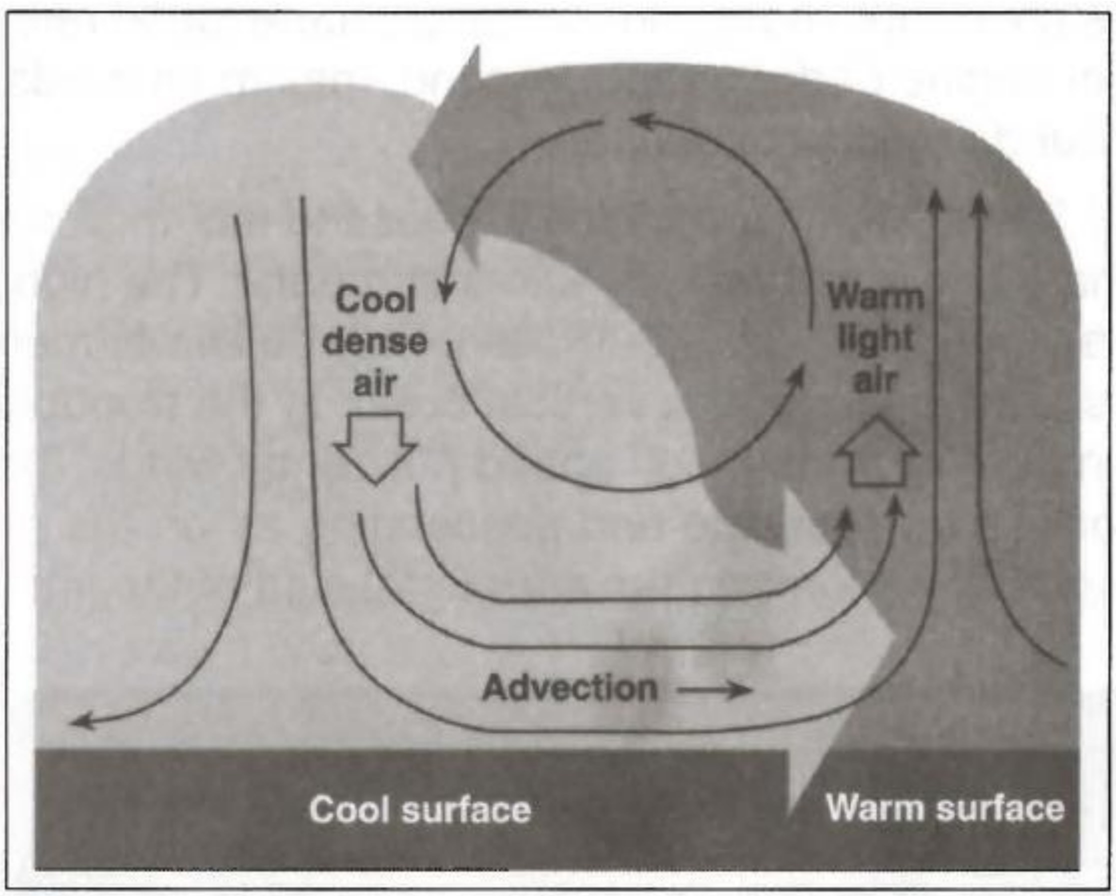
The Atmosphere

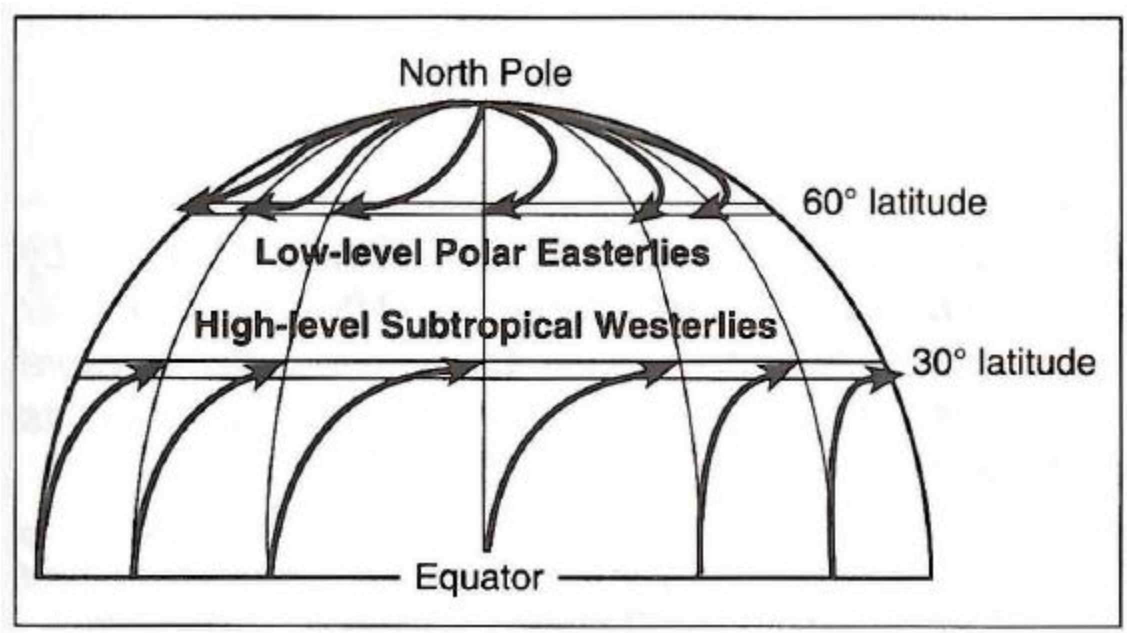
The primary cause of all the Earth's weather is the variation in solar radiation received at the surface. When the surface is warmed by the sun, the air next to it is, in turn, heated and it expands. This creates a low pressure area where the air rises and, at altitude, expands outward. Air from regions of relatively high pressure descends and then moves away from the center of the high toward the lower pressure areas. On both a global and local scale, this movement of air sets off an immensely complex process that generates all the Earth's weather. See Figure 8-1.



Another major influence in the pattern of the weather is a phenomenon known as **Coriolis effect**. This is an apparent force, caused by the Earth's rotation, acting on any movement of air. If the Earth did not rotate, air would move directly from areas of high pressure to areas of low pressure. Coriolis force bends the track of the air over the ground to right in the northern hemisphere and to the left in the southern hemisphere. Viewed from above (as on a weather map) this makes air rotate clockwise around high pressure areas in the northern hemisphere and counterclockwise around lows. In the southern hemisphere, the rotation around highs and lows is just the opposite. In the northern hemisphere, the rotation of air around a low pressure area is called a cyclone and that around a high is called an anticyclone.

