Chapter 9: Glider Flight & Weather

Introduction

Glider pilots face a multitude of decisions, starting with the decision to take to the air. Pilots must determine if weather conditions are safe and if current conditions support a soaring flight. Gliders, being powered by gravity, are always sinking through the air. Therefore, glider pilots must seek air that rises faster than the sink rate of the glider to enable prolonged flight. Glider pilots refer to rising air as lift, not to be confused with the lift created by the wing. This chapter focuses on weather that commonly affects glider flights. However, all pilots should understand weather theory, weather hazards to aviation, and the technical details of aviation weather products. The Aviation Weather Handbook (FAA-H-8083-28) provides comprehensive information.

The Atmosphere

Without the atmosphere, wind, clouds, precipitation, and protection from solar radiation would not exist. The height of the atmosphere represents a small distance when compared to the 3,438 nautical mile radius of the earth. There is no specific upper limit to the atmosphere—it simply thins to a point where it fades away into space. The atmosphere below about 27 NM (164,000 feet) contains 99.9 percent of atmospheric mass. At that altitude, atmospheric density drops to approximately one-thousandth of its value at sea level. [*Figure 9-1*]

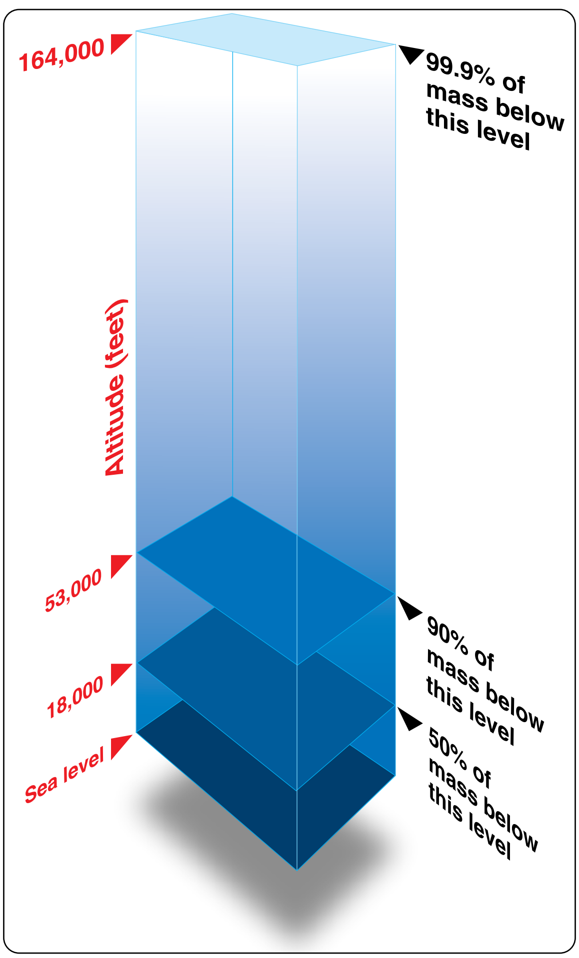


Figure 9-1. *Atmospheric mass by altitude.*

Composition

Two gases, nitrogen (N~2) and oxygen (O~2), comprise 99 percent of the volume of the total atmosphere on average. The remaining volume contains various trace gases and small amounts of water, ice, dust, and other particles. While the proportion of nitrogen to oxygen remains the same to approximately 260,000 feet, the amount of water vapor (H~2O) in the air can vary. For example, water vapor content above tropical areas and oceans accounts for up to 4 percent of the atmosphere by volume and displaces some nitrogen and oxygen gas. Conversely, the water vapor in the atmosphere over deserts and at high altitudes consists of much less than 1 percent of the total volume. [*Figure 9-2*]

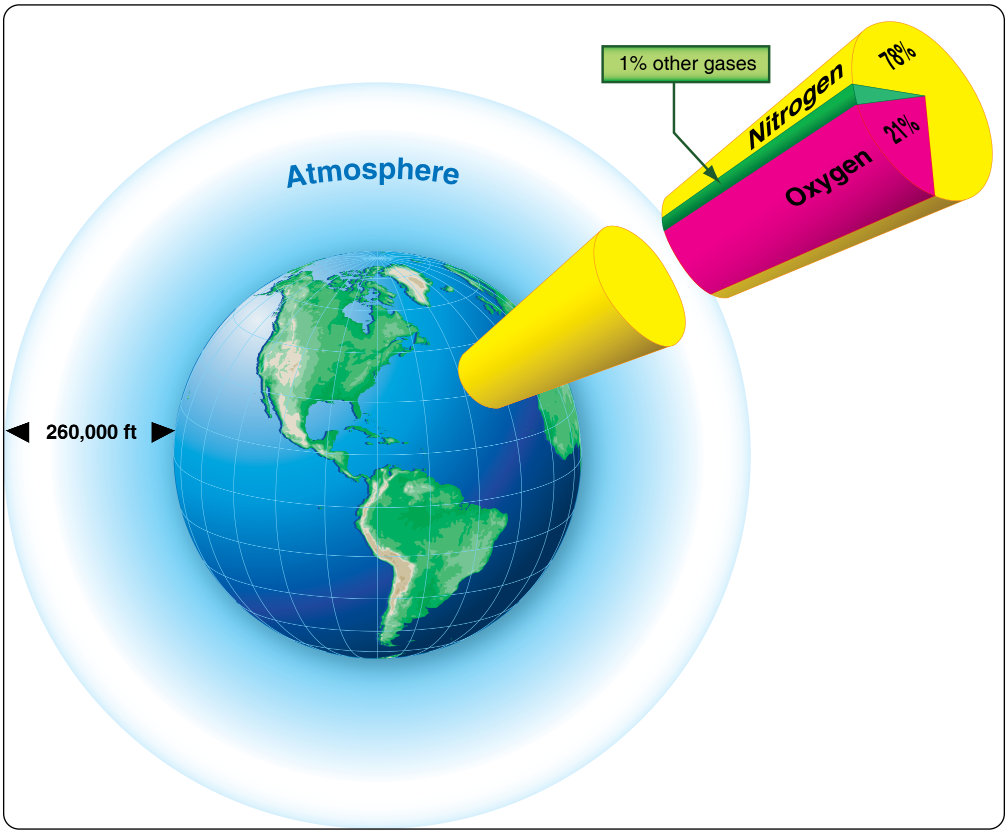


Figure 9-2. *The composition of the atmosphere.*

Although water vapor exists in the atmosphere in small amounts as compared to nitrogen and oxygen, it has a significant impact on weather. The additional physical states of water vapor as a liquid and solid contribute to the formation of clouds, precipitation, fog, and ice.

Atmospheric Measurements

Temperature, density, and pressure measurements provide information about the atmosphere. These variables change over time, and combined with vertical and horizontal differences, the measurements and trends comprise data for weather reports and forecasts.

Temperature

People often describe air temperature in terms of whether the air feels hot or cold. In aviation, quantitative measurements use the Celsius (°C) scale or the Fahrenheit (°F) scale. Temperature of the atmosphere depends on the average kinetic energy of molecules. Fast-moving molecules have high kinetic energy and higher temperatures. Conversely, slow-moving molecules have lower kinetic energy and lower temperatures.

Density

The density of any substance gives its mass per unit of volume. Low air density means a smaller number of air molecules (or less massive molecules on average) in a specified volume, while high air density means a greater number of air molecules (or more massive molecules on average) in a specified volume.

Pressure

Molecules in a volume of air not only possess a certain temperature and density, but they also collide with other gas molecules and push on nearby objects. The collisions result in measurable pressure or a force per unit of area. Since the force created by moving gas molecules acts equally in all directions, localized measurements of gas pressure using calibrated equipment should equal each other. Common units of measure for pressure include pounds per square inch (lb/in*2), inches of mercury ("Hg), and the equivalent units of millibars (mb) or hectopascals (hPA).

Ideal Gas Law

How do temperature, pressure, and density relate to each other? Dry air behaves almost like an ideal gas, meaning it obeys the ideal gas law P/DT = R, where P is pressure, D is density, T is temperature, and R is a constant. In general, the density, pressure, and temperature of an air parcel change predictably in accordance with the variables in the formula.

Standard Atmosphere

To provide a common reference used for temperature and pressure, scientists established the International Standard Atmosphere (ISA). This standard atmosphere uses a representative vertical distribution of temperature and pressure variables for pressure altimeter calibrations. The standard conditions are also a starting point for most aircraft performance data. At sea level, the standard atmosphere consists of a barometric pressure of 29.92 "Hg, 1,013.2 mb, or 14.7 lb/in*2, and a temperature of 15 °C or 59 °F.

Since temperature normally decreases with altitude at a predictable rate, a standard lapse rate calculation gives the standard temperature at various altitudes. Below 36,000 feet, the standard temperature lapse rate is 2 °C (3.5 °F) per 1,000 feet of altitude change. Pressure does not decrease linearly with altitude, but a 1 "Hg decrease for each 1,000 feet of increased altitude approximates the rate of pressure change below 10,000 feet. Pilots can use the standard lapse rates for flight planning purposes with the understanding that variations from standard conditions exist in the atmosphere. [*Figure 9-3*]

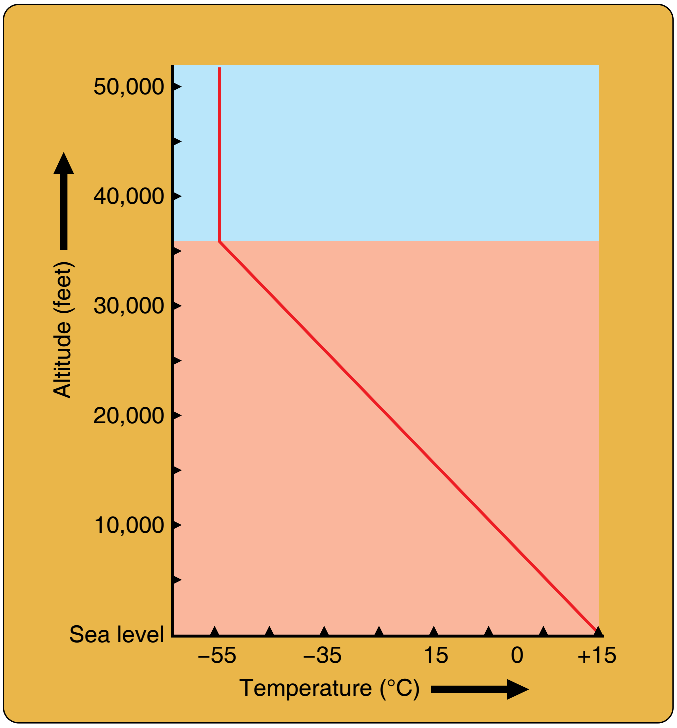


Figure 9-3. *Standard atmosphere temperatures.*

Layers of the Atmosphere

Scientists divide earth's atmosphere into five layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere. [*Figure 9-4*] The rate of change in temperature as altitude increases defines these layers. The lowest layer, called the troposphere, exhibits an average decrease in temperature from the earth's surface to about 36,000 feet above mean sea level (MSL). The troposphere extends to a higher altitude over the tropics and a lower altitude over the polar regions. It also varies seasonally, being higher during the summer and lower during the winter.

