WEATHER TO FLY

BY DAN GUDGEL

RIDGE LIFT

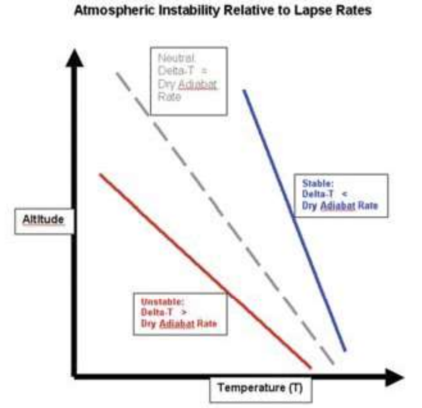
The atmosphere provides vertical air motion or atmospheric lift in various forms and thereby provides the "engine" for soaring pilots to accomplish cross-country flight. In the introduction article of "Weather to Fly," I listed four mechanisms of atmospheric lift used for soaring flight: ridge, thermal, mountain wave, and convergence. We begin our discussion of these specific lift mechanisms with a focus on ***ridge lift*** or the mechanical lifting of air as it encounters the upslope of terrain.

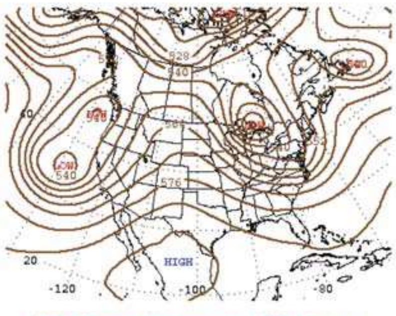
Many of us in the soaring community have heard the general public reference successful soaring flight associated only with the presence of strong wind as if no other lifting mechanisms exist in Nature. Even among soaring pilots this mechanical lift has several names, i.e., ridge, slope, hill, and orographic. Referencing the *Glossary of Meteorology*, orographic lifting is "the lifting of an air current caused by its passage up and over mountains." More specifically, the rise or updraft of air passing over terrain begins on the upwind or windward side of terrain obstructing horizontal air movement (wind).

The development and persistence of useful ridge lift is a function of several factors: atmospheric stability, wind direction and speed, and terrain shape. Ridge lift utilization for soaring flight also must consider atmospheric moisture as the lifting process subsequently can result in cloud formation affecting the ability to maintain visual flight rules and meet cloud clearance requirements. For purposes of this specific article, the development of clouds will not be addressed except with the admonishment that the lifting process can develop instrument flying conditions on a ridge.

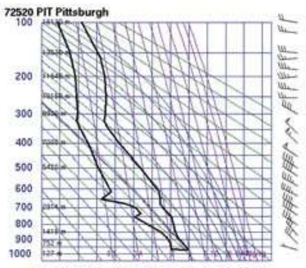
Strong, "classic" ridge lift is characterized by smooth, upward motion on the windward side of slopes, hills, and ridges. For long-distance soaring it requires a synoptic scale meteorological scenario (scale size of 100s if not 1000s of miles). The atmosphere stability is ideally neutral or toward that of being stable. By meteorological definition, a stable atmosphere is one where air disturbed from a given altitude by terrain will want to return to its original level after passing over that terrain. Relative to the rate of decrease in air temperature with an increase in altitude, or lapse rate (*), a stable atmosphere is one where the existing lapse rate is less than the dry adiabatic lapse rate *(see Diagram #1: Atmospheric Instability Relative to Lapse Rates)*. Any disturbance of air forced upward flowing over terrain in an unstable atmosphere would not result in smooth, laminar-like, terrain-formed lift. Instead, the terrain lifting the air would simply act as a trigger for the atmosphere to "turn-over" and rise in pockets, i.e., thermals! The atmosphere becomes neutral in its stability with the presence of stronger winds that mix the atmosphere thoroughly at the lower levels. Neutral stability means that the temperature lapse rate equals the dry adiabatic lapse rate (in unsaturated or clear air). [The development of cloudiness due to ridge lift in a sufficiently moist air mass does change the air's stability characteristics with the energy release from condensation. This will be discussed in a forthcoming article.] Because of strong but steady wind speeds, long-distance flights using ridge lift are commonplace near long mountain ranges around the world. Slope soaring is still possible in an atmosphere tending toward unstable but turbulence from shear in transition between thermals and smooth ridge lift makes for widely varying lift rates and uncomfortable flying conditions. Too much atmospheric instability eventually leads to destruction of steady, reliable ridge lift, as the development of thermal lift on the slope becomes the dominant atmospheric lifting mechanism.