The strength of the Coriolis force is determined by wind speed and the latitude. Coriolis has the least effect at the equator and the most at the poles. It is also reduced in effect when wind speed decreases. Air moving near the Earth's surface is slowed by friction. This reduces the Coriolis force. However, the gradient pressure causing the air to move remains the same. The reduced Coriolis allows air to spiral out away from the center of a high and in toward the center of a low, and at an angle to winds aloft which are out of the friction level.

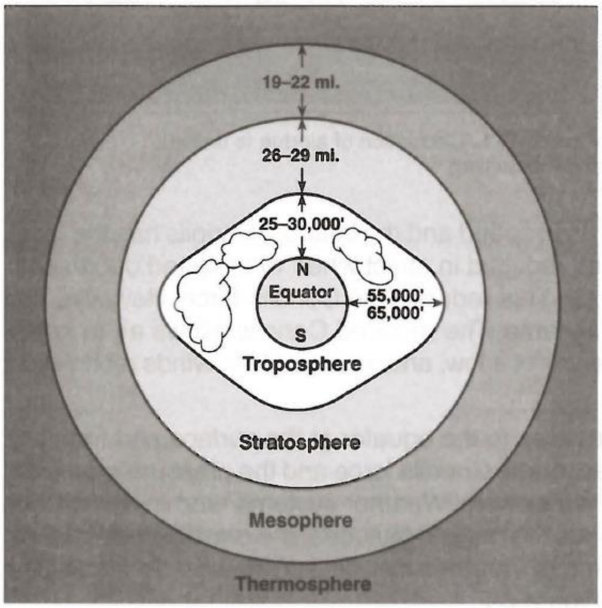
If the Earth did not rotate, air would move from the poles to the equator at the surface and from the equator to the poles at altitude. Because the Earth does rotate, Coriolis force and the pressure gradients tend to form three bands of prevailing winds in each hemisphere. Weather systems tend to move from east to west in the subtropical regions on the "trade winds." In the mid latitudes, the prevailing westerlies move weather systems from west to east. *See* Figure 8-2.



All air carrier flights take place in the two lowest levels of the atmosphere. These are the **troposphere** and the **stratosphere**. The troposphere starts at the surface and extends vertically to roughly 35,000 feet. The thickness of the troposphere varies with latitude, being thicker over the equator than over the poles and with the season of the year (thicker in the summer than in the winter). The stratosphere extends from the top of the troposphere to about 26 to 29 miles altitude. See Figure 8-3. The main characteristic that distinguishes the troposphere from the stratosphere is the temperature lapse rate. In the troposphere, the temperature decreases with increasing altitude at an average rate of two degrees Celsius per one thousand feet of altitude. In the stratosphere, there is little or no change in temperature with altitude. In fact, in some regions the temperature increases with increasing altitude causing temperature inversions.

The thin boundary layer between the troposphere and the stratosphere is called the **tropopause**. The height of the tropopause is of great interest to the pilots of jet aircraft for two reasons. First, there is an abrupt change in the temperature lapse rate at the tropopause and that has a significant effect on jet engine performance. Second, maximum winds (the jet stream) and narrow zones of wind shear are found at the tropopause.

The **jet stream** is a few thousand feet thick and a few hundred miles wide. By arbitrary definition, it has wind speeds of fifty knots or greater. The highest wind speeds can be found on the polar side of the jet core. See Figure 8-4. There may be two or more jet streams in existence at one time. The jet stream is always found at a vertical break in the tropopause where the tropical and polar tropopauses meet. In addition to the high speed horizontal winds, the jet stream contains a circular rotation with rising air on the tropical side and descending air on the polar side. Because of the rising air, cirrus clouds will sometimes form on the equatorial side of the jet.



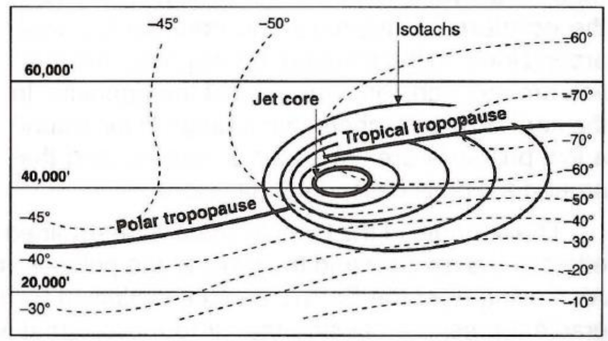


Figure 8-4. Cross-section of the jet stream

Weather Systems

When air masses of different temperature or moisture content collide, they force air aloft along the area where they meet. An elongated line of low pressure is referred to as a trough.

A **front** is defined as the boundary between two different air masses. The formation of a front is called frontogenesis. When a front dissipates, the area experiences frontolysis. All fronts lie in troughs. This means that winds flow around a front more or less parallel to the front, and in a counterclockwise direction. As an aircraft flies toward a front in the northern hemisphere, the pilot will notice a decreasing pressure and a wind from the left of the aircraft. After passing through the front, the pilot will note a wind shift to the right and increasing air pressure.

A front is usually the boundary between air masses of different temperatures. If cold air is displacing warm air, it is called a cold front. When warm air displaces cold air, it is a warm front. The speed of movement of the front is determined by the winds aloft. A cold front will move at about the speed of the wind component perpendicular to the front just above the friction level. It is harder for warm air to displace cold air and so warm fronts move at about half the speed of cold fronts under the same wind conditions.

A stationary front is one with little or no movement. Stationary fronts or slow moving cold fronts can form frontal waves and low pressure areas. A small disturbance can cause a bend in the frontal line that induces a counterclockwise flow of air around a deepening low pressure area. The wave forms into a warm front followed by a cold front. The cold front can then overtake the warm front and force the warm air between the two aloft. This is called an occluded front or an occlusion.

Most fronts mark the line between two air masses of different temperature. However, this is not always the case. Sometimes, air masses with virtually the same temperatures will form a front. The only difference between the two is the moisture content. The front formed in such conditions is called a dew point front or a dry line.

The surface position of a front often marks the line where an arctic and a tropical air mass meet at the surface. The jet stream is located in the area where these air masses meet at the altitude of the tropopause. There is often a rough correlation between the surface position of a front and the location of the jet stream. Generally speaking, the jet stream will lie to the north of the surface position of a front. As a frontal wave forms, the jet will move toward the center of the deepening low pressure area. If an occluded front forms, the jet stream will often cross the front near the point of the occlusion.

Stability and Instability of Air

When a parcel of air is forced to rise it expands because its pressure decreases. Air that is forced to descend is compressed. When the pressure and volume change, so does the temperature. When air expands, it cools and when it is compressed, it warms. This cooling or heating is referred to as being adiabatic, meaning that no heat was removed from or added to the air.

When unsaturated air is forced to rise or descend it cools or heats at a rate of about 3°C per 1,000 feet of altitude change. This called the dry adiabatic rate. The saturated adiabatic rate is normally much lower.