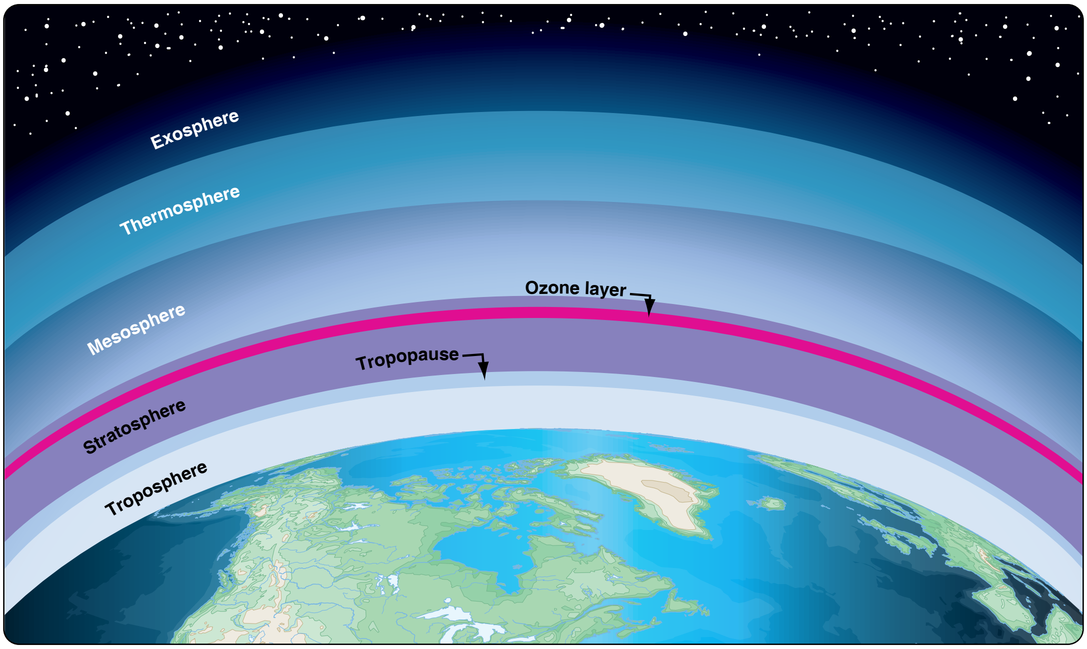


Figure 9-4. *Layers of the atmosphere.*

Almost all of earth's weather occurs in the troposphere as most of the water vapor and clouds are found in this layer. The lower part of the troposphere interacts with the land and sea surface, providing thermals, mountain waves, and sea-breeze fronts. Although temperatures decrease as altitudes increase in the troposphere, local areas where temperature increases with altitude (inversions) commonly occur.

The top of the troposphere or tropopause has a pressure of about ten percent of MSL pressure (0.1 atmosphere) and density drops to about 25 percent of its sea-level value. Temperature reaches its minimum value at the tropopause, approximately –55 °C (–67 °F). For pilots, this is an important part of the atmosphere because it is associated with a variety of weather phenomena, such as thunderstorm tops, clear air turbulence, and jet streams. The vertical limit of the tropopause varies with the height of the troposphere.

The tropopause separates the troposphere from the stratosphere. With increasing height in the stratosphere, the temperature tends to change very slowly at first. However, as altitude increases the temperature increases to approximately 0 °C (32 °F) reaching its maximum value at about 160,000 feet MSL. Unlike the troposphere in which the air moves freely both vertically and horizontally, the air within the stratosphere generally moves horizontally.

Gliders have reached into the lower stratosphere using mountain waves. At high altitudes, supplemental oxygen requirements become mandatory. Layers above the stratosphere have some interesting features that are normally not of importance to glider pilots. However, interested pilots may refer to any general text on weather or meteorology.

Scale of Weather Events

When preparing forecasts, meteorologists consider atmospheric circulation on different scales. To aid the forecasting of short- and long-term weather, various weather events have been organized into three broad categories or scales of circulation. The size and lifespan of the phenomena in each scale are roughly proportional, so that larger scales coincide with longer lifetimes. The term "microscale" refers to features with spatial dimensions of 0.1 to 1 NM, which last for seconds to minutes. An example is an individual thermal. The term "mesoscale" refers to the horizontal dimensions of 1 to 1,000 NM, which last minutes to weeks. Examples include mountain waves, sea breeze fronts, thunderstorms, and fronts. Research scientists break down the mesoscale into further subdivisions to better classify various phenomena. The term "macroscale" refers to the horizontal dimensions greater than 1,000 NM, which last weeks to months. These include the long waves in the general global circulation and the jet streams embedded within those waves. [*Figure 9-5*]

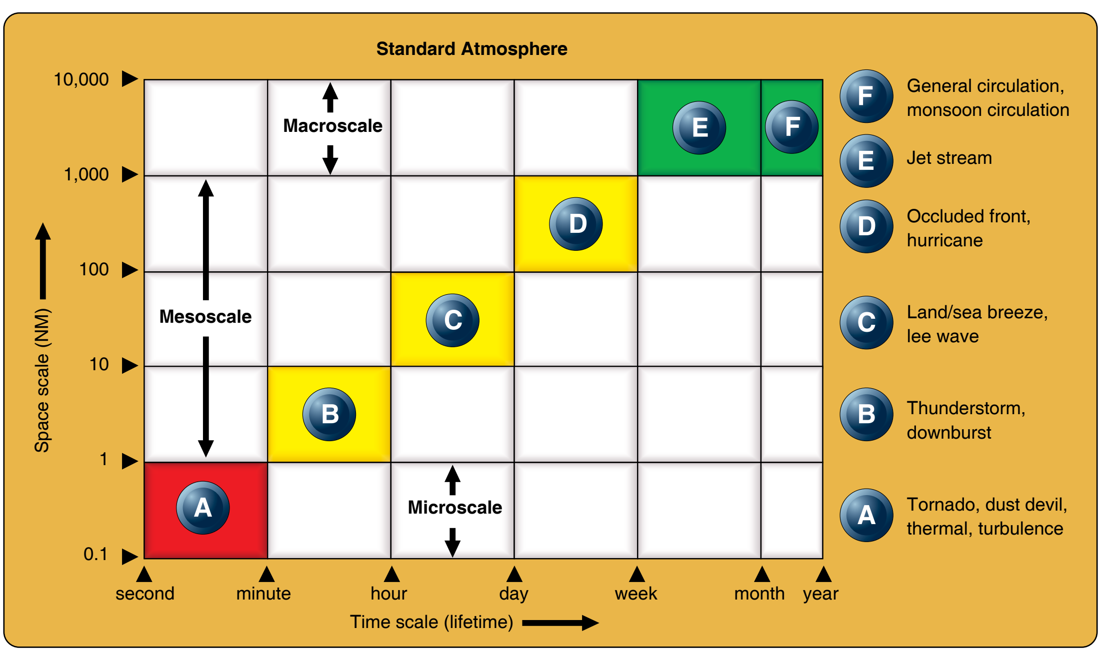


Figure 9-5. *Scale of circulation—horizontal dimensions and life spans of associated weather events.*

Smaller scale features are embedded in larger scale features. For instance, a microscale thermal may be just one of many thermals in a mesoscale convergence line, like a sea breeze front.

The sea breeze front may occur only under certain synoptic (i.e., simultaneous) conditions controlled by the macroscale circulations. The scales interact, with feedback from smaller to larger scales and vice versa, in ways not fully understood by atmospheric scientists. Generally, the behavior and evolution of macroscale features are more predictable, with forecast accuracy decreasing as scale diminishes. For instance, forecasts of up to a few days for major events, such as a trough with an associated cold front, have become increasingly accurate. However, no one can forecast the exact time and location of an individual thermal an hour ahead of time. Since most of the features of interest to soaring pilots lie in the smaller mesoscale and microscale ranges, prediction of gliding weather presents a significant challenge.

Pilots interpreting forecasts should begin with the macroscale, which identifies large-scale patterns that may produce good gliding conditions. This varies from site to site and depends on whether the goal is thermal, ridge, or wave soaring. Then, mesoscale features should be considered. This may include items such as the cloudiness and temperature structure of the air mass behind a cold front, as well as the amount of rain produced by the front. Developing an understanding of lift types and environments in which they form, can help a pilot predict local weather conditions that affect glider flights.

Thermals

Thermals are the most common form of rising air used to sustain glider flight. The paragraphs in this section explore topics related to thermals, including thermal structure, atmospheric stability, and air masses conducive to flight in thermals.

Thermal Shape & Structure

Convection describes a form of heat transfer involving the movement or flow of mass in a fluid (gas or liquid). Rising convection currents of air or "thermals" are one means by which the atmosphere transfers heat energy vertically. Thermals do not necessarily develop on a warm sunny day. Subtle differences in the atmosphere make the difference between a warm, sunny day with plenty of thermals and a warm, sunny day that produces no thermals. Glider pilots who understand the conditions that create thermals can use their own forecasting skills to predict thermal activity.

Two conceptual models exist for the structure of thermals: the bubble model and the column or plume model. These models simplify a complex and often turbulent phenomenon, so pilots should expect many exceptions and variations while flying in thermals. Many books, articles, and Internet resources provide further reading on this subject.

The bubble model describes an individual thermal resembling a vortex ring, with rising air in the middle and descending air on the sides. The air in the middle of the vortex ring rises faster than the entire thermal bubble. The model fits occasional reports from glider pilots. At times, two glider pilots in the same thermal will find different amounts of lift. For example, one glider may be at the top of the bubble climbing only slowly, while a lower glider climbs rapidly in the stronger part of the bubble below. [*Figure 9-6*] Often, a glider flying below another glider circling in a thermal can contact the same thermal and climb, even if the gliders are displaced vertically by 1,000 feet or more. This suggests the column or plume model of thermals is more common. [*Figure 9-7*]

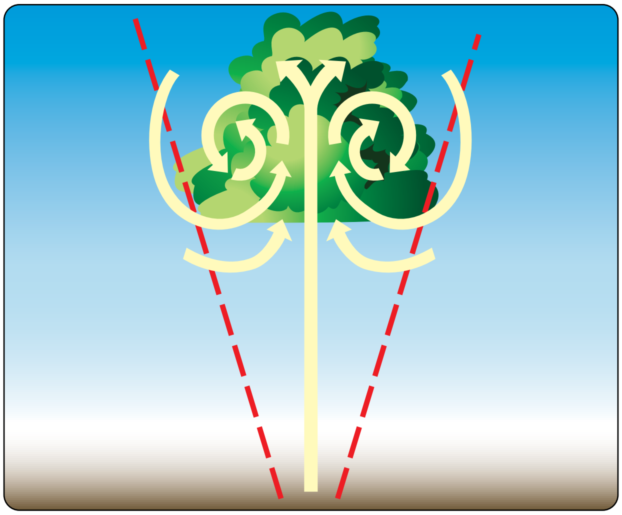


Figure 9-6. *The bubble or vortex ring model of a thermal.*

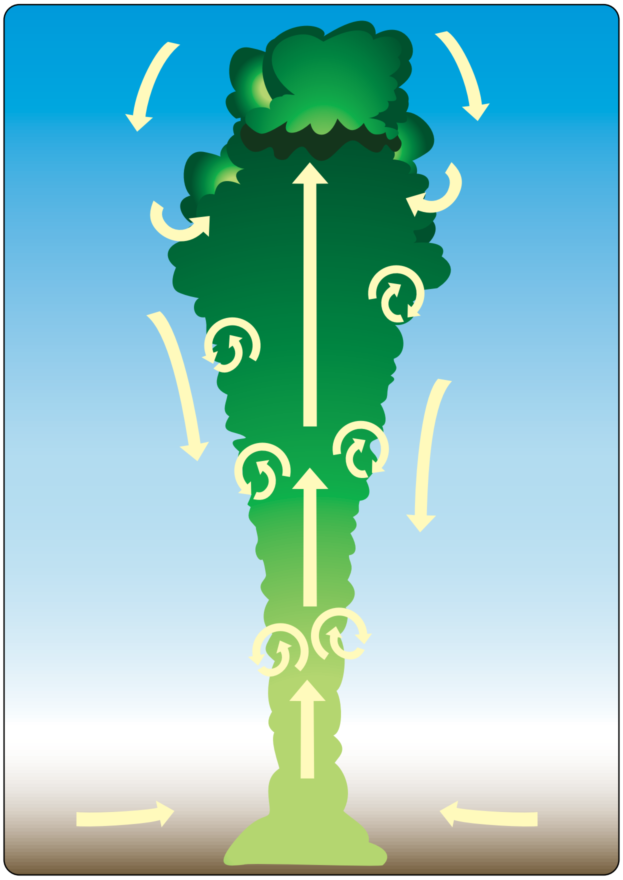


Figure 9-7. *The column or plume model of a thermal.*

The applicability of the models may depend on the supply of warm air near the surface. Within a small, heated area, one single bubble may rise and take all the warmed surface air with it. On the other hand, if a large area becomes warm and one spot acts as the initial trigger, surrounding warm air can flow into the relative void left by the initial thermal. The in-rushing warm air follows the same path, creating a thermal column or plume. Since all the warmed air near the surface does not usually have the exact same temperature, a column could exist with a few or several imbedded bubbles. Individual bubbles within a thermal plume may merge, while at other times, two adjacent and distinct bubbles may exist side by side.

