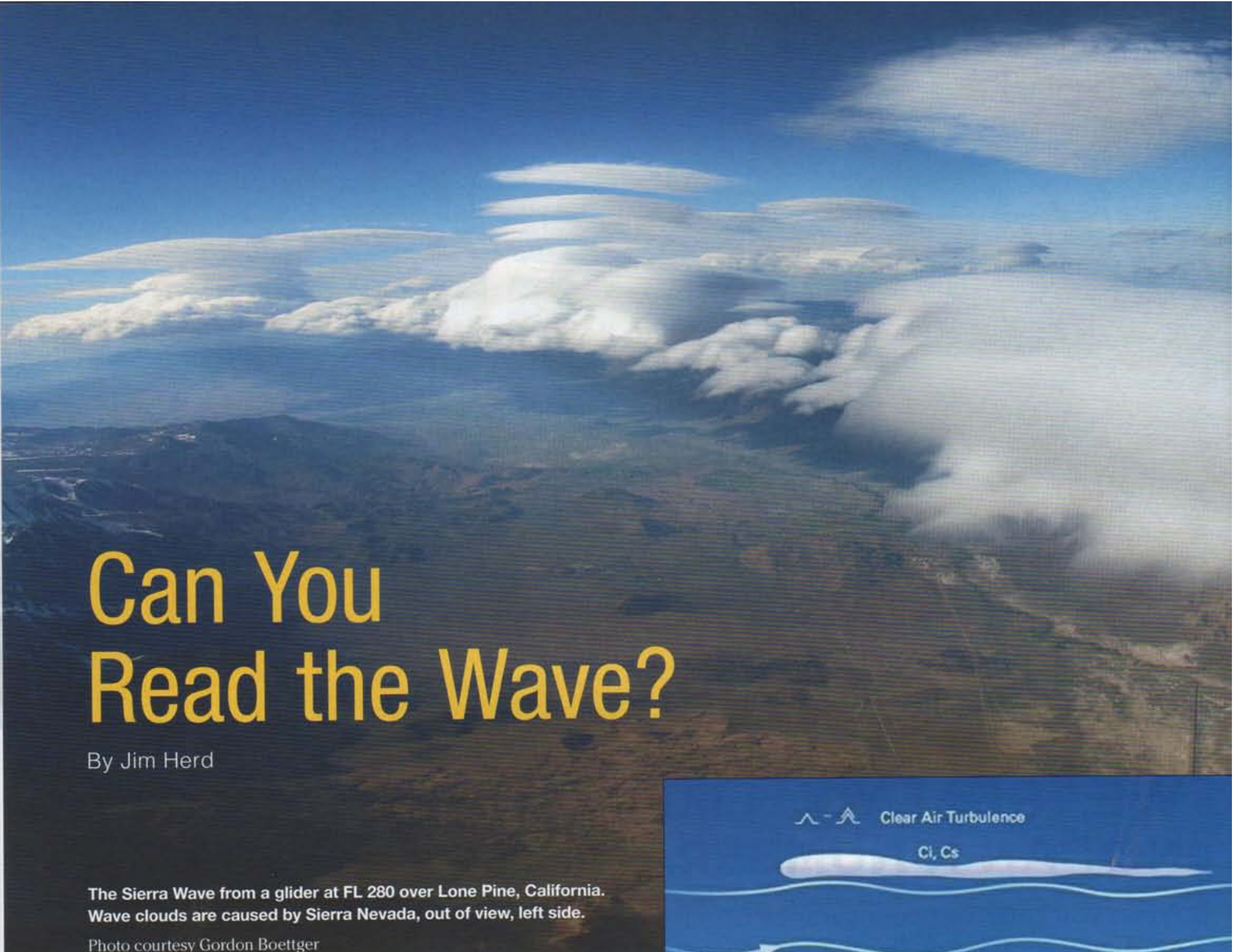

Can You Read the Wave?