When moist air is forced upward, the temperature and the dew point converge on each other at a rate of about 2.5°C per 1,000 feet. At the altitude where the dew point lapse rate and the dry adiabatic rate meet, cloud bases will form. Once the condensation starts taking place the adiabatic rate slows considerably because the process of condensation releases latent heat into the air and partially offsets the expansional cooling.

Saturated air flowing downward will also warm at less than the dry adiabatic rate because vaporization of water droplets uses heat. Once the air is no longer saturated it will heat at the normal dry rate. An example of this is the "katabatic wind" which becomes warmer and dryer as it flows downslope.

The adiabatic rate should not be confused with the actual (ambient) lapse rate. The actual lapse rate is the rate at which the air temperature varies with altitude when air is not being forced to rise or descend. The actual lapse averages about 2°C per 1,000 feet, but that is highly variable. When a parcel of air is forced to rise, the adiabatic rate may be different than the ambient rate.

When a parcel of air becomes colder (and more dense) than the air around it, it will tend to sink back toward its original altitude. If the parcel becomes warmer than the surrounding air, it will tend to rise convectively even though the original lifting force may have disappeared. If this happens, the air is said to be unstable. When a parcel of air resists convective movement through it, it is said to be stable.

The best indication of the stability or instability of an air mass is the ambient temperature lapse rate. If the temperature drops rapidly as the altitude increases, the air is unstable. If the temperature remains unchanged or decreases only slightly as altitude is increased, the air mass is stable. If the temperature actually increases as altitude increases, a temperature inversion exists. This is the most stable of weather conditions.

Fog and Rain

Fog is a surface-based cloud that always forms in stable air conditions. The three main types are radiation fog, advection fog and upslope fog.

Radiation fog occurs when there is a surface-based temperature inversion. On a clear, relatively calm night the surface rapidly cools by radiating heat into space. This in turn cools the air within a few hundred feet of the surface and leaves warmer air aloft. If the temperature drops to the dew point, fog will form. Since the minimum temperature during the day occurs just after sunrise, this type of fog often forms then. This fog will dissipate when the air warms up enough to raise the temperature above the dew point again. However, if the inversion persists, visibility can remain limited due to lingering fog and haze. Wind or any significant movement of air will disperse both radiation fog and haze.

Advection fog and **upslope fog** both require wind to form. Advection fog forms when warm moist air flows over a colder surface. The temperature of the air drops to the dew point and fog forms. This commonly occurs over bodies of water such as lakes or oceans. The fog can drift over land on the leeward (downwind) side of the body of water lowering visibility at nearby airports. If the wind increases to over about 15 knots, the fog will tend to lift into low stratus clouds.

Upslope fog forms when moist, stable air is gradually moved over higher ground by the wind. As the air rises, it cools adiabatically and fog forms. This type of fog is common in mountainous areas.

All clouds are composed of tiny droplets of water (or ice crystals). As these drops of water collide with each other, they form larger drops until they precipitate out as rain. As a general rule, clouds need to be at least 4,000 feet thick to produce precipitation reported as light or greater intensity.

Thunderstorms

Thunderstorms are always generated in very unstable conditions. Warm, moist air is forced upward either by heating from below or by frontal lifting, and becomes unstable. When the rising air cools to its dew point, a cumulus cloud forms. This "cumulus stage" is the first of three in a thunderstorm's life. It is characterized by a continuous updraft as the cloud builds. As the raindrops and ice pellets in the cloud grow larger, their weight begins to overpower the lifting force of the updrafts. As the drops fall through the cloud, they cool the air making it more dense than in the surrounding updrafts. This process causes downdrafts to form within the cloud.

When the **downdrafts** become strong enough to allow the first precipitation to reach the surface, the mature stage of the thunderstorm has begun. Eventually, the downdrafts cut off the updrafts and the storm loses the source of warm air that is its driving force. When the storm is characterized predominantly by downdrafts, it is in the dissipating stage.

Air mass thunderstorms are associated with local surface heating. On a clear, sunny day, local hot spots form that are capable of making the air over them unstable enough to generate a thunderstorm. Because the downdrafts in an air mass thunderstorm shut off the updrafts fairly quickly, this type of storm is relatively short-lived.

Steady-state thunderstorms are usually associated with weather systems. Fronts, converging winds and troughs aloft force upward motion. In a steady-state storm the precipitation falls outside the updraft allowing the storm to continue without abating for several hours.

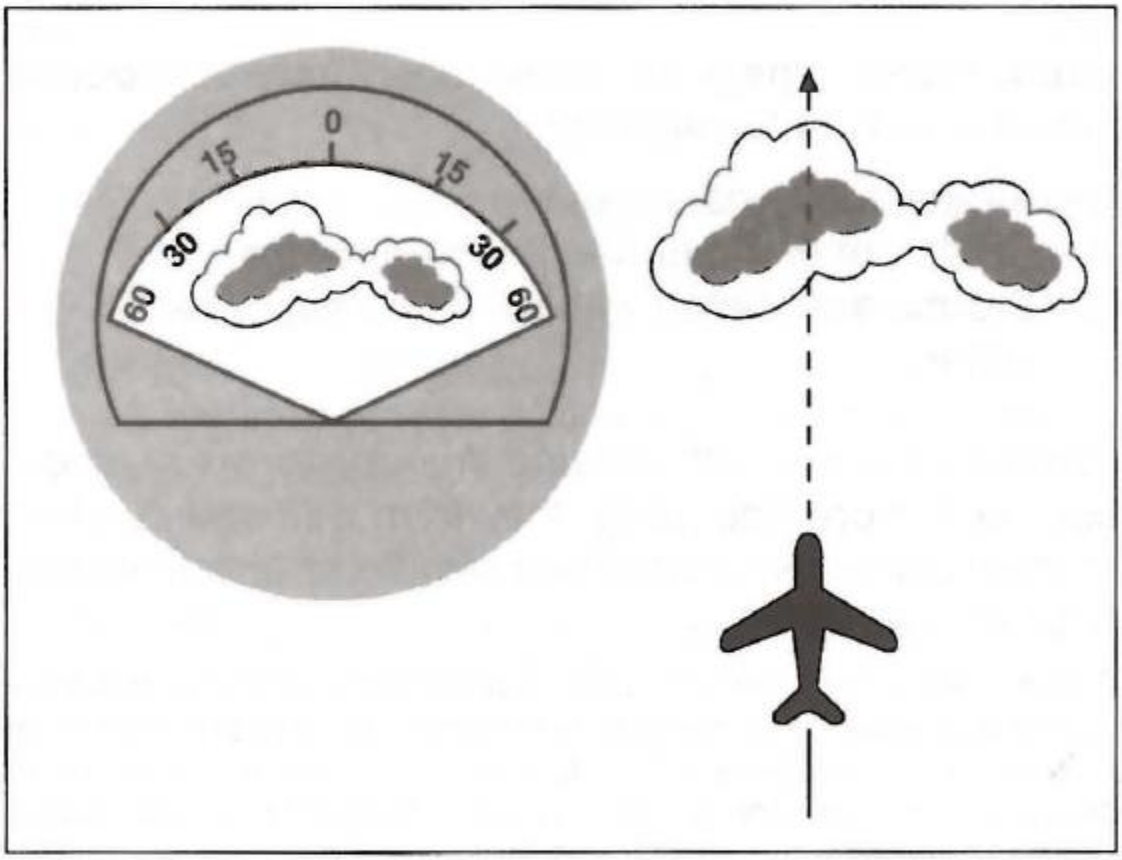
The most violent type of steady-state thunderstorms are those generated by cold fronts or by squall lines. A **squall line** is a non-frontal instability line that often forms ahead of a fast moving cold front. Thunderstorms generated under these conditions are the most likely to develop cumulonimbus mamma clouds, funnel clouds and tornadoes. A severe thunderstorm is one which has surface winds of 50 knots or more, and/or has hail 3/4-inch or more in diameter.

