Wave Soaring

Almost all high-altitude glider flights use mountain lee waves as the primary source of lift. As covered in Chapter 9, Glider Flight and Weather, lee wave systems can contain separate rotor turbulence and smooth wave flow. The use of lee waves for cross-country soaring has enabled flights exceeding 1,500 miles, with average speeds of over 100 mph. [*Figure 10-29*]

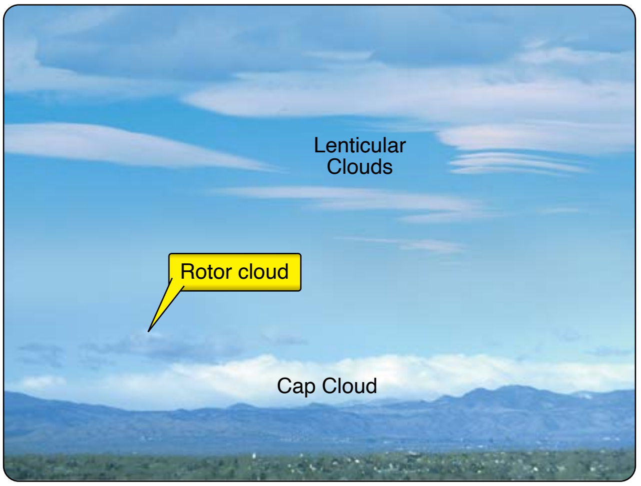

Figure 10-29. *Rotor and cap clouds with lenticulars above.*

Preflight Preparation

Special areas within the continental United States allow glider operations in Class A airspace above 18,000 feet MSL under visual flight rules (VFR). Air Traffic Control (ATC) may open a "wave window" to a specific altitude at specified times. Each wave window has its own set of procedures agreed to by ATC through a Letter of Agreement. Glider pilots should understand the special provisions in the letter of agreement before flying within a wave window.

A flight above 18,000 feet MSL requires extensive preflight preparation. Pilots planning wave flights to lower altitudes can reduce the list of preparation items accordingly.

14 CFR part 91, section 91.211 requires that crewmembers use supplemental oxygen for flight of more than 30 minutes above cabin pressure altitudes of 12,500 feet MSL up to and including 14,000 feet MSL. While above cabin pressure altitudes of 14,000 feet MSL, required crewmembers must use supplemental oxygen. Pilots should preflight the oxygen system, understand signs of hypoxia, know their reactions to high altitude, and consider using oxygen at altitudes well below 12,500 feet MSL.

When flying at high altitudes, the outside air chills the glider interior. Sunlight can help warm portions of the pilot's upper body, but the pilot's lower extremities and feet normally get cold. Pilots planning for a long flight in cold air should wear thermal underwear, warm socks, and shoes and have gloves easily accessible during the flight. Clothing with rechargeable electric heating components can provide hours of warmth.

True airspeed (TAS) becomes a consideration at higher altitudes. To avoid flutter, some glider manuals reduce never-exceed speed (V_{NE}) as a function of altitude. For instance, the Pilot's Operating Handbook (POH) for one common two-seat glider, lists a V_{NE} at sea level of 135 knots. However, at 19,000 feet MSL, it lowers to only 109 knots. Pilots should study the glider's POH carefully for any indicated airspeed limitations.

Some flights might not contact the wave. Sink on the downside of a lee wave can reach 2,000 fpm or more. In addition, missing the wave often means a trip back through the turbulent rotor. To reduce the workload and stress, pilots should calculate minimum return altitudes from several locations before flight. In addition, pilots should plan for worst-case scenarios and consider available off-field landing options if the planned minimum return altitude proves inadequate.

The pilot should begin with a normal preflight of the glider. In addition, the pilot should check the lubricant used on control fittings. Some lubricants get stiff when cold. The pilot should ensure the glider is totally devoid of excess water before flying into freezing temperatures. This includes checking the bottom of the fuselage where water can freeze around rudder and elevator cables and checking spoilers or dive brakes for water from rain or from melting snow cleared from the wing. Water in the spoilers or drive brakes at altitude can freeze and make them difficult or impossible to open. Checking the spoilers or dive brakes occasionally during a high climb helps avoid this problem.

The pilot should check for a freshly charged battery since cold temperatures can reduce battery effectiveness and affect the avionics. The preflight should include checking the radio and accessory equipment, such as the microphone in the oxygen mask. Other specific items to check depend on the systems in the glider.

A briefing with the tow pilot should occur before a wave tow. Prior to flight, the pilots should discuss routes, minimum altitudes, rotor avoidance (if possible), anticipated tow altitude, and other potential situations.