By Jim Herd

The Sierra Wave from a glider at FL 280 over Lone Pine, California. Wave clouds are caused by Sierra Nevada, out of view, left side.

Photo courtesy Gordon Boettger

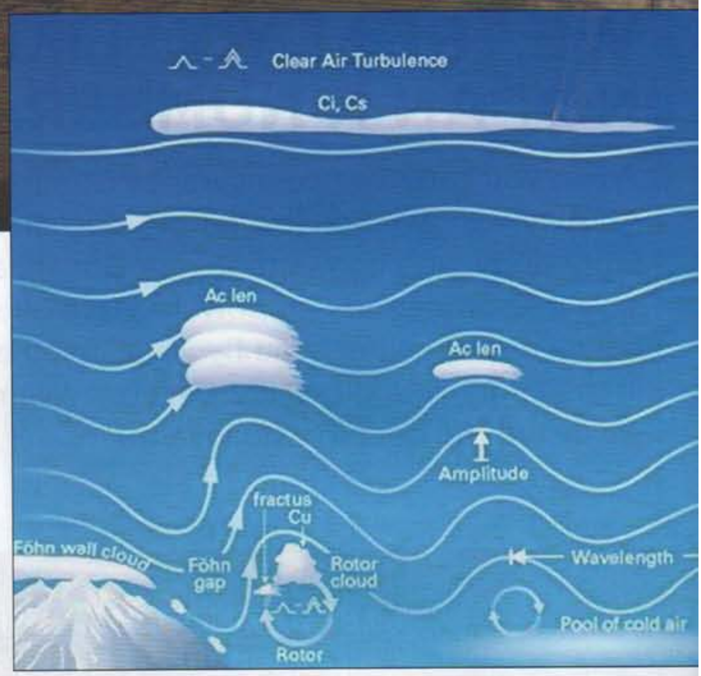

Figure 1: Idealized Mountain Wave Schematic.
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M***ountain wave:*** If you can read the wave, often you can fly the wave – safely, comfortably, and confidently. I hope to convince you of that reality, thereby freeing you from the bonds of remaining ground-bound on mountain wave days or making huge avoidance detours or, worse, getting a very nasty surprise in flight. It is a complex subject and unexpected situations can always arise in aviation, but a rudimentary understanding can help you recognize, anticipate, and avoid the areas of hazardous turbulence. With that, you have intelligent options.

Can you imagine flying from Lake Tahoe to Wyoming (870 miles) with no engine? Or yo-yoing along the Eastern Sierras for a total of 1300 miles in total silence? Sailplane pilot Gordon Boettger made these flights. Or what about flying the length of both islands of New Zealand and then back again, like Terry Delore? All achieved with no engine at altitudes commonly between 10,000' and 28,000' MSL (the RVSM limit). These amazing accomplishments are real, recent, and predictable, though they do require very specific weather conditions that occur somewhat rarely,

and they require the pilot to adjust flight path for conditions that may not permit the most direct route on a cross-country flight. So you can see that positive things can be safely accomplished with mountain wave. If the pilot can read the wave, then no encounter with danger or fear or even discomfort is likely.

I have secured input and endorsements for this article from some of the world's best subject experts. See the reference list below. Sean D. Tucker (world-renowned champion acrobatic pilot) recently earned his glider add-on rating through SoaringNV, and also learned to read and fly mountain wave in Minden, Nevada. He has commented that he can now fly the Sierras in his power plane on wave days, avoiding serious turbulence and even saving fuel by "riding the updrafts."

Mountain wave weather involves tremendous power of nature that must be respected. But there is a key difference when compared with other powerful weather phenomena such as thunderstorms – wave weather is largely predictable (macro and micro), repeatable, readable, and manageable. If you know the terrain (just look out the window or look at a chart) and you know the winds (read your instruments and weather briefings) you can read the wave.