Pressure usually falls rapidly with the approach of a thunderstorm, then rises sharply with onset of the first gust and arrival of the cold downdraft and heavy rain showers. As the storm passes on, the pressure returns to normal.

Even though thunderstorms are cumulus clouds formed in unstable air they can sometimes penetrate overlying bands of stratiform clouds. These are known as “**embedded thunderstorms**.” Because these thunderstorms are obscured by other clouds and it is impossible for a pilot to visually detour around them, they present a particular hazard to IFR flight.

When they can, most pilots prefer to visually avoid thunderstorms by flying around them or, if they can maintain a high enough altitude, by flying over the storm. If you are going to fly over the top of a thunderstorm, a good rule of thumb to follow is that the cloud should be overflown by at least 1,000 feet for each 10 knots of wind speed. Radar is a very useful tool in thunderstorm avoidance, especially at night or in IFR weather. The radar displays an area of precipitation size rain drops as a bright spot on the screen. Since thunderstorms often contain large water drops, they usually show up on the radar screen. A dark area on the screen is one in which no precipitation drops are detected. Areas of clouds may or may not be displayed depending on the size of the drops that make up the clouds.

See Figure 8-5.


0
15
15
30
30
60
60

Wind Shear

Normally we think of changes in wind speed or direction as having an effect only on an aircraft's ground speed and track. However, when there is a very rapid shift in wind speed or direction there is a noticeable change in the aircraft's indicated airspeed as well.

In a situation where there is a sudden increase in headwind (or decrease in tailwind) the aircraft's momentum keeps it moving through space at the same ground speed as before. This means that the aircraft will be moving through the air faster than before and there will be an increase in its indicated airspeed. The aircraft will react to this increase by pitching up and by tending to climb (or descend more slowly). When there is a sudden increase in a tailwind (or decrease in the headwind), just the opposite occurs. There will be a loss of indicated airspeed accompanied by a tendency to pitch down and descend.

Wind shear is defined as any rapid change in wind direction or velocity. Often, there is little or no turbulence associated with wind shear. Severe wind shear is defined as a rapid change in wind direction or velocity causing airspeed changes greater than 15 knots or vertical speed changes greater than 500 feet per minute.

Wind shear may be associated with either a wind shift or a wind speed gradient at any level in the atmosphere. Three common generators of wind shear conditions are thunderstorms, temperature inversions and jet stream winds. Thunderstorms generate a very significant wind shear hazard for two reasons. The shear from thunderstorms is usually encountered close to the ground where there is little time or altitude to recover. The magnitude of the shear is often very severe, especially in situations involving microbursts, which we will discuss shortly. Wind shear can be encountered on all sides and directly under the thunderstorm cell. Often, in a low altitude temperature inversion the winds are very light but just above the inversion layer the wind is much stronger. When an aircraft either climbs or descends through the top of the inversion it can encounter significant wind shear because of the change in wind speed. A jet stream is a narrow "river" of wind where the speed can change a great deal over a very short distance. This is the very definition of wind shear.

Microbursts are a very localized, but very dangerous, wind shear condition. They can occur anywhere that convective weather conditions exist. This includes rain showers, virga and thunderstorms. It is believed that about five percent of thunderstorms produce a microburst.

A microburst is a very narrow downdraft of very high speed wind. The downdraft is typically a few hundred to 3,000 feet across with vertical speeds up to 6,000 feet per minute. When the downdraft approaches the surface, the wind flows outward from the core in all directions. Not only are these outflow winds very strong (up to 45 knots) but their effect is doubled when an aircraft flies through the shear. For example, a 45 knot headwind approaching the microburst will be a 45 knot tailwind flying out the other side-a change of 90 knots. This is usually a short-lived phenomena, seldom lasting more than 15 minutes from the time the burst strikes the ground until it dissipates.

An aircraft approaching a microburst will first experience an increasing headwind as it encounters the outflow. The increasing headwind shear causes the indicated airspeed to increase and gives the aircraft a tendency to pitch up and climb. This increase in performance without an increase in power might induce an unwary pilot into reducing power to maintain airspeed and flight path. As the aircraft flies into the core of the microburst the headwind shifts to a downdraft. The sudden loss of headwind will cause indicated airspeed to drop and cause the aircraft to pitch down and descend. The strong downdraft increases the tendency to descend and the aircraft can quickly get into the situation of having low airspeed and a very high rate of descent. As the aircraft flies out the backside of the microburst, it encounters an increasing tailwind shear that further reduces indicated airspeed and performance.

There are some wind shear conditions that exceed the performance capability of typical air carrier aircraft. For this reason it is imperative that pilots avoid situations where severe wind shear is either reported or is likely to exist. At this time only a couple of airports in the United States have experimental Doppler radar units capable of detecting wind shear. Many airports have the less sophisticated Low Level Wind Shear Alert System (LLWAS), which is used to alert pilots to the possibility of wind shear on or near the airport. This system consists of wind sensors located around the perimeter of the airport as well as a center field wind sensor. When there is a significant difference in speed or direction between any of these sensors and the center field sensor, the tower will broadcast the difference. A typical tower transmission would be:

> "SOUTH BOUNDARY WIND ONE SIX ZERO AT TWO FIVE, WEST BOUNDARY WIND TWO FOUR ZERO AT THREE FIVE."

The greatest danger from a wind shear encounter at low altitude is that the aircraft will pick up such a high rate of descent that the pilots will be unable to stop it before hitting the ground. The technique to be used during a wind shear encounter essentially involves trading airspeed for altitude. The exact procedures vary from one aircraft to another but if an aircraft encounters severe wind shear, the pilot should maintain or increase the pitch attitude, increase power to the maximum available and accept lower than normal airspeed indications. If this does not arrest the descent, the pilot should continue to pitch up until the descent does stop or until "stick shaker" is encountered.