Whether behaving as a bubble or column, the air in the middle of the thermal rises faster than the air near the edges of the thermal. A horizontal slice through an idealized thermal provides a bull's-eye pattern; however, cross sections of real-world thermals exhibit dissymmetry. [*Figure 9-8*]

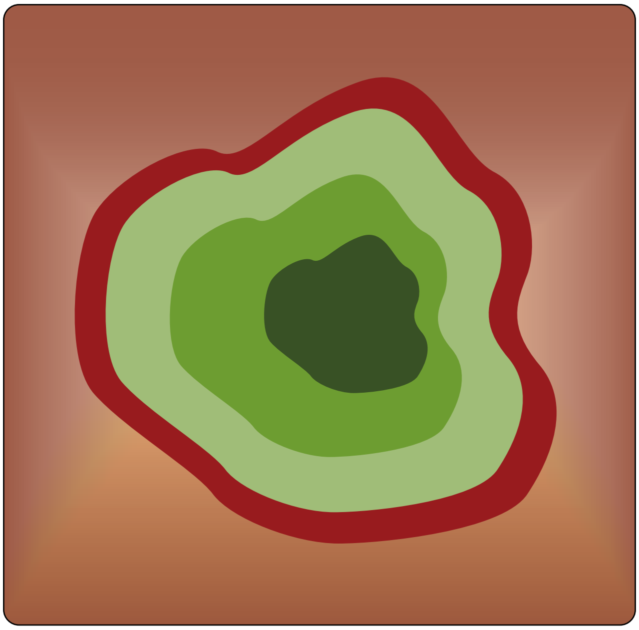


Figure 9-8. *Cross-section through a thermal. Darker green is stronger lift; red is sink.*

A typical thermal cross-section has a diameter of 500–1,000 feet, though the size can vary considerably. Typically, due to mixing with the surrounding air, thermals expand as they rise. Thus, the thermal column may resemble a cone, with the narrowest part near the ground. Thermal plumes also tilt in a steady wind and can distort in the presence of vertical shear. In strong vertical shear, thermals can become very turbulent or become completely broken apart. *Figure 9-9* shows a schematic of a thermal lifecycle in windshear.

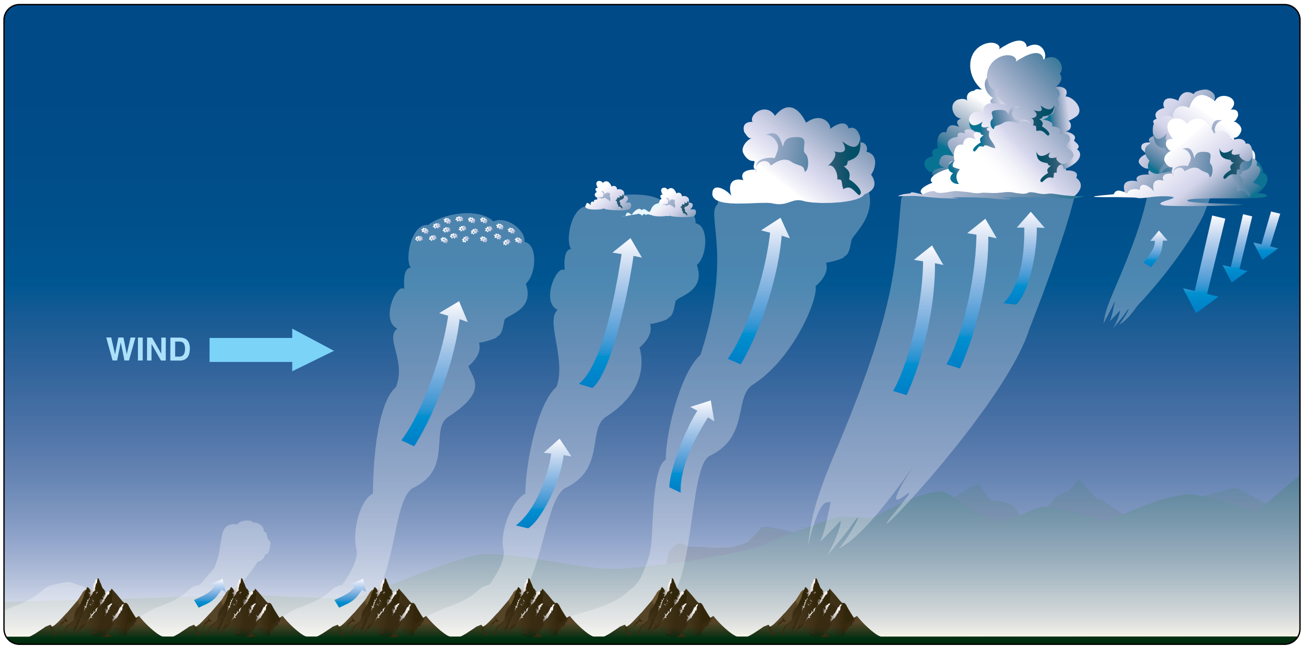


Figure 9-9. *Lifecycle of a typical thermal with cumulus cloud.*

A stable atmosphere hinders vertical motion, while an unstable atmosphere promotes vertical motion. A certain amount of atmospheric instability supports development of thermals. However, moist air and strong atmospheric instability may lead to thunderstorm formation. Thus, an understanding of atmospheric stability promotes recognition of favorable flight conditions as well as recognition of weather hazards and associated risk.

When discussing atmospheric stability, a layer of air in the atmosphere represents the dynamic system and a parcel of air represents the displaced element. In a stable dynamic system, a displaced element returns to its original position. In an unstable dynamic system, a displaced element continues to move farther away from its original position. In a neutral dynamic system, a displaced element neither returns to nor moves farther away from its original position.

A parcel of dry or unsaturated air moving upward in the atmosphere expands and cools as it rises due to decreasing pressure. By contrast, a descending parcel of dry or unsaturated air compresses and warms due to increasing pressure. When no transfer of heat between the displaced parcel and the surrounding ambient air occurs, the process is called adiabatic. During this adiabatic process, a rising unsaturated parcel cools at a lapse rate of 3 °C (5.4 °F) per 1,000 feet. This dry adiabatic lapse rate (DALR) approximates what happens in nature although some mixing of air occurs as thermals rise.

Figure 9-10 below demonstrates one means to predict whether a layer of the atmosphere will function like a stable, unstable, or neutral dynamic system. Panels A and B represent two scenarios with the same temperature of 20 °C at the surface, but with different air layer temperatures at 3,000 feet above ground level (AGL). Using the DALR for both scenarios, a parcel of 20 °C air that lifts from the surface cools to 11 °C by the time it reaches 3,000 feet AGL. In scenario A, the lifted parcel is still warmer than the surrounding air and will continue to rise by convection—a condition of instability that could produce a good thermal. In scenario B, the lifted parcel at 3,000 feet AGL has cooled to a lower temperature than the surrounding air and will descend. In this case, the layer exhibits system stability. See the Aviation Weather Handbook (FAA-H-8083-28) for more information on atmospheric stability.

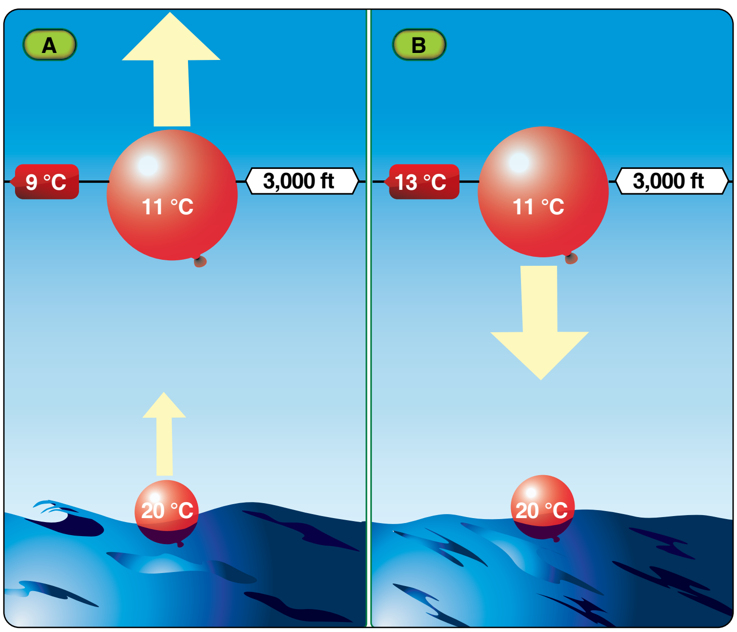


Figure 9-10. *Unstable (A) and stable (B) air.*

Changing the values in *Figure 9-10* illustrates factors that would affect atmospheric stability. A stable layer can turn unstable in one of two ways. In scenario B, if the surface temperature warms by more than 2 °C (to greater than 22 °C), or if the air at 3,000 feet cools by more than 2 °C (to less than 11 °C), the atmospheric layer to 3,000 feet becomes unstable. Warming of lower layers or cooling of higher layers of the atmosphere with no other changes reduces stability and leads to a better environment for thermals. If the layer aloft and at the surface warm or cool by the same amount, then the stability of the layer remains unchanged. The layer exhibits greater stability if the air temperature aloft remains constant, but the surface air cools.

An inversion occurs when the troposphere warms as altitude increases. Inversions can occur at different altitudes and vary in strength. In strong inversions, the temperature can rise as much as 10 °C in a few hundred feet of altitude gain. Along with trapping haze or pollution below, an inversion also effectively caps any thermal activity.

Although moisture in the form of water vapor makes up a small percentage of the atmosphere, it can affect the temperature lapse rate of a rising parcel of air. A rising parcel of air cools at the DALR until it reaches its dewpoint, at which time the water vapor in the parcel begins to condense. The condensation process releases heat, referred to as latent heat, within the rising parcel of air. Therefore, a rising parcel of saturated air cools at a rate lower than the DALR. This saturated adiabatic lapse rate (SALR), varies substantially with altitude. At lower altitudes, it approximates of 1.2 °C per 1,000 feet, whereas at middle altitudes it increases to 2.2 °C per 1,000 feet. Above approximately 30,000 feet, little water vapor exists to condense, and the SALR approaches the DALR.

Air Masses Conducive to Thermal Soaring

Generally, the best air masses for thermals are those with cool air aloft, with conditions dry enough to allow the sun's heating radiation to warm the surface and to limit extensive formation of cumulus clouds. This cool air aloft can originate after passage of a Pacific cold front in the Western United States or from polar continental regions such as interior Canada in the Eastern United States. In both cases, high pressure building into the region often includes an inversion aloft, which keeps cumulus from growing into rain showers or thunderstorms. However, as the high pressure builds after the second or third day, the inversion often lowers to the point that thermals suitable for gliding no longer form. This can lead to warm and sunny, but very stable conditions. Fronts that arrive too close together can also cause poor postfrontal soaring, as high clouds from the next front keep the surface from warming enough. Very shallow cold fronts from the northeast direction (with cold air only one- or two- thousand feet deep) often have a stabilizing effect along the plains directly east of the Rocky Mountains. This is due to cool low-level air undercutting warmer air aloft flowing from the west.