A mountain wave is akin to a fast-flowing stream with a large rock just below the surface. After smoothly rising up and over the rock, the water will then reliably oscillate up and down, just downstream of the rock. Mountain wave is similar, so this visualization is of great help. Another parallel would be when a stream goes through a narrow area – the water speeds up quite dramatically, as does the air when flowing over and through a low pass in mountains. Probably not a good place to be in an airplane.

When you have moderate to strong winds (over 25 knots) flowing roughly perpendicular to mountains that have steep leeside slopes, you have the potential for mountain wave. The eastern side of the Sierra Nevada and the Rockies are the classic U.S. examples, but short and low ridges can also propagate waves. The air spills down the leeside slopes and "bounces" skyward to begin the "primary wave bar" at about three to eight miles downwind of the ridgeline. As the oscillations continue downwind, if conditions are right, the secondary and tertiary wave bars are evident as in **Figure 1**. The remainder of this article boils down to this one simple graphic.

There are two primary factors that suggest mountain wave may be present: steep terrain and strong wind. When your flight plan involves these two factors together, you need to read the wave. If unaware, you are definitely playing with invisible fire – as winds get stronger and terrain steeper, the wave usually gets angrier. There are five principle threats that must be understood and managed, along with rules of thumb that are used by savvy wave pilots (glider and power) to achieve that nirvana we all seek for every flight – safety, comfort, and confidence.

1 ***Strong winds aloft*** – Beware the exaggerated effects on endurance, range, and track/heading versus course line. When cruising along the windward side of lenticular clouds (Altocumulus Lenticular – Ac len) it is particularly easy to get blown downwind into the cloud. The cloud is stationary but the air is not, so you generally will be crabbing upwind. There is also the possibility of clear air turbulence, which can be caused by powerful air masses colliding or by wave bars "breaking," as does a sea surfer's wave. Clear air turbulence can occur anywhere but is more of a factor at high flight speeds.

- Respect your weather briefing, including PIREPs.
- Use proper en route crosswind tracking techniques.
- Check endurance/range frequently in flight if headed into strong wind.
- Keep seat belts tight for a clear air turbulence surprise.

2 ***Major lift and sink areas*** – "Wave bars" will propagate parallel to the line of the mountain range and on the lee side. If conditions are right these "ripples" can repeat downwind, usually for just a few bounces, similar to the rapids downstream of a big rock. If the air is adequately humid there will be the familiar lenticular clouds to mark the bars. On occasion, these bars can repeat a long way downwind. Forward of the leading edge of each lenticular marks the best updraft, with heavy sink on the downwind side. Air can move vertically at 2000 feet per minute or more, and it will usually be seductively smooth.

- "Lennies" indicate lift on their upwind side and sink on the downwind side.
- Watch your VSI and airspeed and keep the macro picture in mind – consider flight path detours.
- Cross the sink bars perpendicularly – downwind escape is much faster. Speed up in sink. [ed. note: Use appropriate engine power and airframe settings to exit strong sink expeditiously but at or below the airplane's weight-adjusted VA. Strong turbulence is likely, and you must be at or below VA to avoid aircraft damage.]
- Low-powered aircraft demand extra vigilance in strong sink.