Frost and Ice

No person may dispatch or release an aircraft, continue to operate en route, or land when in the opinion of the pilot-in-command or aircraft dispatcher, icing conditions are expected or met that might adversely affect the safety of the flight. No person may takeoff when frost, snow or ice is adhering to the wings, control surfaces or propellers of the aircraft.

Deicing is a procedure in which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces. Anti-icing is a process that provides some protection against the formation of frost or ice for a limited period of time.

The equipment most commonly used for deicing and anti-icing airplanes on the ground is the truck-mounted mobile deicer/anti-icer. The two basic types of fluids used are Type 1 (unthickened) fluids and Type 2 (thickened) fluids. Type 1 fluids have a minimum 80% glycol content and a relatively low viscosity, except at very low temperatures. The viscosity of Type 1 fluids depends only on temperature. The holdover time is relatively short for Type 1 fluids. Type 2 fluids have a significantly higher holdover time. Type 2 fluids have a minimum glycol content of 50% with 45% to 50% water plus thickeners and inhibitors. Water decreases the freeze point. The freeze point should be no greater than 20°F below ambient or surface temperature, whichever is less.

There is a one-step process and a two-step process for deicing and anti-icing. The one-step process uses heated fluid to remove snow, ice and frost. The primary advantage of this process is that it is quick and uncomplicated. However, where large deposits of snow or ice must be flushed off, fluid usage will be greater than with the two-step process. The two-step process consists of separate deicing and anti-icing steps. A diluted fluid, usually heated, is used to deice and a more concentrated fluid (either 100% or diluted, depending on the weather), usually cold, is used to anti-ice. Type 1 or 2 fluids can be used for both steps, or Type 1 for step 1 and Type 2 for step 2.

Two precautions to observe when using this equipment are:

1. Do not spray deice/anti-ice fluid at or into pitot inlets, TAT probes, or static ports; and
2. Apply deice/anti-ice fluid on pressure relief doors, lower door sills, and bottom edges of doors prior to closing for flight.

Icing

For ice to form, there must be moisture present in the air and the air must be cooled to a temperature of 0°C (32°F) or less. Aerodynamic cooling can lower the temperature of an airfoil to 0°C even though the ambient temperature is a few degrees warmer.

Ice is identified as clear, rime, or mixed. *Rime ice* forms if the droplets are small and freeze immediately when contacting the aircraft surface. This type of ice usually forms on areas such as the leading edges of wings or struts. It has a somewhat rough looking appearance and is a milky white color. *Clear ice* is usually formed from larger water droplets or freezing rain that can spread over a surface. This is the most dangerous type of ice since it is clear, hard to see, and can change the shape of the airfoil. *Mixed ice* is a mixture of clear ice and rime ice. It has the bad characteristics of both types and can form rapidly.

There are two kinds of icing that are significant to aviation: structural icing and induction icing. *Structural icing* refers to the accumulation of ice on the exterior of the aircraft; *induction icing* affects the powerplant operation. Structural icing occurs on an aircraft whenever supercooled droplets of water make contact with any part of the aircraft that is also at a temperature below freezing.

One inflight condition necessary for structural icing is visible moisture (clouds or raindrops). *Freezing rain* always occurs in a temperature inversion. As the rain falls through air that is below freezing, its temperature begins to fall below freezing yet it does not freeze solid—i.e., freezing rain. The process requires the temperature of the rain to be above freezing before it becomes supercooled. Eventually, the water drops will freeze into ice pellets. Any encounter with ice pellets in flight indicates that there is freezing rain at a higher altitude.

Aircraft structural ice will most likely have the highest accumulation in freezing rain; therefore, an operational consideration if you fly into rain which freezes on impact is that temperatures are above freezing at some higher altitude.

Hazards of Structural Icing

The most hazardous aspect of structural icing is its aerodynamic effects. Ice can alter the shape of an airfoil. This can cause control problems, change the angle of attack at which the aircraft stalls, and cause the aircraft to stall at a significantly higher airspeed. Ice can reduce the amount of lift that an airfoil will produce and increase the amount of drag by several times. It can partially block or limit control surfaces, which will limit or make control movements ineffective. If the extra weight caused by ice accumulation is too great, the aircraft might not be able to become airborne, and if in flight, might not be able to maintain altitude.

For this reason, regulations prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft. Yet another hazard of structural icing is the possible uncommanded and uncontrolled roll phenomenon referred to as "roll upset," which is associated with severe inflight icing. Therefore, pilots flying airplanes certificated for flight in known icing conditions should be aware that severe icing is a condition that is outside of the airplane's certificated icing envelope.

Structural icing can also cause tailplane (empennage) stall. The tail can collect ice faster than the wing and because it is not visible to the pilot inflight, the situation could go undetected. A tailplane stall occurs when, same as with the wing, the critical angle of attack is exceeded. Since the horizontal stabilizer counters the natural nose-down tendency caused by the center of lift of the main wing, the airplane will react by pitching down, sometimes uncontrollably, when the tailplane is stalled. Application of flaps can aggravate or initiate the stall.

Because of this, the pilot should use caution when applying flaps during an approach if there is the possibility of icing on the tailplane. Ice buildup will cause the airplane to require more power to maintain cruise airspeed. Ice on the tailplane can cause diminished nose-up pitch control and heavy elevator forces, and the aircraft may buffet if flaps are applied. Ice on the rudder or ailerons can cause control oscillations or vibrations.

For an airplane to be approved for flight into icing conditions, the airplane must be equipped with systems that will adequately protect various components. Not all airplanes with these components are approved for flight into known icing; check your POH to know if your airplane has been certificated to operate in known icing conditions.

Frost Formation

Frost is described as ice deposits formed by sublimation on a surface when the temperature of the collecting surface is at or below the dew point of the adjacent air and the dew point is below freezing. Frost causes early airflow separation on an airfoil resulting in a loss of lift. Therefore, all frost should be removed from the lifting surfaces of an airplane before flight or it may prevent the airplane from becoming airborne.

Snow always forms in colder than freezing temperatures by the process of sublimation. This is when water goes straight from its vapor state into ice without ever being a liquid. Wet snow occurs when it falls to altitudes with above freezing temperatures and begins to melt.