A pilot wearing a bail-out parachute on wave flights should check its proper fitting and use. When wearing a parachute, the seat can suddenly seem cramped. Once seated in the glider, the pilot should check for full, free rudder movement since larger than normal footwear can affect rudder control. In addition, given the bulky cold-weather clothing, the pilot should check canopy clearance. The pilot's head can break a canopy in rotor turbulence, so seat and shoulder belts should be tightly secured even if difficult to achieve with the extra clothing. Proper placement of the oxygen mask should make it easily accessible within a few seconds since the climb in the wave can be very rapid. Securing everything else before takeoff prevents disorder while encountering the rotor.

Getting into the Wave

Access into the wave occurs in two ways: soaring into it or being towed directly into it. Three main wave entries while soaring include thermalling into the wave, climbing the rotor, and transitioning into the wave from slope soaring.

At times, an unstable layer lower than the mountaintop has a strong, stable layer cap, which may support lee waves. A line of cumulus clouds downwind of and aligned parallel to the ridge or mountain range suggests the presence of these waves. With these conditions present, the pilot can avoid the rotor area and thermal into the wave. Whether lee waves are suspected or not, the air near the thermal top may become turbulent. At this point, the pilot should attempt a penetration upwind into the smooth wave. [*Figure 10-30*]

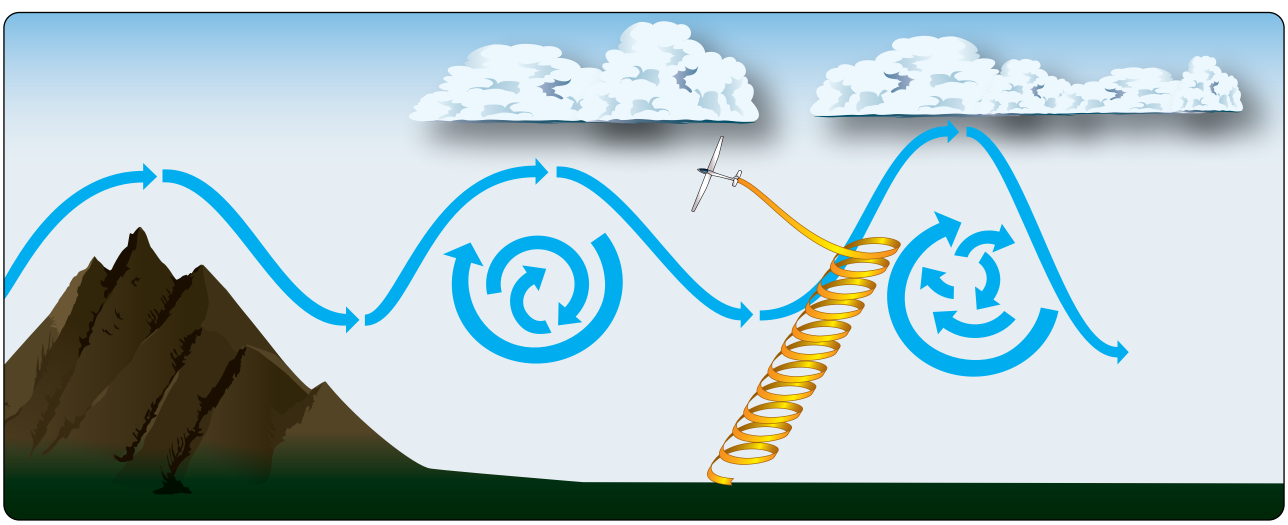

Figure 10-30. *Thermalling into wave.*

Depending on the topography near the soaring site, it may be possible to transition from slope lift into a lee wave created by upwind topography where multiple ridges exist. In this case, the pilot climbs as high as possible in slope lift, then penetrates upwind into the lee wave. With the lee waves in phase with the topography, the pilot can often climb from slope to wave lift without the rotor. At times, the glider pilot may not realize wave has been encountered until finding lift steadily increasing as the glider climbs. Climbing in slope lift and then turning downwind to encounter possible lee waves produced downwind of the ridge should generally not occur. Even with a tailwind, the lee-side sink can put the glider on the ground before contact with the wave.

Another possibility involves a tow into the upside of the rotor and a climb using the rotor to reach the wave. The technique relies on finding the rising part of the rotor. Since rotor lift usually remains stationary over the ground, this may involve flying a "figure-8" in the rotor lift to avoid flying downwind. The pilot can also fly several circles with an occasional straight leg or fly straight into the wind for several seconds until the lift diminishes followed by circling to reposition within the lift. Which choice works best depends on the size of the lift and the strength of the wind. Since the rotor may contain regions of rapidly changing and turbulent lift and sink, staying in it as well as simple airspeed and bank control may prove difficult. Inexperienced pilots should avoid using a tow to the upside of a rotor to reach the wave.