In the desert southwest, the Great Basin, and intermountain west, good summertime thermals often result from intense heating from below, even in the absence of cooling aloft. This dry air mass with continental origins produces cumulus bases 10,000 feet AGL or higher. At times, this air spreads into eastern New Mexico and western Texas. Later in the summer, however, some of these regions come under the influence of the North American Monsoon, which can lead to widespread and daily late morning or early afternoon thundershowers. [*Figure 9-11*]

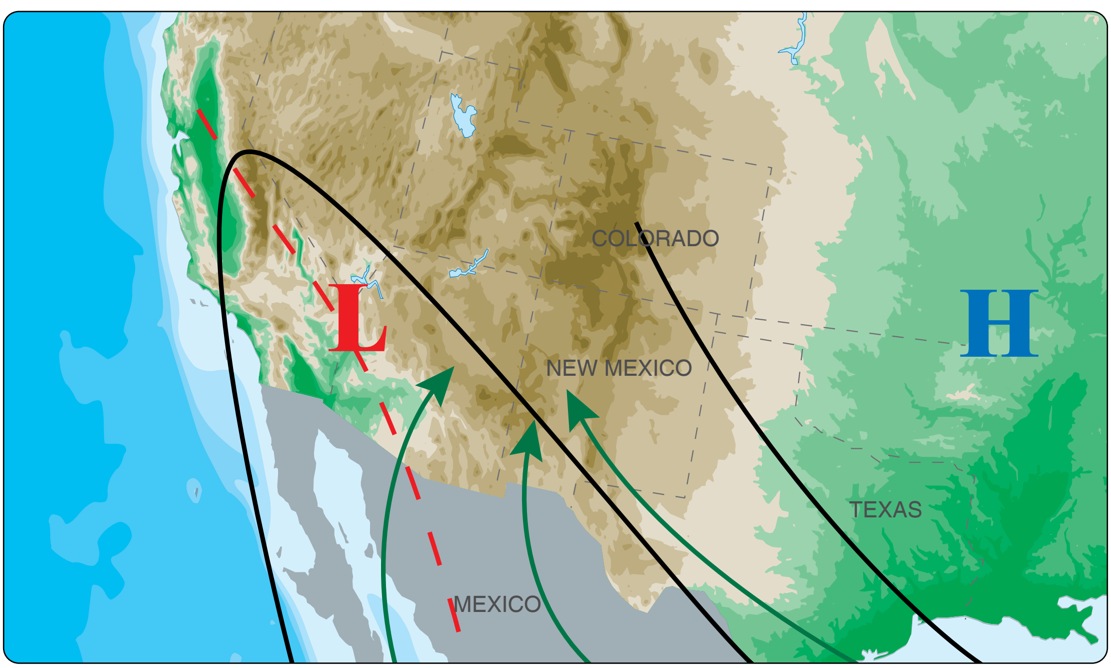


Figure 9-11. *Typical North American monsoon flow.*

Cloud Streets

Cumulus clouds often appear randomly distributed across the sky, especially over relatively flat terrain. Under the right conditions, however, cumulus clouds can align in a long band, called a cloud street. An individual cloud street can extend 50 miles or more while an entire field of cloud streets can extend hundreds of miles. The spacing between streets is typically three times the height of the clouds. Cloud streets align parallel to the wind direction and indicate the pattern of rising and descending air. Glider pilots can often fly many miles with little or no circling, sometimes achieving glide ratios far exceeding the still-air value by flying near and parallel to the clouds while avoiding the space between the clouds. Thus, cloud streets mark an ideal location for flying a downwind cross-country flight.

A cross-section of an idealized cloud street formation illustrates a distinct circulation, with updrafts under the clouds and downdrafts in between. [*Figure 9-12*] Due to the circulation, sink between streets may be stronger than typically found the same distance away from random cumulus clouds.

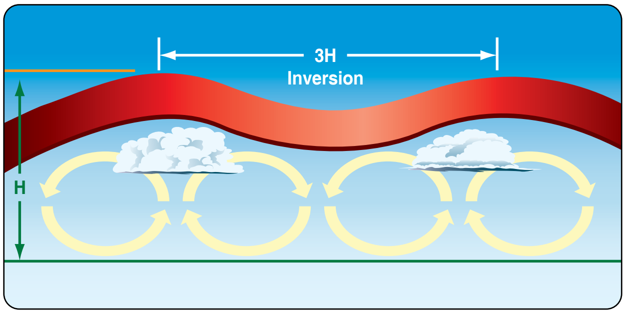


Figure 9-12. *Circulation across a cloud street.*

Cloud streets usually occur over land with cold air outbreaks, for instance, following a cold front. Brisk surface winds and a wind direction remaining nearly constant up to the cloud base are favorable cloud street conditions. Windspeed should increase by 10 to 20 knots between the surface and cloud base, with a maximum somewhere in the middle of or near the top of the convective layer. Thermals should be capped by a notable inversion or stable layer.

Thermal streets, with a circulation like *Figure 9-12*, may exist without cumulus clouds. Without clouds as markers, use of such streets becomes difficult. A glider pilot flying upwind or downwind in consistent sink should alter course crosswind to avoid inadvertently flying along a line of sink between thermal streets that may exist.

Cloud Streets

Figure 9-13 shows a wavelike form for the inversion capping the cumulus clouds. If winds above the inversion run perpendicular to the cloud streets and increase at 10 knots per 5,000 feet or more, cloud street waves can form in the stable air above. Though usually relatively weak, thermal waves can produce lift of 100 to 500 fpm and allow smooth flight along streets above the cloud base.

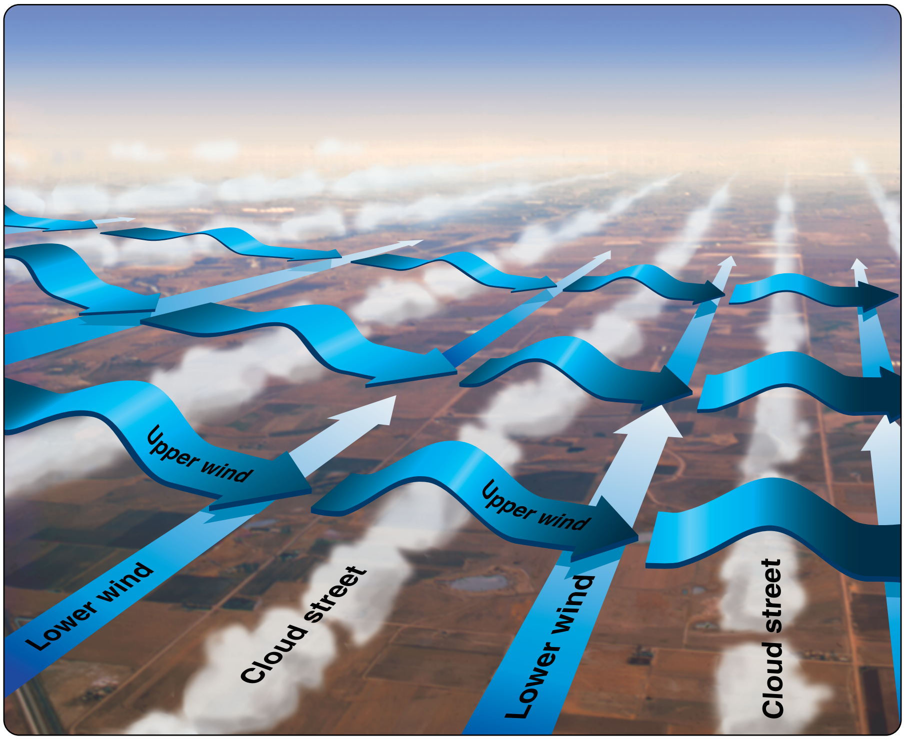


Figure 9-13. *Cloud street thermal wave.*

So-called cumulus waves may exist where the cumulus clouds do not organize in streets. Cumulus waves require a capping inversion or stable layer and increasing wind above cumulus clouds. However, directional shear is not necessary. Cumulus waves may also be short lived, and difficult to work for any length of time. An exception occurs when the cumulus cloud anchors to some feature, such as a ridge line or short mountain range. As a final note, thermal waves can also form without clouds. Without clouds, the possible influence of a ridge or mountain in creating the wave lift becomes difficult to determine.

Thunderstorms

Forecasters sometimes use the term "deep convection" to refer to convection that rises to high levels, which usually means thunderstorms, and they use the term "convective activity" to refer to thunderstorms. The tremendous amount of energy associated with cumulonimbus clouds stems from the release of latent heat as condensation occurs within the growing cloud. While an unstable atmosphere can provide great conditions for thermal formation, an atmosphere that is moist and unstable can create cumulonimbus (Cb) or thunderclouds. Cb clouds are the recognized standard marker of thunderstorms. When Cb builds sufficiently, it changes from rainstorm to thunderstorm status. Not all precipitating, large cumulus formations are accompanied by lightning and thunder, but the presence of these clouds indicates that hazardous conditions exist or may intensify.

Thunderstorms can occur any time of year, though they are more common during the spring and summer seasons. They can occur anywhere in the continental United States but are not common along the immediate West Coast, where an average of only about one per year occurs over a given location. During the summer months, the desert southwest locations, extending northeastward into the Rocky Mountains and adjacent Great Plains, experience an average of 30 to 40 thunderstorms annually. Additionally, in the southeastern United States, especially Florida, between 30 and 50 thunderstorms occur in an average year per location. [*Figure 9-14*] Thunderstorms in the cool seasons usually occur in conjunction with some forcing mechanism, such as a fast- moving cold front or a strong upper-level trough.

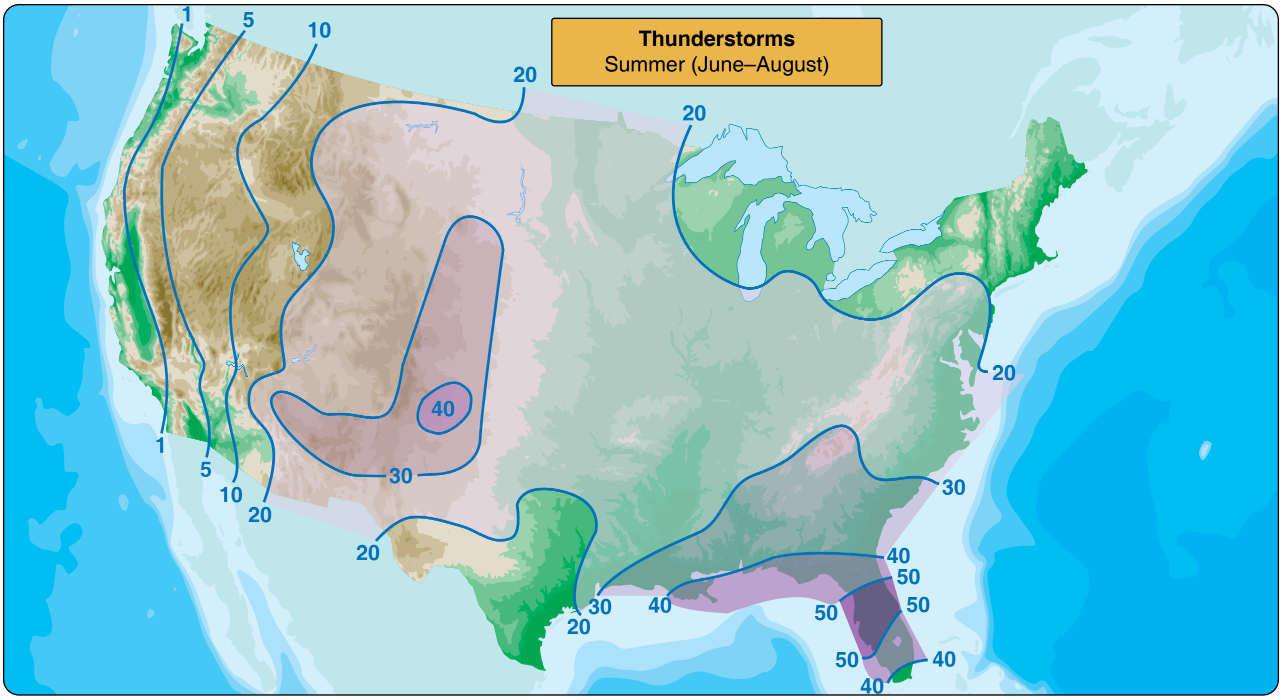


Figure 9-14. *Thunderstorm frequency in the summertime.*

The lifecycle of an airmass or ordinary thunderstorm consists of three main stages: cumulus, mature, and dissipating. The term "ordinary" describes the type of thunderstorm consisting of a single Cb, since individual thunderstorms can develop in a uniform large-scale air mass. The entire lifecycle of an ordinary thunderstorm takes on the order of an hour, though a remnant cloud from the dissipated Cb can last substantially longer.

The cumulus stage of a thunderstorm is characterized by a cumulus cloud growing to a towering cumulus (Tcu). As air rises within the cloud during this stage, the intensity of the updraft increases, and the cloud base broadens to a few miles in diameter. [*Figure 9-15*] As the cloud increases in size, the strong updraft in the middle of the cloud does not entrain or carry along dryer air surrounding the cloud, and general downward motion of air around the Tcu may suppress other smaller cumulus in the vicinity. Toward the end of the cumulus stage, downdrafts and precipitation begin to form within the cloud. On some days, small cumulus can be around for hours, before Tcu form, while on other days, unstable air allows any cumulus cloud that forms to rapidly transform into a Tcu.

