BY DAN GUDGEL

Mountain Wave Comments

The past couple of installments of "Weather To Fly" has concentrated on the lee or mountain wave phenomenon: 1) defining it; and, 2) guidelines to assist in anticipating its development. Before continuing with some of the more academic aspects of the mountain wave, I would like to simply address some miscellaneous aspects of the subject.

Previously mentioned, a "classic" lee or mountain wave is an atmospheric lift phenomenon providing uplift for the soaring pilot in the downwind area of a mountain range (as a disturbing boundary in the face off a moderate to strong wind). But even a single mountain peak can act as that required topographic feature needed to establish a "local" wave under the right circumstances ***(See Photo #1: Mauna Kea Wave; Photo courtesy of Woody Woods)***. All of the wave characteristics, including cloud features, can be present in just a small geographic area: cap cloud, Foehn gap, rotor cloud, and altocumulus standing lenticularis (ACSL) or "lennies." Under what circumstance airflow decides to move vertically in response to the lone mountain peak and develop a mountain wave rather than simply flow around that peak horizontally cannot be described by this author. However, the phenomenon does exist and if the meteorological situation seems to fit wave development soaring pilots should remain aware of the possibility of a "lone peak" wave even if the topography doesn't look "classic." Along the thought *of "lift is where you find it,"* lee wave action may simply exist at the lowest levels of the atmosphere and not extend to high altitudes. On many occasions in the Tehachapi Valley of Interior South-Central California, a moderate-to-strong low-level southeast wind flows across a NE-to-SW oriented 1000-foot high ridge just southeast of Mountain Valley Airport. Departing with glider-in-tow into the wind on Runway 09, I have often utilized a "wave bounce" climbing out on the crosswind leg to enhance the tow plane climb rate and subsequently soared in the same area after release from tow as a glider pilot. The "wave bounce" does not extend typically to very high altitudes, but the effect has been observed up to 3,000 feet AGL and often times only a primary wave is usable for soaring flight. While not objectively measured by instrumentation, the line-of-lift runs parallel to the mountain ridge and a small, low altitude atmospheric lee wave appears to be the only mechanism for such lift. Remember that the atmosphere is a fluid so visualizing airflow behavior like one might see water wave behavior downstream from a smooth rock in the stream is advantageous for a soaring pilot to find lift areas in mountainous terrain.

Mauna Kea Wave

While focusing on the features and airflow action associated with the mountain wave, descriptions have concentrated largely on the primary lee wave. However, it is important to remember that the sinusoidal action of the lee wave, if no other terrain influence interferes, can lead to multiple wave crests (and troughs) downstream before the action dampens. In the open Mojave Desert southeast of the Tehachapi Mountains, multiple wave crests are often seen when the lee wave develops. But anywhere in the country that frequently supports mountain wave development, multiple wave crests are often marked by parallel lines of clouds ***(See Photo #2: Stratocumulus Standing Lenticular Clouds over the Southwest San Joaquin Valley)***.

While I have addressed the mountain wave as a meteorologist, I feel compelled to mention a few things from a flight instructor point-of-view in regard to safety considerations:

Per the Federal Aviation Regulations, Title 14, Part 91, visibility and cloud clearance requirements increase in Class E airspace above 10,000 feet mean sea level (MSL) in the contiguous United States. Mountain wave altitudes above 10,000 feet MSL are commonplace and glider pilots operate under Visual Flight Rules (VFR). At those altitudes, the horizontal distance from any cloud feature is mandated to be one statute mile for VFR flight. However, the ability to use lift provided by the mountain wave may not be available more than one mile in front of the rotor/roll clouds or lenticulars. While I am *not* endorsing or encouraging pilots to break this regulation to accomplish soaring flight, I do wish to put the strongest emphasis on *why* that regulation is in place and the safety threat that results from violating cloud separation requirements. Aircraft above 10,000 feet MSL are allowed to fly above the 250-knot speed limit up to Mach One speed. Therefore, a pilot loitering "close" to a lenticular in soaring flight could near instantaneously find themselves in a mid-air collision with any one of a number of fast-moving jet aircraft legally flying under Instrument Flight Rules. I admonish anyone violating this very practical rule to consider the aforementioned situation and avoid the risk of disaster from such a violation!

Stratocumulus Standing Lenticular Clouds over the Southwest San Joaquin Valley

The loss of visual references for VFR flight is ever-present in mountain wave conditions in a couple of ways. Since the presence of cloud features is dependent upon a moist layer of air or sufficient moisture to form clouds in the uplift of the wave, cloud features develop and dissipate as the moisture field varies. An unobservant pilot flying in unrestricted visibility below or abreast of clouds might suddenly find that an undercast quickly forms trapping the airman in VFR-on-top conditions. Since cloud layers can form quickly in the mountain wave, soaring pilots must respond at the first indications of cloud layers developing below them to plan for sufficient time to descend in a safe manner. Further threatening loss of visibility is that of canopy frost! Air temperatures aloft in a winter mountain wave will easily reach 30 degrees below zero Celsius at altitudes above 18,000 feet MSL. In combination with the super-chilled canopy from this very cold air, moisture from a pilot's respiration and perspiration inside a glider cockpit results in sublimation and frost on the glider canopy inhibiting visibility for VFR flight in the least; and in the worst, frost obscures all outside visual references. Be prepared for canopy frost in wave flight by constructing "clear panels" that will keep sections of the canopy clear for VFR flight.

Wind speeds aloft increase with a gain in altitude but the mountain wave is essentially a stationary phenomenon. A pilot will need to increase his airspeed to remain in proper position in the wave as he/she climbs. Aircraft "Never Exceed Speed" (Vne) design limitations are established to avoid aircraft control surface flutter and are a function of true air speed (TAS). With flight at much higher altitudes comes much faster true air speeds and the threat of control surface flutter. Consider even a wave flight reaching a "modest" altitude of 18,000 feet MSL. Applying the old "rule-of-thumb" of a 2% increase in TAS per 1000 feet of altitude gained for the same indicated air speed (IAS), a sailplane flying at 100 knots IAS would have a TAS of 136 knots. Therefore, wave conditions subsequently flown in very high winds aloft pose a threat to the sailplane due to the high TAS experienced in soaring such a wave. Strong winds aloft are often prevalent in the deep winter months when the Jetstream is farther south and speeds are frequently in excess of 100 knots at altitudes above 18,000 feet MSL. Pilots utilizing "wave windows" for soaring altitudes above 18,000 feet must especially be cognizant of their aircraft design speed limitations in relationship to TAS. ☛