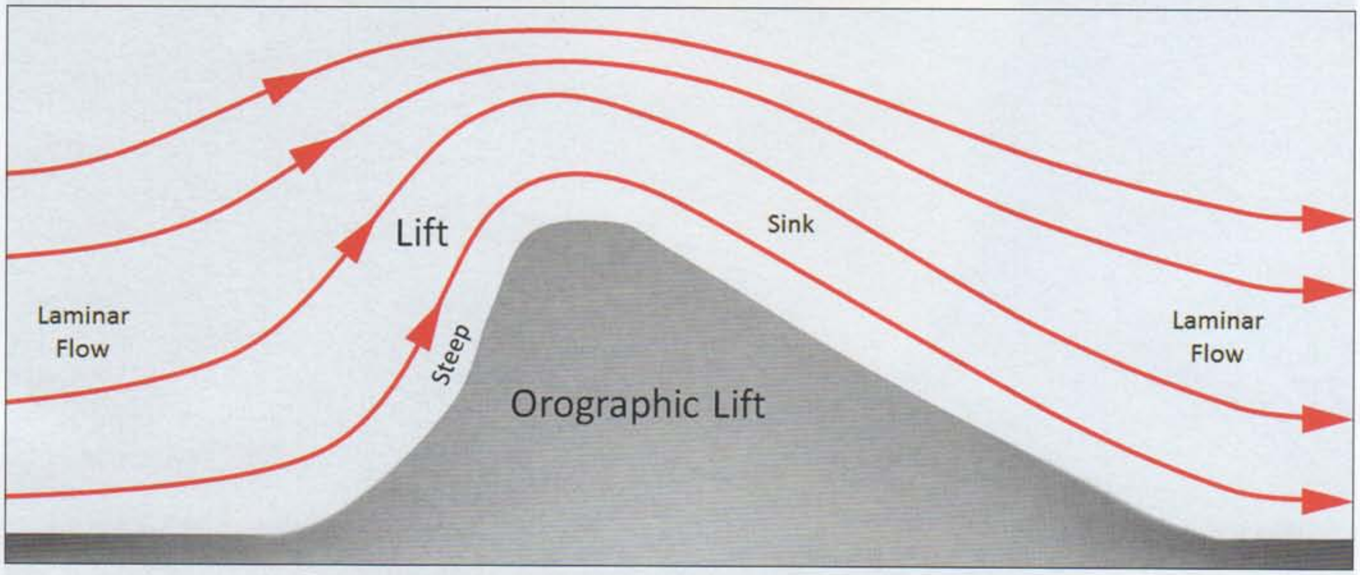

Figure 2: Orographic Lift is directly tied to the terrain. (Reprinted with permission)

- Enjoy the lift bars for "free" height and speed, but avoid over-speeding and busting altitudes.
- If cloudless, use the stream flow analogy to *read the wave.*

3 ***Rotor turbulence*** – This occurs most prominently in the lee shadow of the propagating mountain ridge line. This is a bad place to be in a power plane, and it is the culprit for much of the bad reputation of mountain wave. But again, its location is predictable, within a mile or two on the lee side and within a couple thousand feet AGL, and this is distinctly separate from the lift and sink bars.

- Rotor clouds often look "wispy" and/or angry – stay away.
- Never fly close to terrain on the lee side.
- Remain 2000 feet above upwind terrain.
- If rotor is encountered simply control airspeed (green arc – I like 100 KIAS in my A36) and attitude and turn away – escape downwind and away from terrain if possible.
- Rotor turbulence will be confined to a small area but may also be associated with, and below, secondary or tertiary wave bars.
- Rounded terrain won't usually generate much rotor turbulence.

4 ***Mechanical effects*** – Flying close to terrain, even if it is flat, is similar to a shallow stream flowing over a rocky bottom. There may be a lot of choppy turbulence.

- Never get low and close to terrain – minimum 2000 feet above.
- Cross ridge lines a minimum 2000 feet above and perpendicular to the ridge line, with an escape route.