Figure 9-15. *A cumulus cloud becoming a towering cumulus.*

As the development of a thunderstorm continues, it reaches the mature stage. By this time, downdrafts known as downbursts or microbursts reach the ground and spread out creating strong and sometimes damaging surface winds. Glider pilots should avoid flight toward these downdrafts and their associated windshear, as the glider might lose the capability to reach a selected landing area.

Note: hazardous windshear creates a significant risk for any ground launch or aerotow, and these operations should not occur if the pilot suspects a windshear encounter associated with Cb may occur. Depending on the size of windshear, the towplane could be in a tailwind while the glider is in a headwind.

Pilots need to watch dissipating thunderstorms closely for new dark, firm bases that indicate formation of a new cell. In addition, outflow from a Cb may cause the air it encounters to rise. The relatively cool air in the outflow can provide nearby air with a boost, leading to formation of a nearby Cb, not connected to the original Cb.

The risk from thunderstorms involves several hazards, including turbulence, strong updrafts and downdrafts, strong shifting surface winds, hail, icing, poor visibility or low ceilings, lightning, and even tornadoes. Once a cloud has grown into Cb, these hazards may develop, with or without obvious signs. Since thermal soaring weather can rapidly deteriorate into thunderstorm weather, understanding the risk associated with these hazards should prompt a glider pilot to remain on the ground or avoid them in the air. The following paragraphs provide more information about these hazards.

Turbulence

A pilot should never intentionally fly into a Cb since severe or extreme turbulence leading to structural failure can occur anywhere within the thunderstorm. Violent updrafts can be followed a second or two later by violent downdrafts, with occasional side gusts. Severe turbulence commonly occurs close to the storm, and moderate turbulence may exist within several miles of a thunderstorm. Below the base of the Cb, moderate to severe turbulence can occur along the boundary between the cool outflow and warm air feeding the Cb. Pilots should expect turbulence near the surface from a gust front as cool outflow spreads from the storm. Unpredictable smaller scale turbulent gusts can occur anywhere near a thunderstorm and avoiding the gust front does not guarantee avoidance of severe turbulence.

Updrafts and Downdrafts

Large and strong updrafts and downdrafts accompany thunderstorms in the mature stage. Updrafts feeding the Cb from under the base can exceed 1,000 fpm. Near the cloud base, a pilot may have difficulty determining the distance to the edge of the cloud, and strong updrafts could suck a glider into the storm cloud. During the late cumulus and early mature stage, updrafts feeding the cloud can cover many square miles. As the storm enters its mature stage, downbursts or microbursts can occur even without very heavy precipitation present. Downbursts can also cover many square miles with descending air of 2,000 fpm or more. A pilot flying under a forming downburst, which may not be visible, could encounter sink of 3,000 fpm or greater in extreme cases. Such a downburst encountered at pattern altitude can cut the normal time available to the pilot for executing an approach. While a normal pattern from 800 feet AGL to the ground could span 3 minutes, contact with the ground occurs in 19 seconds in 2,500 fpm sink.

Outflow Winds

When a downburst or microburst hits the ground, the downdraft spreads out, leading to strong surface winds, known as thunderstorm outflow. Typically, the winds strike quickly and give little warning of their approach. While flying, pilots should keep a sharp lookout between any storm and the intended landing spot for signs of a wind shift. Blowing dust, smoke, or wind streaks on a lake caused by wind from the storm may indicate a rapidly approaching gust front. Thunderstorm outflow winds usually travel at speeds of 20 to 40 knots for a period of 5 to 10 minutes before diminishing. However, winds can easily exceed 60 knots, and in some cases, with a slow- moving thunderstorm, strong winds can last substantially longer. Although damaging outflow winds usually do not extend more than 5 or 10 miles from the Cb, winds of 20 or 30 knots can extend 50 miles or more from large thunderstorms.

Hail

Hail associated with any thunderstorm can exist within part of the main rain shaft. Hail can also occur many miles from the main rain shaft, especially under the thunderstorm anvil. Pea-sized hail does not usually damage a glider, but the large hail associated with a severe storm can dent metal gliders or damage the gelcoat on composite gliders, both in the air or on the ground.

Icing

Icing can create a significant problem within a cloud or where visible moisture exists, especially at levels where the outside temperature is approximately -10 °C. Under these conditions, supercooled water droplets (water existing in a liquid state 0 °C and below) can rapidly freeze upon contact with wings and other glider surfaces. Early precipitation below a cloud base from a developing storm may be difficult to see. At times, precipitation can even be falling through an updraft feeding the cloud. Snow, graupel (a snow/frozen water combination), or ice pellets falling from the forming storm above can stick to the leading edge of the wing and degrade performance. Ice can form on the canopy and interfere with the pilot's forward vision.

Low Visibility

Poor visibility due to precipitation or low ceilings as air below a thunderstorm cools creates another concern for the pilot. Even light or moderate precipitation can reduce visibility dramatically. Often, under a precipitating Cb, confusion distinguishing between the precipitation and cloud can occur.

Lightning

Lightning strikes are completely unpredictable. Lightning in a thunderstorm may occur within one cloud, jump from one cloud to another if a nearby storm exists, or jump from cloud to ground. Some strikes emanate from the side of the Cb and travel horizontally for miles before turning abruptly toward the ground. Inflight damage to gliders has included burnt control cables and blown-off canopies. In some cases, strikes have caused little more than mild shock and cosmetic damage. At the other extreme, a composite training glider in Great Britain suffered a strike that caused complete destruction of one wing; fortunately, both pilots parachuted to safety. In that case, the glider was two or three miles from the thunderstorm. Pilots and ground personnel should avoid ground launching, especially with a metal cable, with a thunderstorm in the vicinity.

Tornadoes

Severe thunderstorms can sometimes spawn tornadoes a few hundred to a few thousand feet across with winds that can exceed 200 mph. Tornadoes that do not reach the ground are called funnel clouds. Pilots should consider any tornado watch or warning information and remain well clear of funnel clouds and tornadoes.

Weather for Slope Soaring

Wind deflects horizontally, vertically, or some combination of the two when it encounters topography. Slope or ridge soaring relies on updrafts produced by the mechanical lifting of air as it encounters the upwind slope of a hill, ridge, or mountain.

Individual or isolated hills tend not to produce slope lift because the wind deflects around the hill, rather than over it. A somewhat broader hill with a windward face of approximately a mile, might produce some slope lift over a small area. The best ridges for slope soaring span at least a few miles. While ridges only 100 or 200 feet high can produce slope lift, the pilot might not find sufficient rising air to climb above the top of the ridge.

Slope lift can extend to a maximum of two or three times the ridge height. [*Figure 9-16*] Generally, the higher the ridge extends above the adjacent valley, the higher the glider pilot can climb. The pilot should maintain a safe maneuvering altitude and sufficient altitude to land if necessary. Pilots should consider flight between 500 to 1,000 feet above the adjacent valley as a minimum safe height.

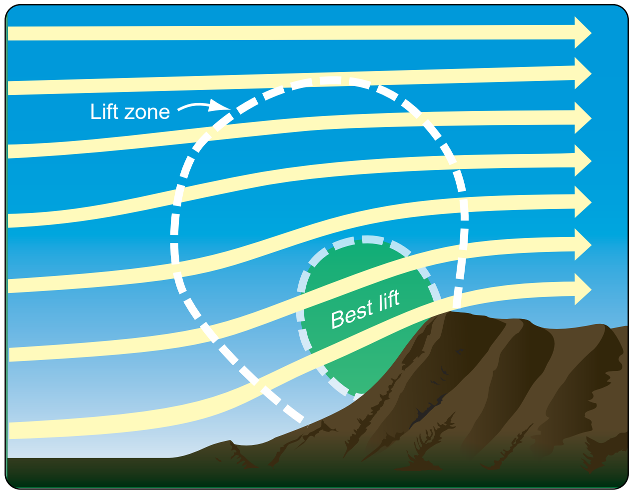


Figure 9-16. *Lift zone for slope soaring.*

Depending on the slope, windspeed of 10 to 15 knots blowing nearly perpendicular to the ridge produces usable updrafts. However, wind directions up to 30° or 40° from perpendicular may still produce slope lift. High ridges may have little or no wind along the lower slopes, but the upper parts of the ridge may be in winds strong enough to produce slope lift, creating a vertical wind shear.

The area of best lift varies with height. Below the ridge crest, the best slope lift is found within a few hundred feet of the ridge, depending on the slope and wind strength. Very steep ridges require extra speed and caution since eddies and turbulence can form on the upwind side. Above the ridge crest, the best lift usually occurs further upwind from the ridge as the glider gains altitude. [*Figure 9-17*]

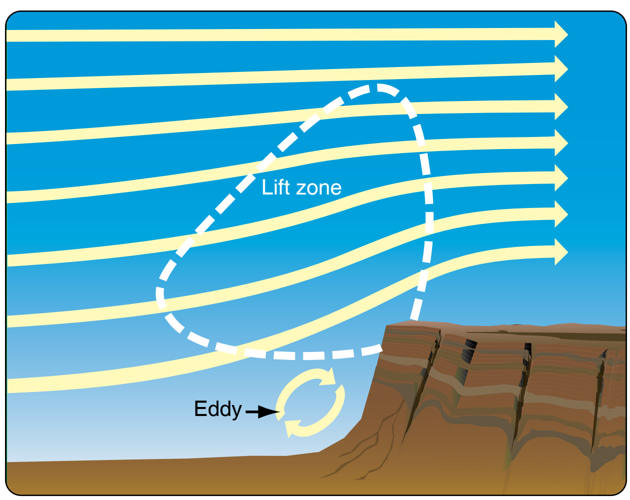


Figure 9-17. *Slope lift and eddy with near-vertical slope.*

An ideal ridge has a slope on the order of 1 to 4. For each four feet of horizontal travel, the terrain increases vertically by 1 foot. Shallower slopes do not create a vertical wind component strong enough to compensate for the glider's sink rate. Very steep, almost vertical slopes create lift, but may also produce turbulent eddies along the lower slope or anywhere close to the ridge itself. In such cases, only the upper part of the slope may produce updrafts, although steeper slopes allow a quick escape to the adjacent valley.

Slope lift in stable air can be very smooth, enabling safe soaring close to the terrain. In unstable air, thermals may flow up the slope. Depending on thermal strength and windspeed, the thermal may rise well above the ridge top, or it may drift into the lee downdraft and break apart. Downdrafts on the sides of thermals can easily cancel the slope lift, and require extra speed and caution, especially below the ridge crest near the terrain. The combination of unstable air and strong winds can make slope soaring unpleasant or even dangerous for an inexperienced glider pilot.

Upwind terrain can block the low-level wind flow of an otherwise promising ridge. Additionally, any waves produced by an upwind ridge or mountain can enhance or destroy ridge lift downstream, depending on the interference pattern of the waves. Locally, the downdraft from a thermal just upwind of a ridge can cancel slope lift for a short distance. The pilot should assume any slope lift could vanish and have plans for that eventuality.

While the flow deflects upward on the windward side of a ridge, it deflects downward on the lee side. [Figure 9- 18] This downdraft can reach 2,000 fpm or more near a steep ridge in strong winds (panel A). Flat-topped ridges offer little refuge since sink and turbulence can combine to make flight above the flat challenging or impossible (panel B). Finally, an uneven upwind slope with ledges or “steps” requires extra caution since small-scale eddies, turbulence, or sink can form (panel C). If crossing ridges in windy conditions, the pilot should plan for heavy sink on the lee side and stick to a set of personal minimum altitudes for crossing.