Towing into the wave occurs by towing ahead of the rotor or through the rotor. Complete avoidance of the rotor by towing around it will generally increase the time on tow, but the reduced turbulence increases the tow pilot's willingness to perform future wave tows. [*Figure 10-31*] If the launch site sits near one end of the wave-producing ridge or mountain range, a tow around the rotor and then directly into the wave lift becomes more feasible.

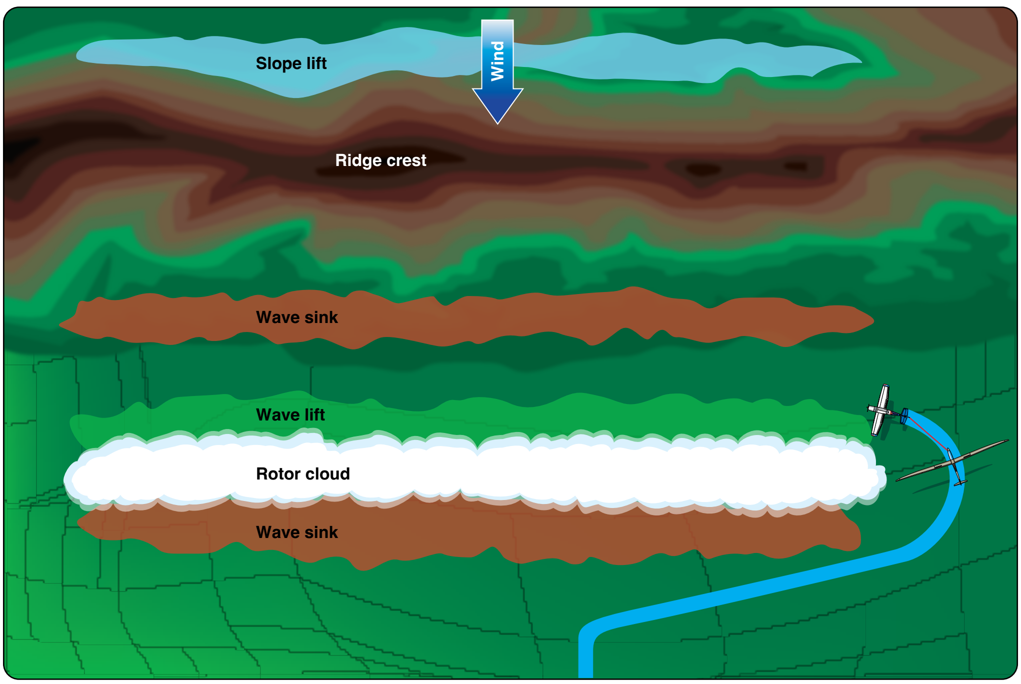

Figure 10-31. *A tow around the rotor directly into the wave avoids turbulence.*

Often, a tow directly through the rotor provides the only route to the wave. The tow will usually encounter moderate to severe rotor turbulence. The nature of rotor turbulence differs from a turbulent thermal. The rotor subjects the aircraft to sharp, chaotic horizontal and vertical gusts along with rapid accelerations and decelerations. At times, the rotor can become so rough that even experienced pilots will elect to remain on the ground. Any pilot without experience flying through rotors should obtain instruction before attempting a tow through a rotor.

During a tow through a rotor, the glider often gets out of position, and the glider pilot should attempt to maintain position horizontally and vertically. Turbulence too violent to handle may require an immediate release. Slack-producing situations occur commonly due to a rapid deceleration of the towplane. The glider pilot should recognize the onset of slack line and correct accordingly. The glider pilot should maintain the high-tow position because any tow position lower than normal runs the risk of the slack line coming back over the glider. On the other hand, the glider should fly no higher than normal to avoid a forced release should the towplane suddenly drop. Gusts may also cause an excessive bank of the glider, and it may take a moment to roll back to a level attitude. The pilot may need to use full aileron and rudder deflection for a few seconds.