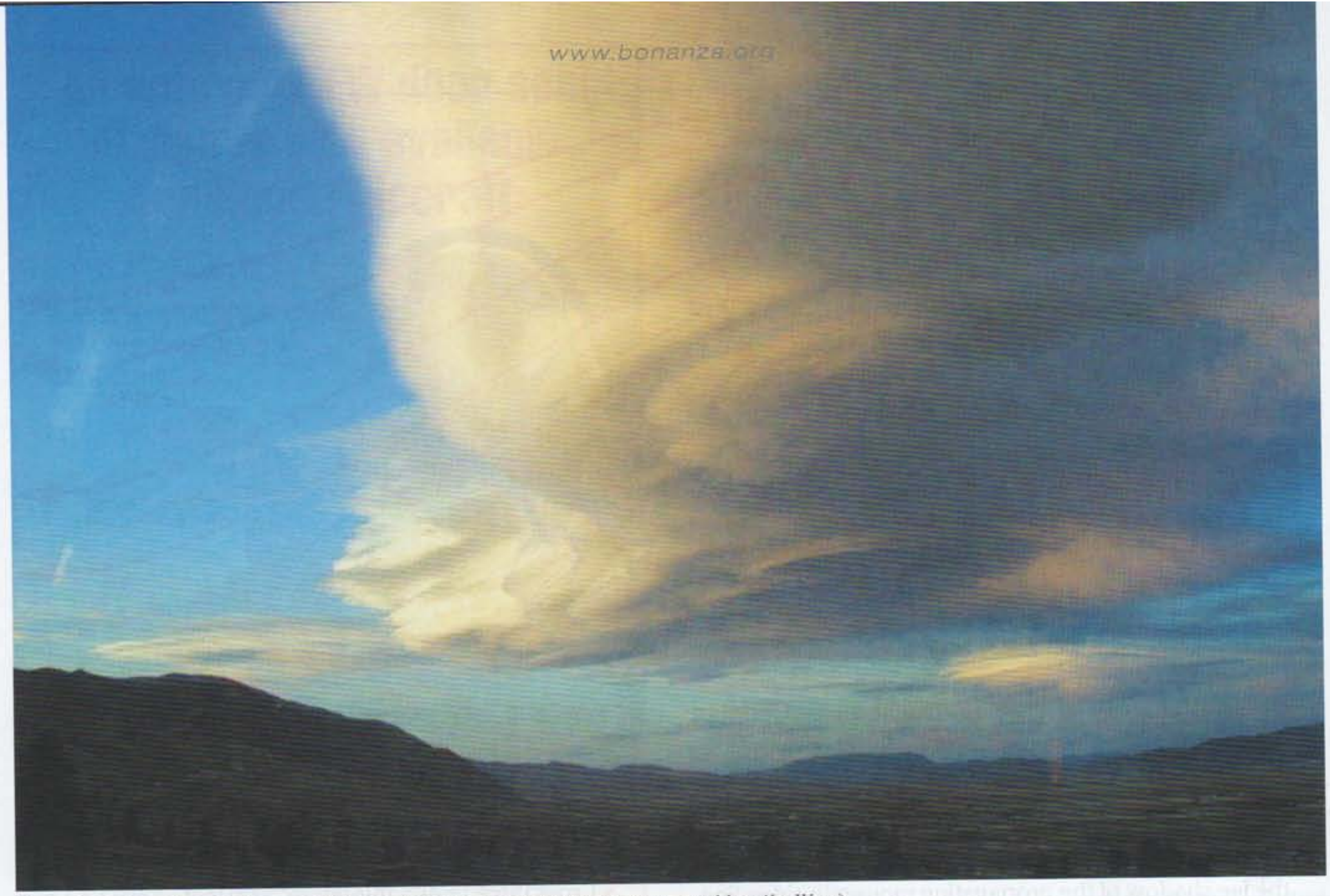

Figure 3: Classic Lenticular over Minden, Nevada, recently. (Photo courtesy of Jennifer Ware)

[ed. note: Virtually all mountain flying resources call for crossing ridges at least 2000 feet above the highest peak and *at a 45° angle*, to reduce the amount of turn necessary to escape an area of sink, and permit turning back to the side of the pass from which you came if you encounter sink immediately after crossing the ridge].

- Stay away from narrow passes.

5 ***Landing and taking off*** – This is a critical segment of flight that requires the pilot to read the wave when downwind of big terrain. There is an added element beyond strong/cross/gusty surface winds. The rotor is highly variable and can reach down to the ground, where it can cause extreme turbulence and fluctuations in runway wind speed and direction over just a few seconds.