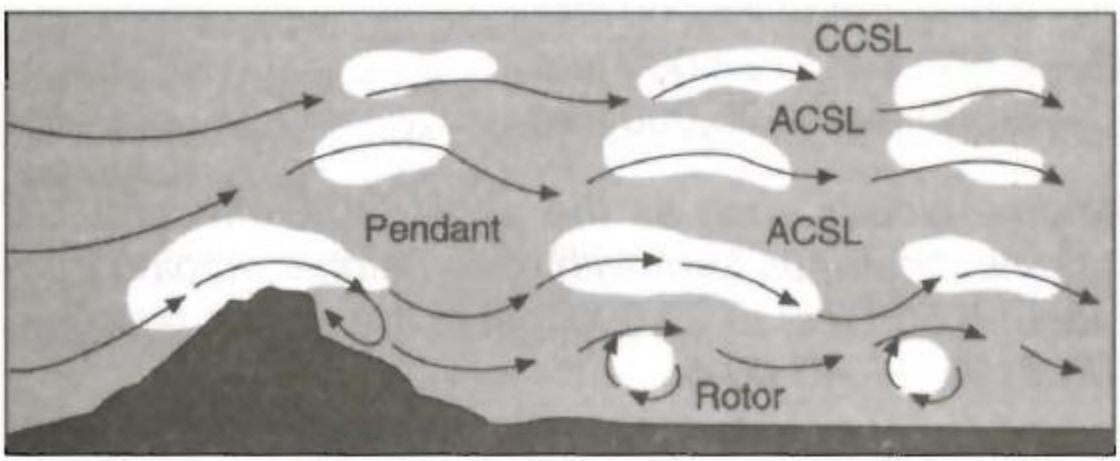
Test data indicate that ice, snow, or frost formations having a thickness and surface roughness similar to medium or course sandpaper on the leading edge and upper surface of a wing can reduce wing lift by as much as 30% and increase drag by 40%.

Turbulence

Light chop causes slight, rapid and somewhat erratic bumpiness without appreciable changes in altitude or attitude. Light turbulence causes momentary slight erratic changes in altitude and/or attitude. Light chop causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Moderate turbulence is similar to light turbulence, but of greater intensity. Changes in altitude or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Severe turbulence causes large, abrupt changes in altitude or attitude. It usually causes large variations in indicated airspeed. The aircraft may be momentarily out of control. In extreme turbulence the aircraft is violently tossed about and is practically impossible to control. Extreme turbulence may cause structural damage.

Turbulence that occurs less than 1/3 of the time should be reported as occasional. Turbulence that occurs 1/3 to 2/3 of the time is intermittent. Turbulence that occurs more than 2/3 of the time is continuous. High altitude turbulence (normally above 15,000 feet MSL) not associated with cumuliform cloudiness should be reported as **CAT (Clear Air Turbulence).**

Strong winds across mountain crests can cause turbulence for 100 or more miles downwind of the mountains and to altitudes as high as 5,000 feet above the tropopause. If there is enough moisture in the air, a mountain wave can be marked by standing lenticular clouds. These clouds mark the crest of each wave. Under the right conditions, several lenticulars can form one above another. A rotor current forms below the crest of a mountain wave. This is sometimes marked by a rotor cloud which will be the lowest of a group of stationary clouds. See Figure 8-6.



The jet stream is a common source of CAT. The strong winds and steep wind gradients will almost always produce some turbulence. The most likely place to find turbulence is on the polar side of the stream in an upper trough. The strongest turbulence will be found in a curving jet stream associated with such a trough. If you encounter turbulence in the jet stream and you have a direct headwind or tailwind you should change course or altitude. With the wind parallel to your heading, you are likely to remain in the jet and the turbulence for a considerable distance. If you approach a jet stream from the polar side the temperature will drop. When you approach it from the tropical side, the temperature rises. Recall that there is a downdraft on the polar side and an updraft on the tropical side. Therefore, to avoid jet stream turbulence descend if the temperature is falling and climb if the temperature is rising as you approach the stream.

Fronts often have turbulence due to the wind shift associated with a sharp pressure trough. Try to cross the front at right angles to minimize the time you are exposed to this turbulence.

Aviation Routine Weather Report (METAR)

Weather reports (METAR) and forecasts (TAF) follow the format shown in Figure 8-7.

Key to Aerodrome Forecast (TAF) and Aviation Routine Weather Report (METAR)

TAF KPIT 091730Z 0918/1024 15005KT 5SM HZ FEW020 WS010/31022KT
FM091930 30015G25KT 3SM SHRA OVC015
TEMPO 0920/0922 1/2SM +TSRA OVC008CB
FM100100 27008KT 5SM SHRA BKN020 OVC040
PROB30 1004/1007 1SM -RA BR
FM101015 18005KT 6SM -SHRA OVC020
BECMG 1013/1015 P6SM NSW SKC

Note: Users are cautioned to confirm ***DATE*** and ***TIME*** of the TAF.
For example FM100000 is 0000Z on the **10th**. Do not confuse with ***1000Z!***

METAR KPIT 091955Z COR 22015G25KT 3/4SM R28L/2600FT TSRA OVC010CB 18/16 A2992 RMK SLP045 T01820159

Forecast	Explanation	Report
TAF	Message type: TAF: routine or TAF AMD: amended forecast; METAR: hourly; SPECI: special or TESTM: noncommissioned ASOS report	**METAR**
KPIT	ICAO location indicator	**KPIT**
091730Z	Issuance time: ALL times in UTC "Z", 2-digit date, 4-digit time	**091955Z**
0918/1024	Valid period: Either 24 hours or 30 hours. The first two digits of EACH four-digit number indicate the date of the valid period, the final two digits indicate the time (valid from 18Z on the 9th to 24Z on the 10th).	
	In U.S. **METAR**: CORrected ob; or AUTOmated ob for automated report with no human intervention; omitted when observer logs on.	**COR**
15005KT	Wind: 3-digit true-north direction, nearest 10 degrees (or VaRiaBle); next 2–3 digits for speed and unit, KT (KMH or MPS); as needed, Gust and maximum speed; 00000KT for calm; for **METAR**, if direction varies 60 degrees or more, Variability appended, e.g., 180V260	**22015G25KT**
5SM	Prevailing visibility: In U.S., Statute Miles and fractions; above 6 miles in **TAF** Plus6SM. (Or, 4-digit minimum visibility in meters and as required, lowest value with direction.)	**3/4SM**
	Runway Visual Range: R; 2-digit runway designator Left, Center, or Right as needed; "/"; Minus or Plus in U.S., 4-digit value, FeeT in U.S. (usually meters elsewhere); 4-digit value Variability, 4-digit value (and tendency Down, Up or No change)	**R28L/2600FT**
HZ	Significant present, forecast and recent weather: See table (to the right)	**TSRA**
FEW020	Cloud amount, height and type: SKy Clear 0/8, FEW >0/8-2/8, SCaTtered 3/8-4/8, BroKeN 5/8-7/8, OVerCast 8/8; 3-digit height in hundreds of feet; Towering CUmulus or CumulonimBus in **METAR**; in **TAF**, only CB. Vertical Visibility for obscured sky and height "VV004". More than 1 layer may be reported or forecast. In automated **METAR** reports only, CLeaR for "clear below 12,000 feet."	**OVC010CB**
	Temperature: Degrees Celsius; first 2 digits, temperature "/" last 2 digits, dewpoint temperature; Minus for below zero, e.g., M06	**18/16**
	Altimeter setting: Indicator and 4 digits; in U.S., A: inches and hundredths; (Q: hectoPascals, e.g., Q1013)	**A2992**