The trend of the variometer often indicates the progress through the rotor. General downswings get replaced by general upswings, usually along with increasing turbulence. The penetration into the smooth wave lift can occur in a matter of seconds or it can occur gradually. The glider pilot should note any lenticulars above as a position upwind of the clouds helps confirm contact with the wave. If in doubt, the tow may continue for a few moments longer to confirm wave contact. Once confident of the wave lift, the glider pilot makes the release. If on a crosswind heading, the glider should release and fly straight or with a crab angle. If flying directly into the wind, the glider should turn a few degrees to establish a crosswind crab angle. The pilot should avoid drifting downwind and immediately losing the wave. After release, the towplane should descend and/or turn away and create separation from the glider. The glider and tow pilot should brief any nonstandard release procedures before takeoff. [*Figure 10-32* and *Figure 10-33*]

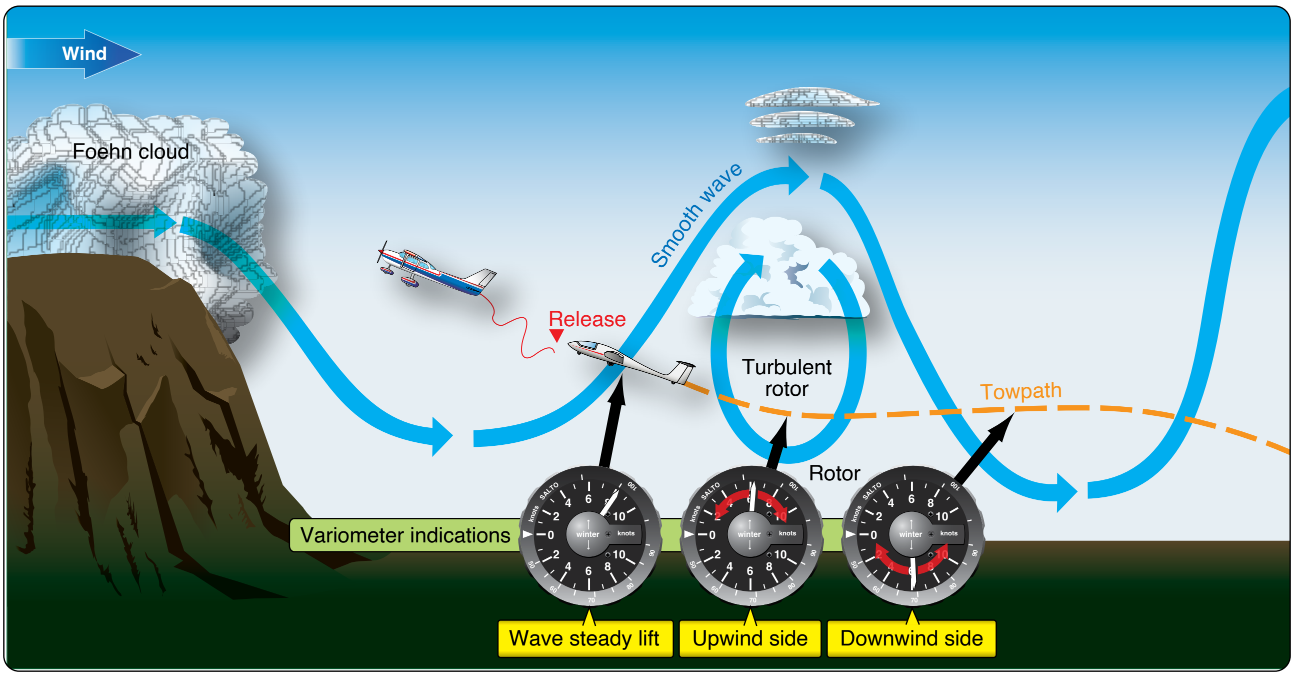

Figure 10-32. *Variometer indications during the penetration into the wave.*

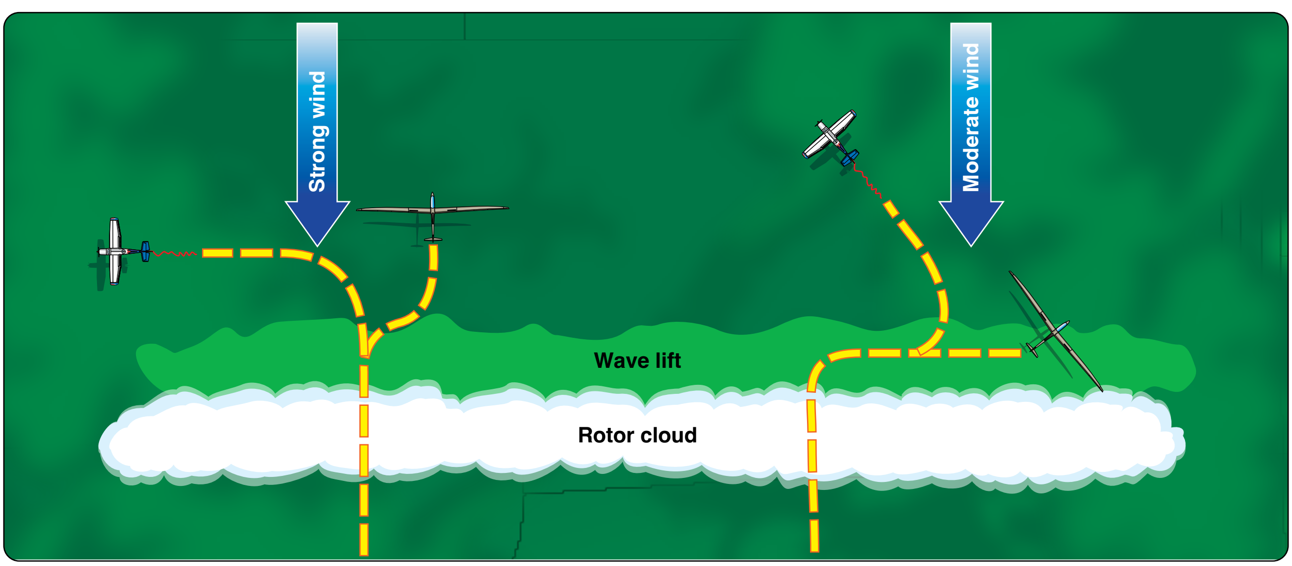

Figure 10-33. *Possible release and separation on a wave tow.*

Flying in the Wave

After wave contact, the best technique for utilizing the lift depends on the extent of the lift and the strength of the wind. In weak lift, the pilot should stay with the initial slow climb as better lift should develop as the climb continues. At other times, the variometer may peg at 1,000 fpm directly after release from tow.

In strong winds (40 knots or more), the pilot should find the strongest portion of the wave, point into the wind, and adjust speed so that the glider remains in the strong lift. The best lift usually occurs along the upwind side of the rotor cloud or just upwind of any lenticulars. In the best-case scenario, the required speed matches the glider's minimum