- Anticipate sudden, extreme wind shift near ground in the lee shadow of high and steep terrain.

Figure 4: Lenticular clouds developing over associated rotor clouds at Minden, Nevada. Note blowing dust. (Photo courtesy of Jennifer Ware)

- Observe wind conditions for at least 15 minutes before any flight decision.
- Consider an alternate airport if landing, or cancelling the flight if departing.
- Seek smooth lift or sink bars to climb or descend to/from cruise altitude.

Things are not always textbook, so caution is always advisable with any powerful weather scenario. When mountains and ridgelines are not orderly or the wind direction is oblique, the air flow may be "confused." Wavelength is variable – longer with stronger winds. And wave is less likely in summer because it is disrupted by instability and thermals. It can be fun figuring it all out in flight, and it is smart to set personal limits based on real conditions. Start by setting wide safety margins, commensurate with your training, skills, and experience.

We must differentiate two other phenomena that often get confused because they, too, involve strong winds and mountains. "Cap clouds" are sometimes seen as lenticulars "capping" peaks. These are easily avoided, and if no cloud is evident you still want to stay away from peaks in strong winds. "Orographic ridge lift" occurs on the upwind side of mountain ridges and only exists close to the terrain, so simply stay away from these localized areas in strong wind. Mountain wave is very different because it appears to "detach" from the

The fatal crash of a 58P driven into terrain from 18,000 feet ("Safety Pilot," October 2014) was attributed by NTSB to a mountain wave encounter (*www.ntsb.gov* report CEN09FA097). It was likely the result of entering such an area of sink and either failing to immediately execute an escape turn, or entering mountain wave without assuring that it was always possible to turn and descend out of the wave while maintaining terrain clearance. ABS plotted the course of the fatal flight in question. When approaching the ridge where the flight ended, the course was almost parallel to the ridge line, on the leeward side. He was in essence trying to maintain course and altitude in the breaking part of the wave. The performance of the plane could not overcome the sink. A simple turn left or right would have most likely solved the problem.

Figure 5: Satellite view of wave bars propagated far downwind of the mountain source. (NOAA photo)

terrain for many miles downwind, and the rotor harbors the most serious turbulence. If there are no telltale clouds it can be difficult to read the wave, but the guidance above will reveal what is going on.

There is tremendous benefit from getting a glider add-on rating and experiencing mountain wave with a fully qualified wave instructor who can show you how to safely soar the wave. Not interested in the add-on rating? Then at least take a glider ride in wave. The soaring businesses below offer special training for power pilots. Or get in your own plane with a competent wave pilot and explore the wave and all its glory. You will learn to read the wave quite well after just one flight. Your future passengers will be astonished at how you can predict the lift, sink, and the onset of a bit of turbulence that can be "dabbled" without fright.

The fear of unknown "bad air" that may be just ahead almost vanishes when you can read the wave. You will know when/where to go, and when not, based on rational personal limits. When winds at ridge tops and below are 40 to 50 knots, I stay on the ground.

Article reviewed and endorsed by:

Sean D. Tucker – Perhaps the most internationally recognized contemporary air show acrobatic pilot.

Terry Delore – Many world records in gliders in mountain wave around the world, and partner with Steve Fossett for most of his soaring records.

Gordon Boettger – Active ATP and wave soaring expert based at Minden, Nevada.

Gavin Wills – Internationally recognized mountain wave instructor and proprietor of the premiere soaring school in New Zealand – Glide Omarama. Also a pioneer power pilot in the New Zealand Southern Alps on wheels and skis.

For further study:

- SoaringNV: *www.soaringnv.com*
- Glide Omarama: *www.glideomarama.com*
- OSTIV: *mwp.flightplanner.info/Beschreibengl.htm*
- Perlan Project: *www.perlanproject.org*
- *Exploring the Monster* by Robert F. Whelan
- *Meteorology for Glider Pilots* by C.E. Wallington