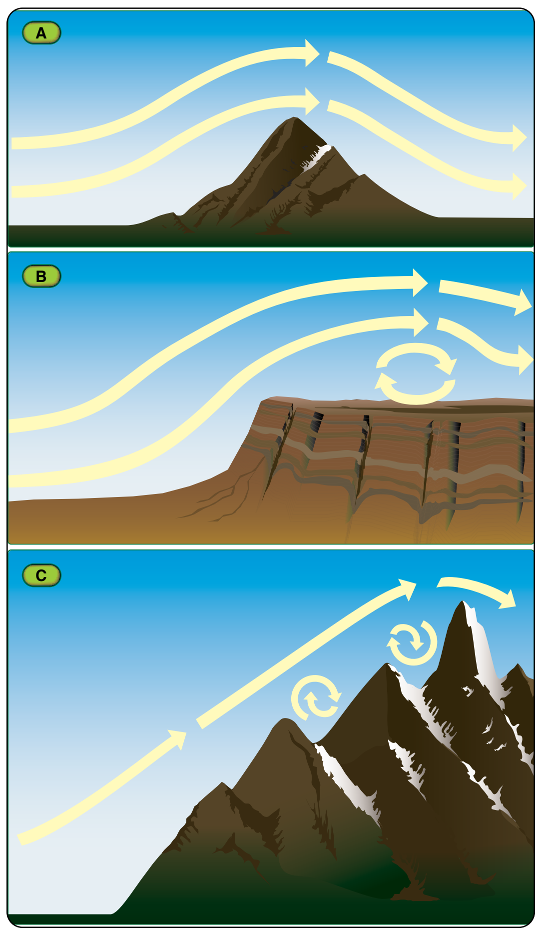


Figure 9-18. *Airflow along different ridges.*

Three-dimensional effects are important as well. For instance, a ridge with cusps or bowls may produce better lift on the upwind-facing edge of a bowl if the wind is at an angle from the ridge. However, the pilot may encounter sink on the lee side of a bowl edge. [*Figure 9-19*]

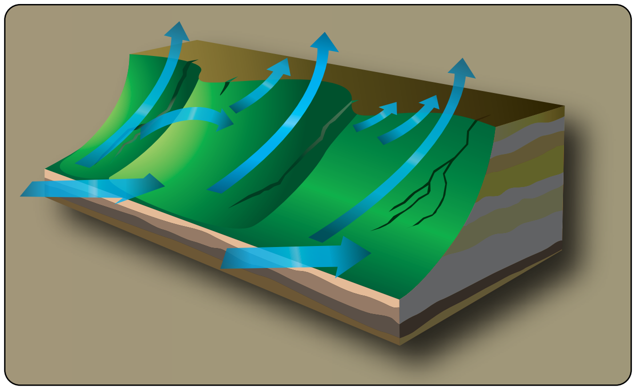


Figure 9-19. *Three-dimensional effects of oblique winds and bowls.*

Moist air rising from contact with a slope that cools sufficiently may form a so-called cap cloud. [*Figure 9-20*] The cloud may form above the ridge, and if the air moistens over time, the cloud slowly lowers onto the ridge and down the upwind slope, limiting the usable height of the slope lift. Under certain conditions, a morning cap cloud may rise as the day warms, then slowly lower again as the day cools. Since the updraft forms the cloud, a pilot could climb into the cap cloud and lose outside visual references.

Figure 9-20. *Cap cloud.*

Mountain Waves

Wind blowing over mountains or ridges can produce waves, the most powerful of which have lifted gliders to above 49,000 feet in the United States. With strong and widespread winds aloft and stable atmosphere, mountain waves can extend downwind along the entire length of a mountain range. Pilots refer to these waves as mountain waves, lee waves, mountain lee waves, or standing waves. Pilots have achieved multi-leg flights of over 2,000 kilometers in mountain waves. Note that for brief periods in some parts of the world, mountain waves reach into the stratosphere and receive a boost from the polar vortex. Pilots in an experimental pressurized glider reached altitudes above 76,000 feet in 2018 using this phenomenon in Argentina.

Water flowing in a stream or small river illustrates mountain wave formation. A submerged rock causes ripples (waves) in the water downstream, which slowly dampen out. In the case of mountain waves, the airflow over the mountain displaces a parcel of air from its equilibrium level. Since the atmosphere contains variations in the stability profile, wind blowing over a mountain does not always produce downstream waves. Anyone seeking more information regarding mountain wave formation than presented in this chapter should consult the Aviation Weather Handbook (FAA-H-8083-28).

Mountain waves differ fundamentally from slope lift. Slope soaring occurs on the upwind side of a ridge or mountain, while mountain wave soaring occurs on the downwind side. Mountain waves can tilt upward with height, and at times near the top of the wave, the glider pilot may be almost directly over the mountain or ridge that produced the wave.

Isolated small hills or conical mountains do not form classic lee waves. In some cases, they do form waves emanating at an angle to the wind flow like water waves created by the wake of a ship. A single peak may require only a mile or two in the dimension perpendicular to the wind for high-amplitude lee waves to form, though wave lift produced this way occurs in a relatively small area.

Mechanism for Wave Formation

Stable air can support wave formation when a disturbance causes vertical motion of the air and wind causes horizontal displacement. As illustrated in *Figure 9-21* at dashed line 1, the dry unsaturated parcel (depicted by the red dot) sits at rest at its equilibrium level. After upward displacement of the parcel (dashed line 2), the lifted parcel, now cooler than the surrounding air, accelerates downward toward its equilibrium level. It overshoots the level due to momentum and keeps going down. Dashed line 3 shows that the parcel, now warmer than the surrounding air and at a lower altitude than at dashed line 1, moves upward again. The process continues with the motion eventually damping out. The number of oscillations depends on the initial parcel displacement and the stability of the air. In the lower part of the figure, wind has been added, illustrating the wave pattern the parcel makes as it oscillates vertically. If there were no wind, a vertically displaced parcel would just oscillate up and down, while damping at one spot over the ground.

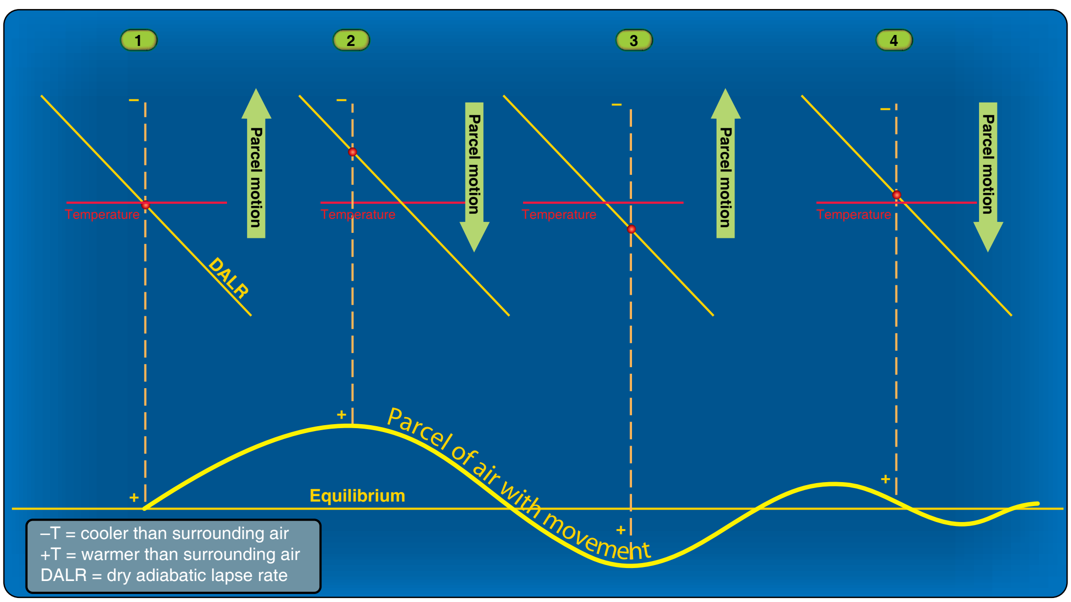


Figure 9-21. *Parcel displaced vertically and oscillating around its equilibrium level.*

The lower part of *Figure 9-21* also illustrates two features of any wave. The wavelength is the horizontal distance between two adjacent wave crests. Typical mountain wavelengths vary considerably, between 2 and 20 miles. The amplitude is half the vertical distance between the trough and crest of the wave.

Figure 9-22 illustrates a two-dimensional conceptual model of a mountain with wind and temperature profiles. Note the increase in windspeed (blowing from left to right) with altitude and a stable layer near mountaintop height with less stable air above and below. As the air flows over the mountain, it descends the lee slope (below its equilibrium level in stable air), which sets up a series of oscillations downstream. While the wave exhibits smooth flow, a low-level turbulent zone exists below, with an embedded rotor circulation under each crest. Turbulence, especially within the individual rotors, while usually moderate to severe, can occasionally become extreme.

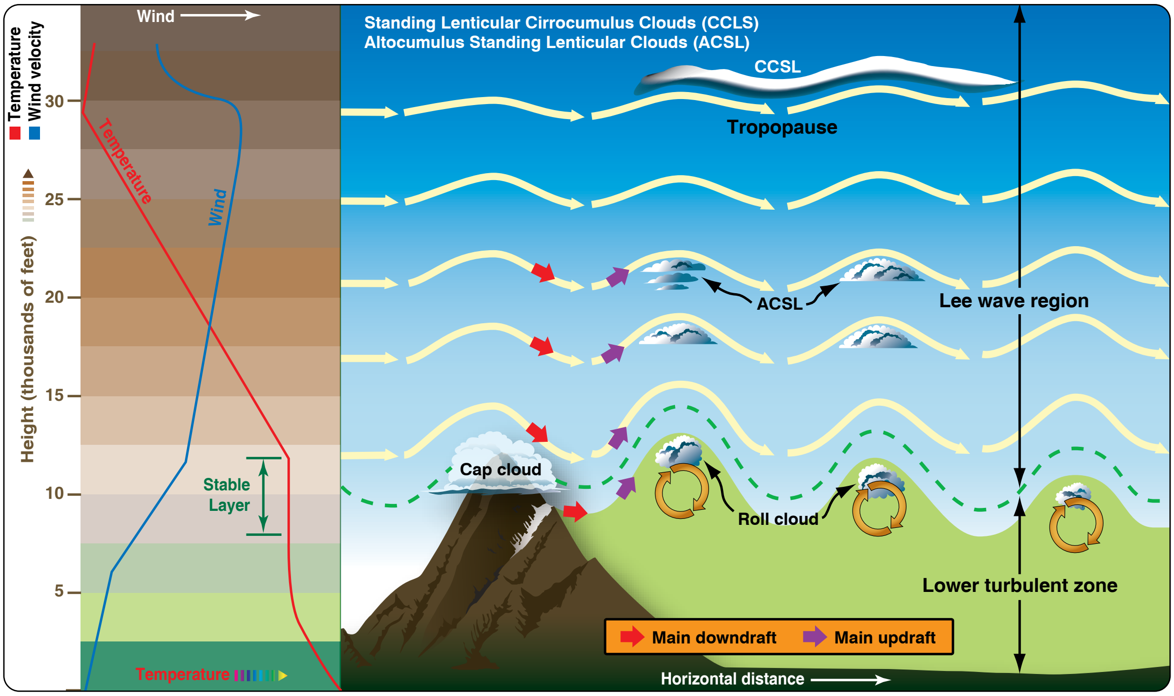


Figure 9-22. *Mountain lee wave system.*

This simple conceptual model has many possible variations. For instance, the topography could have many complex three-dimensional features, such as large ridges, or spurs at right angles to the main range. Variations can occur when a North-South range curves to become oriented Northeast-Southwest. In addition, numerous variations of the wind and stability profiles can occur. In some conditions, the second or third wave crests increases in amplitude, and the pilot can fly higher if flying that portion of the wave.

Low-level turbulence can range from unpleasant to dangerous. While difficult to predict, the intensity of rotor turbulence increases with the amplitude of lee waves and can vary based on location and conditions. At times, rotor turbulence is uniformly rough everywhere below the smooth wave flow. At other times, turbulence becomes severe under wave crests. On occasion, moderate or severe turbulence exists only within a small-scale rotor under the wave crest. Typically, the worst turbulence occurs on the leading edge of the primary rotor.

Figure 9-22 above indicates cloud types associated with a mountain wave system. A cap cloud flowing over the mountain tends to dissipate as the air forced down the mountain slope warms and dries. The first (or primary) wave crest features a roll or rotor cloud with one or more lenticulars forming above. Wave harmonics further downstream may also create lenticulars or rotor clouds. If the wave reaches high enough altitudes, lenticulars may also form at cirrus levels.