sink speed. In quite strong winds, the pilot flies faster than minimum sink to maintain position in the best lift. Under those conditions, flying slower would allow the glider to drift downwind (fly backward over the ground) and into the downside of the wave. Once on the downside, getting back to the frontside requires penetrating a strong headwind. With strong lift, stronger winds aloft might push the glider downwind, so the pilot should monitor the position relative to rotor clouds or lenticulars. If no clouds exist, the pilot can use nearby ground references and increase speed with altitude as needed to maintain position in the best lift. In a wind not strong enough for the glider to remain stationary over the ground, the glider slowly moves upwind out of the best lift. If this occurs, the pilot should turn slightly from a direct upwind heading, drift slowly downwind into better lift, and turn back into the wind before drifting too far. [*Figure 10-34*]

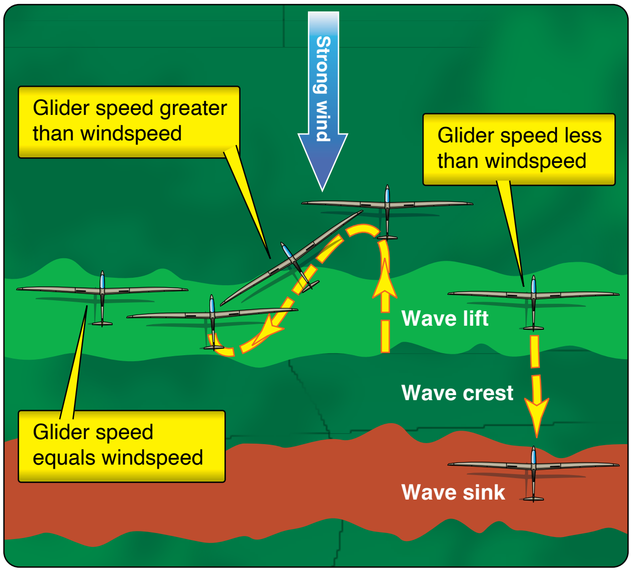

Figure 10-34. *Managing wave position with speed.*

Often, the wave lift moves over the ground since small changes in windspeed or stability can alter the wavelength of the lee wave within a few minutes. If lift begins to decrease while climbing in the wave, one of these things has occurred: the glider approached the top of the wave, the glider moved out of the best lift, or the wavelength of the lee wave has changed. In any case, the pilot can explore the area for better lift by searching upwind first. Searching upwind allows the pilot to drift downwind back into the rising part of the wave if not finding better lift upwind. Searching downwind first can make it difficult or impossible to contact the lift again if encountering sink on the downwind side of the wave. In addition, the pilot might exceed the glider's maneuvering speed or redline for rough air as gliding from the downwind to upwind could put the glider back in the rotor. [*Figure 10-35*]