Continued

Key to Aerodrome Forecast (TAF) and Aviation Routine Weather Report (METAR)

Forecast	Explanation	Report
WS010/ 31022KT	In U.S. **TAF**, nonconvective low-level (≤2,000 feet) Wind Shear; 3-digit height (hundreds of feet); "/"; 3-digit wind direction and 2–3 digit wind speed above the indicated height, and unit, KT	
	In **METAR**, ReMarK indicator and remarks. For example: Sea-Level Pressure in hectoPascals and tenths, as shown: 1004.5 hPa; Temp/ dewpoint in tenths °C, as shown: temp. 18.2°C, dewpoint 15.9°C	**RMK SLP045 T01820159**
FM091930	FroM: Changes are expected at: 2-digit date, 2-digit hour, and 2-digit minute **beginning** time: indicates significant change. Each FM starts on a new line, indented 5 spaces	
TEMPO 0920/0922	TEMPOrary: Changes expected for <1 hour and in total, < half of the period between the 2-digit date and 2-digit hour **beginning**, and 2-digit date and 2-digit hour **ending** time	
PROB30 1004/1007	PROBability and 2-digit percent (30 or 40): Probable condition in the period between the 2-digit date and 2-digit hour **beginning** time, and the 2-digit date and 2-digit hour **ending** time	
BECMG 1013/1015	BECoMinG: Change expected in the period between the 2-digit date and 2-digit hour **beginning** time, and the 2-digit date and 2-digit hour **ending** time	

Table of Significant Present, Forecast and Recent Weather – Grouped in categories and used in the order listed below; or as needed in TAF, No Significant Weather

QUALIFIERS

Intensity or Proximity

"–" = Light   **No sign** = Moderate   "+" = Heavy

"VC" = Vicinity, but not at aerodrome. In the U.S. **METAR**, 5 to 10 SM from the point of observation. In the U.S. **TAF**, 5 to 10 SM from the center of the runway complex. Elsewhere, within 8000m.

Descriptor

BC	Patches	**BL**	Blowing	**DR**	Drifting	**FZ**	Freezing
MI	Shallow	**PR**	Partial	**SH**	Showers	**TS**	Thunderstorm

WEATHER PHENOMENA

Precipitation

DZ	Drizzle	**GR**	Hail	**GS**	Small hail or snow pellets		
IC	Ice crystals	**PL**	Ice pellets	**RA**	Rain	**SG**	Snow grains
SN	Snow	**UP**	Unknown precipitation in automated observations				

Obscuration

BR	Mist (≥5/8SM)	**DU**	Widespread dust	**FG**	Fog (<5/8SM)	**FU**	Smoke
HZ	Haze	**PY**	Spray	**SA**	Sand	**VA**	Volcanic ash

Other

DS	Dust storm	**FC**	Funnel cloud	**+FC**	Tornado or waterspout		
PO	Well-developed dust or sand whirls			**SQ**	Squall	**SS**	Sandstorm

- Explanations in parentheses "( )" indicate different worldwide practices.
- Ceiling is not specified; defined as the lowest broken or overcast layer, or the vertical visibility.
- NWS **TAF**s exclude BECMG groups and temperature forecasts, NWS **TAF**s do not use PROB in the first 9 hours of a TAF; NWS **METAR**s exclude trend forecasts. U.S. Military **TAF**s include Turbulence and Icing groups.

Arctic and Tropical Weather Hazards

"Whiteout" is a visibility restricting phenomenon that occurs in the Arctic when a layer of cloudiness of uniform thickness overlies a snow or ice covered surface. Parallel rays of the sun are broken up and diffused when passing through the cloud layer so that they strike the snow surface from many angles. The diffused light then reflects back and forth between the clouds and the snow eliminating all shadows. The result is a loss of depth perception that makes takeoff or landing on snow-covered surfaces very dangerous.

"Tropical Cyclone" is the term for any low that originates over tropical oceans. Tropical cyclones are classified according to their intensity based on average one minute wind speeds. These classifications are:

Tropical Depression—highest sustained winds up to 34 knots.
Tropical Storm—highest sustained winds of 35 knots through 64 knots.
Hurricane or Typhoon—highest sustained winds of 65 knots or more.

The movement of hurricanes is erratic and very difficult to predict with any degree of precision. As a general rule, hurricanes in the northern hemisphere tend to move to the northwest while they are in the lower latitudes and under the influence of the trade winds. Once they move far enough north to come under the influence of the prevailing westerlies of the mid-latitudes their track tends to curve back to the northeast.

The Weather Depiction Chart

The Weather Depiction Chart is put together from surface aviation (SA) reports to give a broad view of the weather conditions at the time of the observations. The chart shows the actual sky cover, visibility restrictions, and type of precipitation at the reporting stations. In addition, the chart groups stations that are reporting VFR, Marginal VFR or IFR weather conditions.

Stations that report a ceiling of less than 1,000 feet or a visibility of less than 3 miles are classified as IFR and included in a hatched area surrounded by a smooth line. Stations that report ceilings of 1,000 to 3,000 feet or visibilities of 3 to 5 miles are MVFR (marginal VFR) and are included in a non-hatched area surrounded by a smooth line. Stations that have a ceiling greater than 3,000 feet and visibilities greater than 5 miles are VFR and are not outlined. This chart says nothing about the weather between reporting stations.

The Terminal Aerodrome Forecast (TAF)

TAFs use the same code used in the METAR weather reports. (*See* Figure 8-7.)

Enroute Forecasts

The **Area Forecast (FA)** is the single source reference that contains information regarding frontal movement, turbulence and icing conditions for a specific region.

Winds and temperatures aloft are forecast for various stations around the country. Wind directions are always relative to true north and the speed is in knots. Temperatures, in degrees Celsius, are forecast for all altitudes except for 3,000 feet. At altitudes where the wind or temperature is not forecast, a blank space is used to signify the omission. At 30,000 feet and above the minus sign is deleted from the temperature to save space.

When winds are light and variable the notation 9900 is used. When wind speeds exceed 99 knots, fifty is added to the wind direction and only the last two digits of the wind speed is printed. For example, an FB (previously FD) forecast of "731960" at FL390 is 230° true (73 - 50 = 23) at 119 knots with a temperature of -60°C. When winds exceed 199 knots they are indicated as a forecast speed of 199 knots. For example, winds from 280° at 205 knots are coded as 7899.