The entire mountain wave system can form in completely dry conditions without clouds, and the presence of clouds depends on the amount of moisture at various levels. If only lower-level moisture exists, only a cap cloud and rotor clouds might occur with no lenticulars above, as in *Figure 9-23* (panel A). On other days, only mid-level or upper-level lenticulars appear with no rotor clouds beneath them. When low- and mid-levels contain enough moisture, a deep rotor cloud may form, with lenticulars right on top of the rotor cloud, with no clear air between the two cloud types.

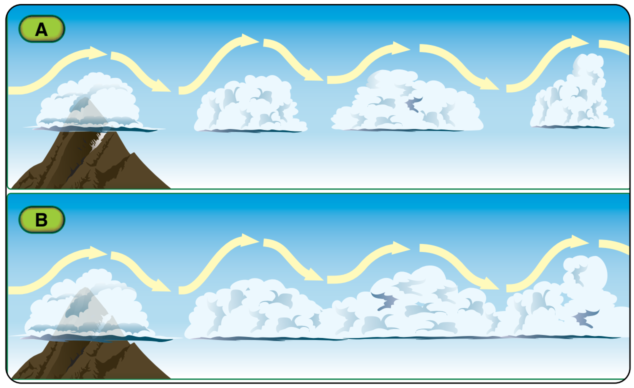


Figure 9-23. *Cloud cover associated with variations in moisture.*

In wet climates, the moist air moving horizontally, can completely close the gap between the cap cloud and primary rotor. This closure could strand a glider on top of the clouds [*Figure 9-23* (Panel B)]. Pilots should consider this possibility when above rotor clouds in moist conditions.

Wave amplitude depends partly on topography. Relatively low ridges of 1,000 feet or less vertical relief can produce lee waves, and uniform height of the mountaintops along a range produces better organized waves. The shape of the lee slope also affects wave production. Very shallow lee slopes can produce waves of sufficient amplitude to support a glider. Different wind and stability profiles favor different topography profiles, and one mountain height, width, and lee slope may produce usable waves only in certain weather conditions. Hence, experience with a particular soaring site can assist pilot prediction of wave conditions.

The weather requirements for wave soaring include sufficient wind and a proper stability profile. Windspeed should be at least 15 to 20 knots at mountaintop level with increasing winds above. The wind direction should be within about 30° perpendicular to the ridge or mountain range. Air stability at the DALR near the mountaintop would not likely produce lee waves even with adequate winds. A well-defined inversion at or near the mountaintop with less stable air above would increase the likelihood of wave production.

Weak lee waves may form without much increase in windspeed as altitude increases, but an actual decrease in windspeed with height usually caps the wave at that level. When winds decrease dramatically with height, for instance, from 30 to 10 knots over two or three thousand feet, turbulence is common at the top of the wave. On some occasions, the flow at mountain level may be sufficient for wave flight, but then begins to decrease with altitude just above the mountain, leading to a phenomenon called “rotor streaming.” In this case, the air downstream of the mountain breaks up and becomes turbulent, with no lee waves above.

Lee waves experience diurnal effects, especially in the spring, summer, and fall. Height of the topography also influences diurnal effects. For smaller topography, as morning leads to afternoon and the air becomes unstable to heights above the wave-producing topography, lee waves tend to disappear. On occasion, the lee wave still exists but the pilot needs more height to reach the smooth wave lift. Toward evening as thermals again die down and the air stabilizes, lee waves may again form. During the cooler season, when the air remains stable all day, lee waves are often present all day, provided the winds aloft continue. Large-mountain dissipation of lee waves during daytime appears less significant. For instance, during the 1950s Sierra Wave Project (searchable online), the wave amplitude reached a maximum in mid to late afternoon, with convective heating at a maximum. Rotor turbulence also increased dramatically at that time.

Topography upwind of the wave-producing range can also affect propagation, as illustrated in *Figure 9-24*. In the first case [*Figure 9-24* Panel A], referred to as destructive interference, the wavelength of the wave from the first range is out of phase with the distance between the ranges. Lee waves do not form downwind of the second range, despite favorable winds and stability aloft. In the second case [*Figure 9-24* (Panel B)], referred to as constructive interference, the ranges are in phase, and the lee wave from the second range has a larger amplitude than it might otherwise.

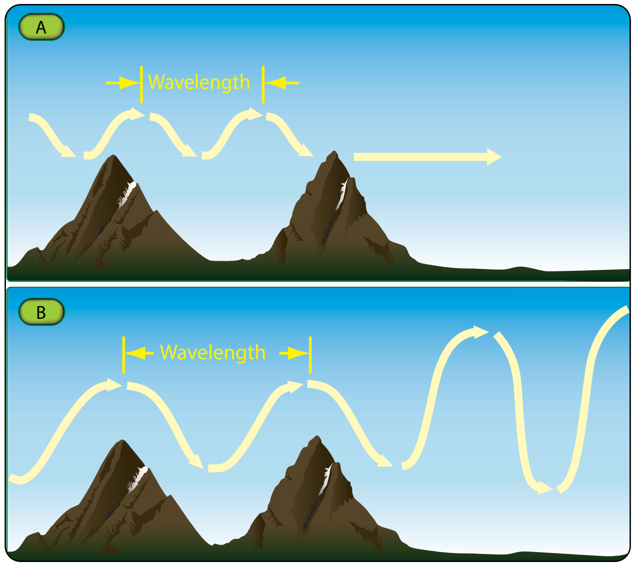
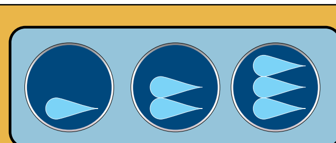


Figure 9-24. *Destructive and constructive interference.*

Wave flight requires planning and appropriate equipment. Additionally, flight in Class A airspace requires Federal Aviation Administration (FAA) notification. The Soaring Society of America (SSA) offers soaring pilots Lennie Awards for completing and documenting a wave flight. [*Figure 9-25*]



While working out of the Bishop, California, airport in the late 1940s, mountain pilot and wave pilot pioneer Robert F. Symons created a new and unique system of awards for wave flying, which he called "lennie" pins. Pilots who soared to great heights in the Sierra Wave received a one-lennie pin for attaining an altitude of 25,000 to 35,000 feet, a two-lennie pin for reaching 35,000 to 40,000 feet, and a three-lennie pin for exceeding 40,000 feet.

Very early, Symons recognized the excellent soaring conditions in the Owens Valley and helped organize a soaring group in 1938. As a professional pilot engaged in cloud seeding, he learned first hand of the power generated in the Sierra Wave and became well known for his studies and lectures on mountain wave phenomena. Although his lists are incomplete, it is believed that he issued some 35 one-lennie, 16 two-lennie, and 10 three-lennie pins. The awarding of these pins ceased in 1958, when Symons lost his life in a glider accident.

In 1962 Carl Burson, Jr., saw one of these pins and upon learning of its history, became interested in reestablishing their issuance as a memorial to Bob Symons. In 1963, the program was reestablished under the official auspices of the SSA, with each new pin holder also receiving a handsome wall plaque. The pin itself is 7mm in diameter (the same as the FAI Gold Badge) and has one, two, or three white lenticular clouds against a blue background with a silver rim. Each pin is consecutively numbered.

Figure 9-25. *Lennie Awards are given for completing and documenting a wave flight.*

Convergence Lift

Convergence lift occurs when two opposing air masses meet, and air moves upward in response to the opposing winds. Air does not need to meet head on to go up. Wherever air piles up in this fashion, it leads to convergence and rising air.

One type of convergence commonly found near coastal areas results from a sea-breeze. Inland areas heat during the day, while the air over the adjacent water maintains about the same temperature. Inland heating leads to lower pressure, drawing in cooler air. Sometimes, as the cooler air moves inland, it behaves like a miniature shallow cold front, and lift forms along a convergence line. At other times, cooler air acts as a focus for a line of thermals. When unstable inland air exists, a sea-breeze can cause frontal effects and act as a focus for a line of thunderstorms. Additionally, since the air on the coast side of the sea-breeze front consists of cool air, passage of the front can end thermal soaring for the day.

Air over water often has a higher dewpoint than drier inland air. As shown in *Figure 9-26*, a curtain cloud sometimes forms, which marks the area of strongest lift. Since colder and warmer air mixes in the convergence zone, pilots should expect turbulence in any thermals associated with a sea breeze front.

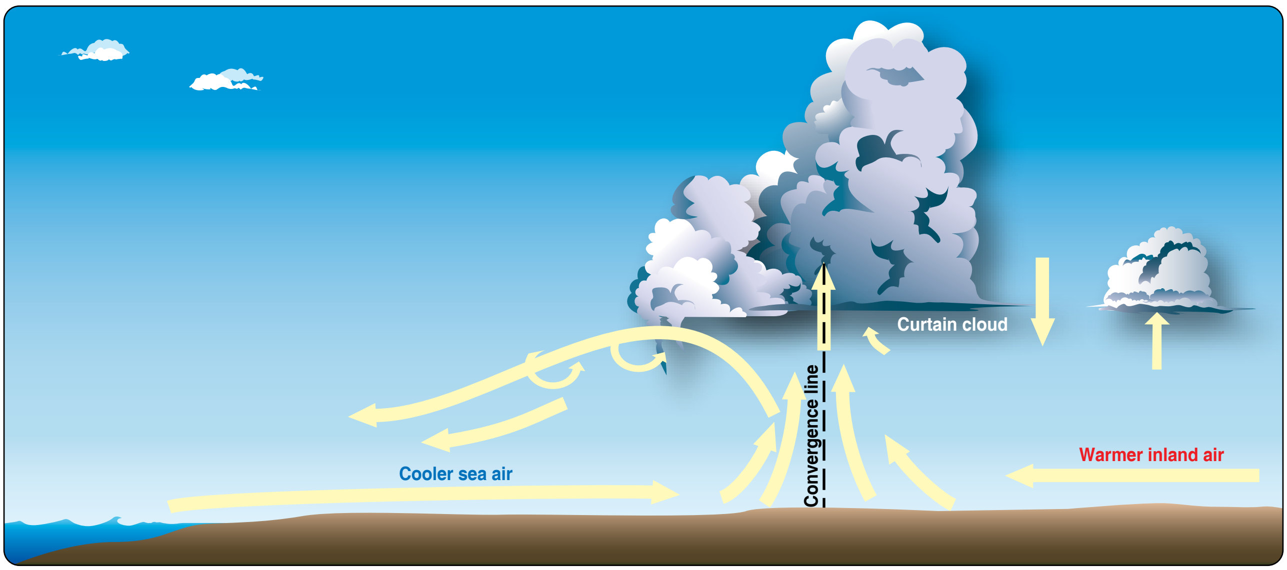


Figure 9-26. *Sea-breeze front.*

Several factors influence the sea-breeze front characteristics (e.g., turbulence, strength, speed of inland penetration, the degree of inland heating, and the land/sea temperature difference). For instance, a small land/sea temperature difference at sunrise with overcast cirrus clouds can reduce ground heating and impede or weaken sea-breeze front formation. Another factor is the synoptic wind flow (general flow of wind for a particular place and time). A weak synoptic onshore flow may allow quicker inland penetration of the sea-breeze front, while a strong onshore flow may remove conditions that allow development of a sea-breeze front. A moderate offshore flow generally prevents any inland penetration of a sea-breeze front.

In a well-defined sea-breeze front marked by a curtain cloud, the pilot can fly straight along the line in steady lift. A poorly defined, weaker convergence line often produces more lift than sink. The pilot should fly slower in lift and faster in sink.

Convergence can also occur along and around mountains or ridges. In *Figure 9-27* Panel A, flow deflected around a ridgeline meets as a convergence line on the lee side of the ridge. The line may be marked by cumulus or a boundary with a sharp visibility contrast. The latter occurs if the air coming around one end of the ridge flows past a polluted urban area, such as in the Lake Elsinore soaring area in southern California. In very complex terrain, with ridges or ranges oriented at different angles to one another, or with passes between high peaks, small-scale convergence zones can be found in adjacent valleys, depending on wind strength and direction. *Figure 9-27* Panel B illustrates a smaller-scale convergence line flowing around a single hill or peak and forming a line of lift stretching downwind from the peak.