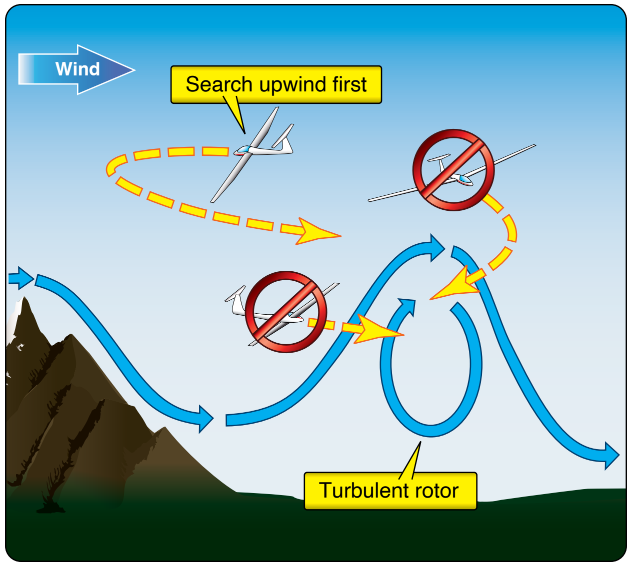

Figure 10-35. *Search upwind first to avoid sink behind the wave crest or the rotor.*

In moderate winds (20 to 40 knots) and if the wave extends along the ridge or mountain range for a few miles, the pilot can fly back and forth along the wave lift while crabbing into the wind. The pilot can use the rotor cloud or lenticular as a reference. All turns should occur into the wind to avoid moving to the downside of the wave or back into the rotor. When making an upwind turn to change course 180°, the pilot changes heading less than 180°, with the reduction in turn based on the strength of the wind. The pilot notes the crab angle needed to stay in lift on the first leg and can use that same amount of into-the-wind crab angle initially after completing the next upwind turn. With no cloud, ground references allow the pilot to establish and maintain the proper crab angle. While climbing higher into sufficiently strong winds, the pilot may transition from crabbing back and forth to a stationary upwind heading. [*Figure 10-36*]

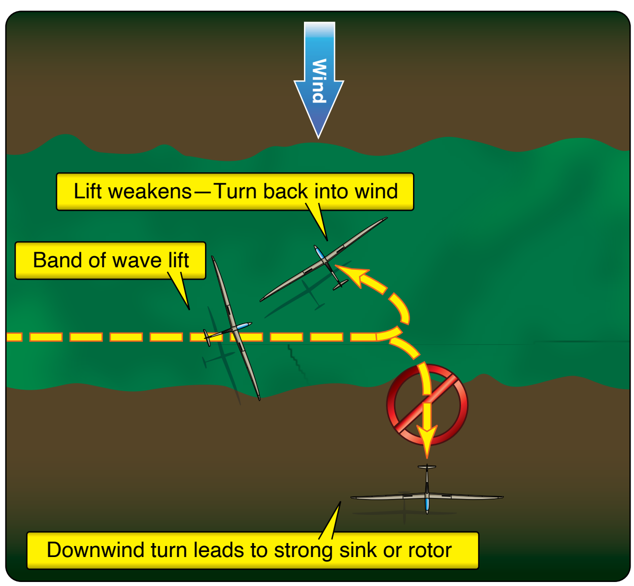

Figure 10-36. *Crabbing and turns in a wave*

Weaker winds (15 to 20 knots) may call for different techniques. Lee waves from smaller ridges can form in relatively weak winds of approximately 15 knots, and wave lift from larger mountains rapidly decreases when climbing to a height where winds aloft diminish. In a small area that still provides lift near the wave top, the pilot can fly shorter figure 8 patterns to reach the maximum altitude. The pilot can also fly an oval-shaped pattern straight into the wind in lift and fly a quick 360° turn to reposition and as it diminishes. If a consistent climb is not possible, the pilot can fly a series of circles with an occasional leg into the wind to avoid drifting too far downwind. In a sufficiently large lift area, the pilot can use a technique like that used in moderate winds. [*Figure 10-37*]