The temperature in the tropopause (36,000 feet and above) is approximately -56°C. ISA at sea level is 15°C and decreases at a rate of 2° / 1,000 feet up to 36,000 feet MSL.

Forecast winds and temperatures aloft for international flights may be obtained by consulting wind and temperature aloft charts prepared by a Regional Area Forecast Center (RAFC).

Surface Analysis and Constant Pressure Charts

The Surface Analysis Chart shows pressure patterns, fronts and information on individual reporting stations. The pressure patterns are shown by lines called **isobars**. The isobars on a surface weather map represent lines of equal pressure reduced to sea level.

Constant pressure charts are similar in many ways to the surface analysis chart in that they show the pressure patterns and some weather conditions for reporting stations. These charts show conditions at one of five pressure levels from 850 millibars to 200 millibars. These pressure levels correspond roughly with altitudes from 5,000 feet MSL to 39,000 feet MSL. The chart is for a pressure level rather than an altitude. The altitude (in meters) of the pressure level is shown by height contours. In addition to the height contour lines, constant pressure charts can contain lines of equal temperature (isotherms) and lines of equal wind speed (isotachs). Since these are both dotted lines, be careful not to get them confused when looking at a chart. Six items of information are shown on the charts for reporting stations. These are the wind, temperature, temperature/dew point spread, height of the pressure level and the change of the height level over the previous 12 hours.

These charts can be used to locate the jet stream and its associated turbulence and wind shear. When there is a large change in wind speed over a short distance, as indicated by closely spaced isotachs, the probability of turbulence is greatly increased. Since the jet stream is associated with discontinuities in the temperature lapse rate at breaks in the tropopause, closely spaced isotherms indicate the possibility of turbulence or wind shear.

Charts can be used together to get a three dimensional view of the weather. For example, lows usually slope to the west with increasing height. If a low stops moving, it will extend almost vertically. This type of low is typical of a slow moving storm that may cause extensive and persistent cloudiness, precipitation, and generally adverse flying weather.

Prognostic Charts

A prognostic chart depicts weather conditions that are forecast to exist at a specific time in the future shown on the chart. The **Low-Level Significant Prog Chart** forecasts weather conditions from the surface to the 400 millibar level (about 24,000 feet). The **High-Level Significant Weather Prog Chart** forecasts conditions from 25,000 feet to 63,000 feet. This encompasses FL250 to FL600.

The upper two panels of the Low-Level Significant Weather Prognostic Chart are the 12-hour and the 24-hour Significant Weather Prog Charts. These two charts forecast areas of MVFR and IFR weather as well as areas of moderate or greater turbulence. In each case, the turbulence is forecast to be of moderate intensity as shown by the inverted "V" symbol. The underlined number next to the turbulence symbol indicates that the turbulence goes up to that altitude. If the turbulence started at an altitude other than the surface, a number would also appear below the line.

The lower two panels are the 12-hour and the 24-hour surface prog charts. These forecast frontal positions and areas of precipitation.

An area surrounded by a dotted and dashed line has showery precipitation. An area surrounded by a continuous line has either continuous or intermittent precipitation. If the area is shaded, the precipitation will cover more than half the area. The type of precipitation expected is shown by the symbols used within the area.

Reports and Forecasts of Hazardous Weather

A **Convective Outlook (AC)** describes the prospects for general thunderstorm activity during the following 24 hours. Areas in which there is a high, moderate or slight risk of severe thunderstorms are included as well as areas where thunderstorms may approach severe limits.

The **Severe Weather Outlook Chart** is a preliminary 24-hour outlook for thunderstorms presented in two panels. A line with an arrowhead delineates an area of probable general thunderstorm activity. An area labeled APCHG indicates probable general thunderstorm activity may approach severe intensity. "Approaching" means winds of 35 to 50 knots or hail 1/2 to 3/4 of an inch in diameter.

AIRMETs and **SIGMETs** are issued to alert pilots to potentially hazardous weather not adequately forecast in the current Area Forecast (FA). They are appended to the current FA and are broadcast by the FSS upon issue and at H+ 15 and H+45 while they are in effect. ARTCC facilities will announce that a SIGMET is in effect and the pilot can then contact the nearest FSS for the details.

AIRMET forecast:

- Moderate icing
- Moderate turbulence
- Sustained winds of 30 knots or more at the surface
- Widespread areas of ceilings less than 1,000 feet or visibilities of less than 3 miles
- Extensive mountain obscurement

SIGMET forecast:

- Severe and extreme turbulence
- Severe icing
- Widespread dust storms, sandstorms or volcanic ash lowering visibility to below three miles

Convective SIGMETs cover the following:

- Tornadoes
- Lines of thunderstorms
- Embedded thunderstorms
- Thunderstorm areas greater than or equal to intensity level 4
- Hail greater than 3/4 of an inch in diameter

Convective SIGMETs are each valid for one hour and are removed at H+40. They are reissued as necessary. On an hourly basis, an outlook is made up for each of the WST regions. This outlook covers the prospects for 2 to 6 hours.

Telephone Information Briefing Service (TIBS) is provided by automated flight service stations (AFSS). It is a continuous recording of meteorological and aeronautical information, available by telephone by calling 1-800-WX-BRIEF. Each AFSS provides at least four route and/or area briefings. In addition, airspace procedures and special announcements (if applicable) concerning aviation interests may also be available. Depending on user demand, other items may be provided, such as METAR observations, terminal aerodrome forecasts, wind/temperatures aloft forecasts, etc. TIBS is not intended to substitute for specialist-provided preflight briefings. It is, however, recommended for use as a preliminary briefing, and often will be valuable in helping you to make a "go or no go" decision.

PIREPs

A pilot weather report (PIREP) is often the most timely source of information about such weather conditions as icing and multiple cloud layers. While area forecasts and freezing level charts can give the pilot a good idea of the potential for icing, only a PIREP can let the pilot know what is happening currently. A typical PIREP appended to an SA is:

FTW UA /OV DFW 18005/TM 1803/FL095/TP PA 30/SK 036 OVC 060/070 OVC 075/OVC ABV

The translation is:

FTW / UA — PIREP from reporting station FTW.
OV DFW 18005 — location is the DFW 180° radial at 5 miles.
TM 1803 — time of the report is 1803.
FL095 — altitude is 9,500 feet.
TP PA 30 — Type of aircraft is a PA 30.
SK 036 OVC 060/070 OVC 075/OVC ABV — Sky condition. The base of an overcast layer is at 3,600 feet with top at 6,000 feet. A second overcast layer has its base at 7,000 feet and its top is 7,500 feet. There is another overcast layer above the aircraft's altitude of 9,500 feet.