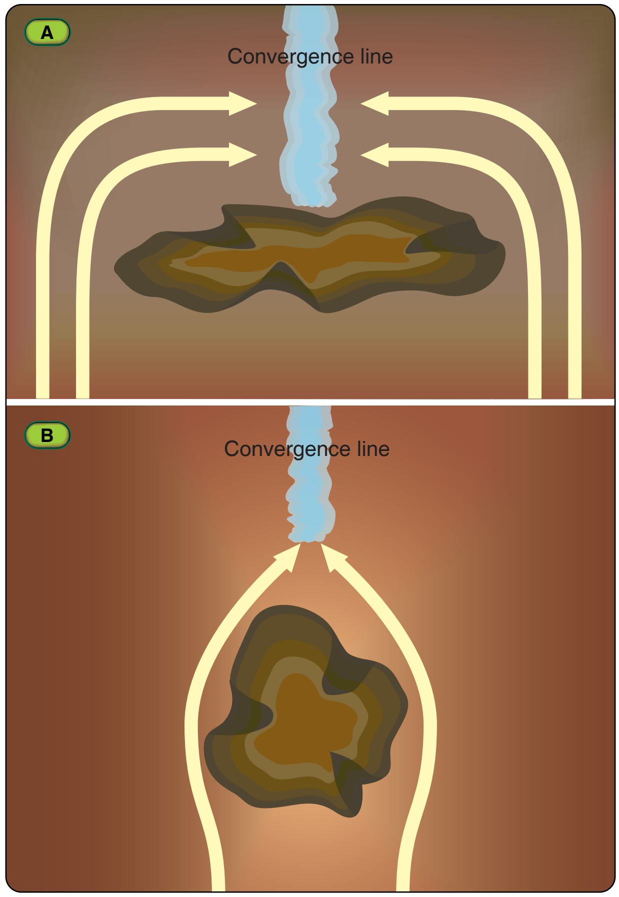


Figure 9-27. *Convergence induced by flow around topography (as viewed from above).*

Convergence can sometimes occur along the top of a ridgeline or mountain range. In *Figure 9-28*, drier synoptic- scale wind flows up the left side of the mountain, while a moist valley breeze flows up the right side of the slope. The two flows meet at the mountain top and form lift along the entire range. If clouds are present, the air from the moist side condenses first, often forming one cloud with a well-defined step, marking the convergence zone. For this scenario, the better lift conditions occur on the Western dry side rather than the East side where clouds are more likely to form.

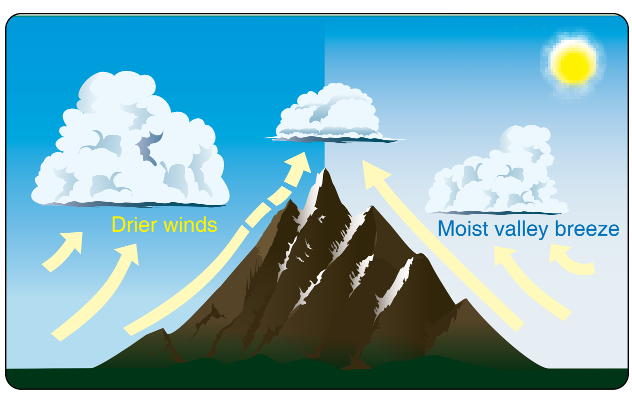


Figure 9-28. *Mountaintop convergence.*

As a final example, when daytime heating abates in mountainous terrain, a cool katabatic wind or drainage wind may flow down mountain slopes. The flow down the slope converges with air in the adjacent valley to form an area of weak lift. The convergence, often too weak to create lift to support glider flight, may act as a trigger for the last thermal of the day. [*Figure 9-29*]

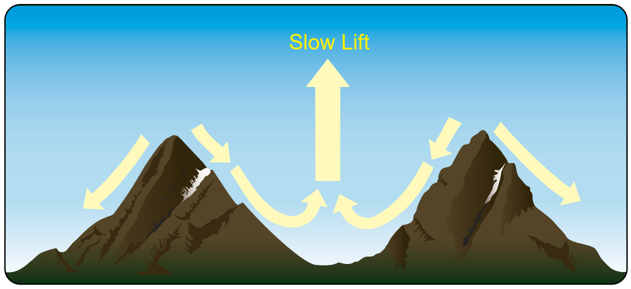


Figure 9-29. *Convergence induced by flow around topography.*

Obtaining Weather Information

For visual flight rules (VFR) flights, federal regulations require pilots to review weather reports and forecasts if they plan to depart the airport vicinity. Even for a local flight, glider pilots should know the current and forecast weather to avoid flight in hazardous conditions.

For additional details regarding available weather services and products, glider pilots should refer to the current version of the Pilot's Handbook of Aeronautical Knowledge, FAA-H-8083-25, Chapter 12, Aviation Weather Services and the Aviation Weather Handbook, FAA-H-8083-28. These sources include a wealth of information. A pilot familiar with relevant and available weather reports and forecasts can analyze weather hazards and mitigate any associated risks. Pilots who understand weather can experience safe flight in a variety of conditions.

Preflight Weather Briefing

The FAA delivers flight services to pilots in the CONUS, Alaska, Hawaii, and Puerto Rico. Services are provided by phone at 1-800-WX-BRIEF, on the internet through the Flight Service Pilot Web Portal, and in person (Alaska only) at 17 Flight Service Stations (FSS). Services include, but are not limited to: preflight weather briefings, flight planning, and in-flight advisory services.

Weather briefers do not actually predict the weather; they simply translate and interpret weather reports and forecasts within the vicinity of the airport, route of flight, or the destination airport if the flight is a cross-country. A pilot may request one of four types of briefings: standard, abbreviated, soaring [*Figure 9-30*], or outlook.

Soaring Forecast

National Weather Service Denver/Boulder, Colorado
645 AM MDT Wednesday August 25, 2010

This forecast is for Wednesday August 25, 2010:

If the trigger temperature of 77.3 F/25.2 C is reached...then
Thermal Soaring Index....................... Excellent
Maximum rate of lift........................ 911 ft/min (4.6 m/s)
Maximum height of thermals.................. 16119 ft MSL (10834 ft AGL)

Forecast maximum temperature................... 89.0 F/32.1 C
Time of trigger temperature.................... 1100 MDT
Time of overdevelopment........................ None
Middle/high clouds during soaring window....... None
Surface winds during soaring window............ 20 mph or less
Height of the -3 thermal index................. 10937 ft MSL (5652 ft AGL)
Thermal soaring outlook for Thursday 08/26..... Excellent

Wave Soaring Index............................. Poor
Wave Soaring Index trend (to 1800 MDT)......... No change
Height of stable layer (12-18K ft MSL)......... None
Weak PVA/NVA (through 1800 MDT)................ Neither
Potential height of wave....................... 14392 ft MSL (9107 ft AGL)
Wave soaring outlook for Thursday 08/26........ Poor

Remarks...

Sunrise/Sunset.................... 06:20:55 / 19:42:44 MDT
Total possible sunshine........... 13 hr 21 min 49 sec (801 min 49 sec)
Altitude of sun at 13:01:25 MDT... 60.82 degrees

Upper air data from rawinsonde observation taken on 08/25/2010 at 0600 MDT

Freezing level.................. 15581 ft MSL (10296 ft AGL)
Additional freezing level....... 54494 ft MSL (49209 ft AGL)
Convective condensation level... 13902 ft MSL (8617 ft AGL)
Lifted condensation level....... 14927 ft MSL (9641 ft AGL)
Lifted index.................... -3.4
K index......................... +9.7

* * * * * * Numerical weather prediction model forecast data valid * * * * * *

08/25/2010 at 0900 MDT	08/25/2010 at 1200 MDT
K index... +4.0	K index... -0.7

This product is issued twice per day, once by approximately 0630 MST/0730 MDT (1330 UTC) and again by approximately 1830 MST/1930 MDT (0130 UTC). It is notcontinuously monitored nor updated after its initial issuance.

The information contained herein is based on rawinsonde observation and/or numerical weather prediction model data taken near the old Stapleton Airport site in Denver, Colorado at

North Latitude: 39 deg 46 min 5.016 sec
West Longitude: 104 deg 52 min 9.984 sec
Elevation: 5285 feet (1611 meters)

and may not be representative of other areas along the Front Range of the Colorado Rocky Mountains. Note that some elevations in numerical weather prediction models differ from actual station elevations, which can lead to data which appear to be below ground. Erroneous data such as these should not be used.

The content and format of this report as well as the issuance times are subject to change without prior notice. Comments and suggestions are welcome and should be directed to one of the addresses or phone numbers shown at the bottom of this page. To expedite a response to comments, be sure to mention your interest in the soaring forecast.

DEFINITIONS:

Convective Condensation Level - The height to which an air parcel possessing the average saturation mixing ratio in the lowest 4000 feet of the airmass, if heated sufficiently from below, will rise dry adiabatically until it just becomes saturated. It estimates the base of cumulus clouds that are produced by surface heating only.

Convection Temperature (ConvectionT) - The surface temperature required to make the airmass dry adiabatic up to the given level. It can be considered a "trigger temperature" for that level.

Freezing Level - The height where the temperature is zero degrees Celsius.

Height of Stable Layer - The height (between 12,000 and 18,000 feet above mean sea level) where the smallest lapse rate exists. The location and existence of this feature is important in the generation of mountain waves.

K Index - A measure of stability which combines the temperature difference between approximately 5,000 and 18,000 feet above the surface, the amount of moisture at approximately 5,000 feet above the surface, and a measure of the dryness at approximately 10,000 feet above the surface. Larger positive numbers indicate more instability and a greater likelihood of thunderstorm development. One interpretation of K index values regarding soaring in the western United States is given in WMO Technical Note 158 and is reproduced in the following table:

below -10	no or weak thermals
-10 to 5	dry thermals or 1/8 cumulus with moderate thermals
5 to 15	good soaring conditions
15 to 20	good soaring conditions with occasional showers
20 to 30	excellent soaring conditions, but increasing probability of showers and thunderstorms
above 30	more than 60 percent probability of thunderstorms

Lapse Rate - The change with height of the temperature. Negative values indicate inversions.

Lifted Condensation Level - The height to which an air parcel possessing the average dewpoint in the lowest 4000 feet of the airmass and the forecast maximum temperature must be lifted dry adiabatically to attain saturation.

Lifted Index - The difference between the environmental temperature at a level approximately 18,000 feet above the surface and the temperature of an air parcel lifted dry adiabatically from the surface to its lifted condensation level and then pseudoadiabatically thereafter to this same level. The parcel`s initial temperature is the forecast maximum temperature and its dewpoint is the average dewpoint in the lowest 4000 feet of the airmass. Negative values are indicative of instability with positive values showing stable conditions.

Lift Rate - An experimental estimate of the strength of thermals. It is computed the same way as the maximum rate of lift but uses the actual level rather than the maximum height of thermals in the calculation. Also, none of the empirical adjustments based on cloudiness and K-index are applied to these calculations.

Maximum Height of Thermals - The height where the dry adiabat through the forecast maximum temperature intersects the environmental temperature.

Figure 9-30. *Soaring forecast.*

Weather-Related Information

Pilots can also find weather-related information on the Internet, including sites directed toward aviation. Pilots should verify the timeliness and source of the weather information provided by any Internet sites to ensure the information is up to date and accurate. For example, a source of accurate information includes the NWS website.

Interpreting Weather Charts, Reports, & Forecasts

Knowing how to interpret and understand weather information requires knowledge and practice. Weather charts and reports record observed atmospheric conditions at certain locations at specific times. The NWS collects data from automated sources or from trained observers using electronic instruments, computers, and personal observations as well as radiosonde observations or model generated soundings to produce the weather products pilots use to determine if a flight can be conducted safely. This same information can be used by soaring pilots to determine if sufficient lift for a planned flight may exist, where to find it, and how long the lift should last.

Chapter Summary

Pilots use several different types of lift to make extended glider flights. The lift comes from thermals, mountain ridges, wave formation, or convergence zones. The stability of the atmosphere affects several of these sources. Each source of lift has its own set of hazards and associated risks. For example, weather leading to thermals can also lead to thunderstorms. Pilots looking for weather conditions that favor extended flight should also know how to identify conditions and hazards that prompt them not to fly. Pilots should not fly near thunderstorms, in low visibility, or in high winds that affect the safety of takeoffs and landings. Pilots can get general and specific information from a variety of sources and should make certain that any source of weather information used before flight is accurate. The FAA has information and documents regarding weather products and services on its website.