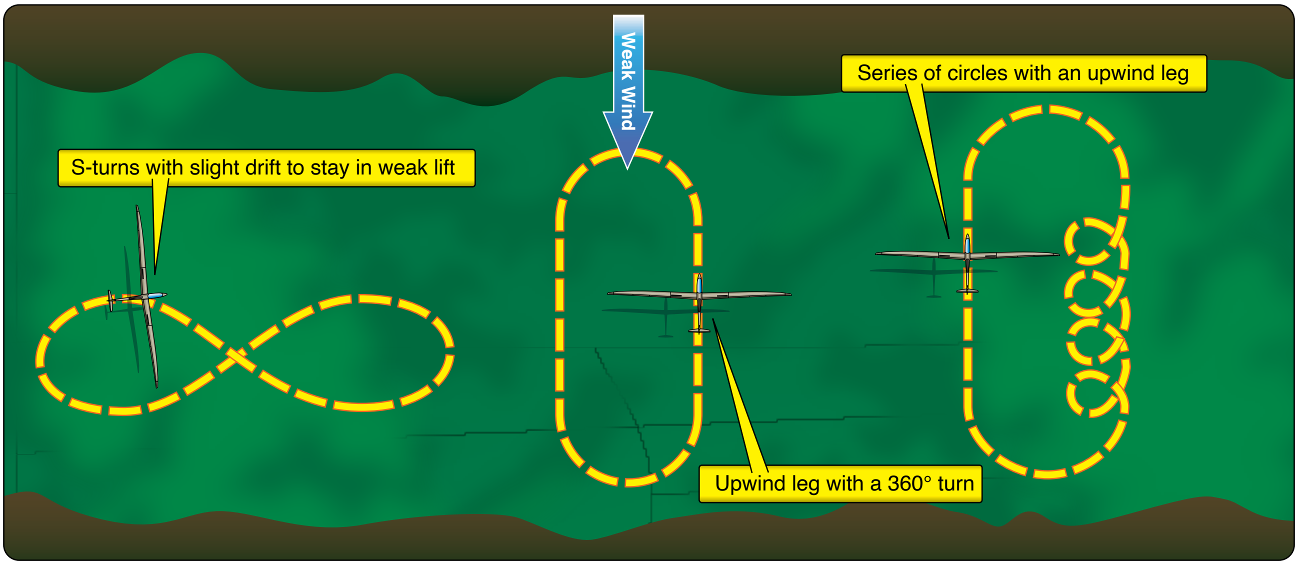

Figure 10-37. *Techniques for working lift near the top of the wave in weak winds.*

The discussion thus far assumed a climb in the primary wave. The pilot can also climb using any secondary or tertiary lee wave and then penetrate the next wave upwind. The success of this strategy depends on wind strength, clouds, the intensity of sink downwind of wave crests, and the performance of the glider. Depending on the height attained in the secondary or tertiary lee wave, a trip through the rotor of the next wave upwind could occur. Pilots should exercise caution if penetrating upwind at high speed. The transition into the downwind side of the rotor can be as abrupt as on the upwind side, so the pilot should reduce speed at the first hint of turbulence. In any case, the glider could lose a significant amount of altitude while penetrating upwind through the sinking side of the next upwind wave. [*Figure 10-38*]

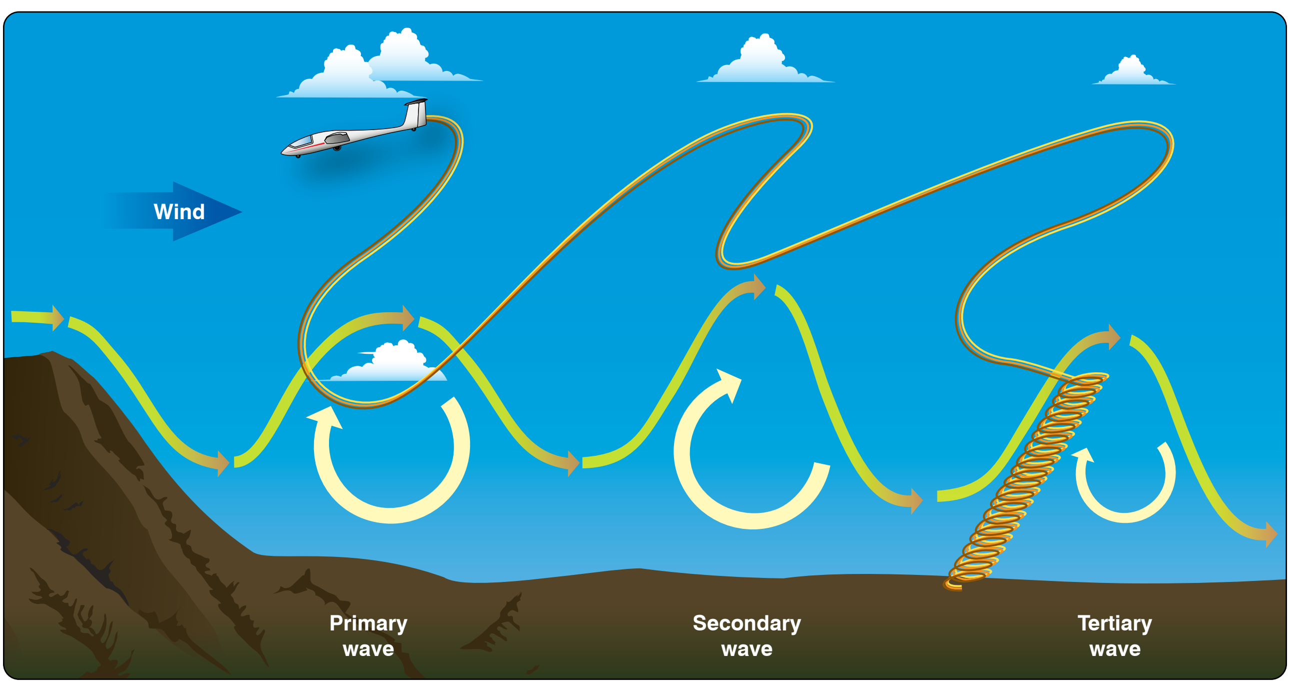

Figure 10-38. *Possible flightpath while transitioning from the tertiary into the secondary and then into the primary.*

The sink downwind of the wave crest can assist a pilot who decides to make a quick descent as sink can easily attain twice the strength of the lift encountered on the upwind side of the wave crest. Eventual descent into downwind rotor might also occur. An inadequate space between a rotor cloud and overlying lenticulars can prevent a safe downwind transition that might then occur with reduced visibility. In this case, the pilot can make a crosswind detour if a short ridge or mountain range produces the wave. If clouds negate a downwind or crosswind departure from the wave, a descent on the upwind side of the wave crest can occur. Spoilers or dive brakes may be used to descend through the updraft, followed by a transition under the rotor cloud and through the rotor. The pilot should control speed during flight through the rotor. In addition, lift on the upwind side of the rotor may make it difficult to stay out of the rotor cloud. This type of descent requires caution and emphasizes the importance of an exit strategy before climbing too high in the wave. Pilots should remember that conditions and clouds can evolve rapidly during the climb.

Some of the dangers and precautions associated with wave soaring include:

- Symptoms of hypoxia—check the oxygen system, and immediately begin a descent to lower altitudes that do not require supplemental oxygen. Do not delay!
- Extreme cold—descend before becoming uncomfortably cold.
- Severe or extreme rotor turbulence—exercise caution on tow and when transitioning from smooth wave flow (lift or sink) to rotor. Rotors near the landing area can cause strong shifting surface winds of 20 or 30 knots. Wind shifts up to 180° sometimes occur in less than a minute at the surface under rotors.
- Restricted vision—warm, moist exhaled air may cause frost formation on the canopy and restrict vision. Opening air vents may alleviate the problem or delay frost formation. The pilot can use heated panels or descend before frost becomes a hazard.
- Entrapment above clouds—wet waves associated with a great deal of cloud formation may close gaps beneath the glider and the pilot should descend in visual conditions before becoming trapped. If trapped above clouds, the pilot could attempt a benign spiral through the cloud as an emergency maneuver only if previously explored and stable for the glider in visual conditions.
- Inadvertent night flight—at sunset, bright sunshine still exists at 25,000 feet while the ground below gets quite dark. Know the time of actual sunset. Even at an average 1,000 fpm descent, it takes 20 minutes to lose 20,000 feet.

Caution: Flights under a rotor cloud can encounter high sink rates and pilots should approach those areas with caution.

Soaring Convergence Zones

Pilots can most easily spot a convergence zone in the presence of cumulus clouds. They may appear as a single well-defined straight or curved cloud street. The edge of a field of cumulus can mark convergence between a relatively moist or unstable mesoscale air mass from a drier or more stable one. Often, the cumulus along convergence lines have a base lower on one side.

With no cloud present, pilots can sometimes spot a convergence zone by a difference in visibility across it, which may be subtle or distinct. Even without any clues in the sky, conditions on the ground can indicate a convergence zone. Pilots can look for wind differences on lakes a few miles apart. A lake showing a wind direction different from the ambient flow for the day may indicate conditions that can create a convergence zone. Wind direction shown by blowing smoke can also indicate convergent conditions. A few dust devils, or a short line of them, may indicate the presence of ordinary thermals versus those triggered by convergence. Spotting these subtle clues takes practice and good observational skills and explains why a few pilots can continue soaring while other cannot.

The best soaring technique for this type of lift depends on the nature of the convergence zone itself. For instance, curtain clouds mark a well-defined, sea-breeze front, and the pilot can fly straight along the line in steady lift. A weaker convergence line often produces more lift than sink. An even weaker convergence line may simply serve as the focus for more frequent