The typical weather scenario for classic ridge soaring in the U.S. is following cold-frontal passage in a mid-latitude wave (Low Pressure with its associated fronts) across the Appalachian Mountain Ranges. A good example of such a scenario for ridge lift occurred on April 4, 2006, *(see Surface Weather Map and 500mb Upper Air Chart)*. The associated post-frontal temperature sounding for Pittsburgh is also provided *(see Upper Air Profile)*. Behind the cold-front surface pressures rise ahead of the oncoming High Pressure center with an axis of higher pressure extending eastward over the mid-Atlantic area. While the atmosphere tends toward unstable near Low Pressure centers and fronts, the atmosphere tends toward stabilizing with the presence of higher pressure. The reason for this stabilization of the air is the associated sinking or subsiding air within and ahead of the High Pressure center. Concurrently large pressure differences (the pressure gradient) between the High center and the departing Low center support strong, low-level or surface winds. Steady surface wind speeds and wind direction chang-





500-Millibar Height Contour at 7:00 A.M. E.S.T.
500mb Upper Air Chart; April 4, 2006

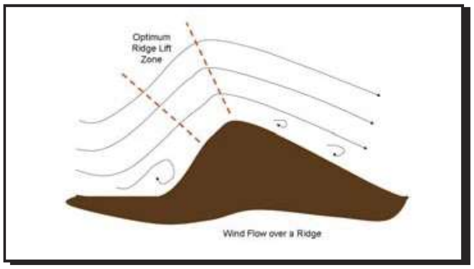


Upper Air Profile; Pittsburgh, PA

ing minimally with altitude, and an atmosphere tending from stable (for lower or threshold wind speeds) to neutral stability (with stronger wind speeds) provides the atmospheric ingredients for development of consistent ridge lift. The temperature profile from April 4, 2006, depicts a generally neutral atmosphere in its stability with wind speeds in the 30-40 knot range below 10,000 feet. [Note the presence of a surface-based nocturnal temperature inversion and the light wind right at the surface on this sounding. This inversion soon broke after the sounding was taken with higher winds aloft mixed to the surface at that time.]

Wind direction for slope lift should be within 10 to 20 degrees normal or perpendicular to the disturbing ridge or range axis with some references indicating that oblique angles up to 40 degrees could generate ridge lift. Wind direction aloft should only gradually change with an increase in altitude. Generally, a wind speed of 15 knots impinging on a mountain ridge or range is considered a typical threshold value for ridge lift considerations. The upward air motion generated is up to 6 feet per second or 360 feet per minute (fpm), that results in climb rates of 200 fpm for even moderate performing gliders. However, wind speeds less than 15 knots with good atmospheric stability conditions and smooth slopes do generate lift sufficient for gliders with a lighter wing loading. A moderate terrain slope of 30 degrees can provide lift for soaring flight with a wind speed of 10 knots.

Having discussed atmospheric stability and wind characteristics, we need to discuss the orographic or the physical nature of the terrain. Unlike the meteorological aspects that can be objectively defined, terrain features can be difficult to describe in absolutes in their influence on ridge soaring. The slope as well as shape of the terrain affects the flow of air over and around mountains.



Wind flowing over a ridge is arguably the easiest of the various forms of lift to visualize as used for soaring *(see Photo and Diagram #2: Wind Flow over a Ridge)*. Because the atmosphere is a fluid, and therefore behaves much like water in a stream flowing over rocks, a soaring pilot need only pay attention to wind direction at the surface and at the lower atmospheric levels to have a good idea where ridge uplift can be found. Slope lift generation is a function of both wind speed and terrain slope. The greater the slope of the terrain and/or the higher the wind speed, the stronger the lift. Like water flow, air passing over terrain will show its greatest lift rate on the windward side of the hill. The lifting zone extends upward and outward from about 45 to 30 degrees off the vertical from the best angle-of-rise on the terrain disturbing the wind flow. Generally, the best lift is found even with the brow or top of the hill. While shallow slopes may not provide enough lift to support soaring, too steep of a slope can result in the formation of turbulent eddies that make slope soaring difficult or impossible at lower points along a ridge, thereby limiting useful soaring only to the area adjacent to the ridge top.

"Eddy" or turbulent wind currents pose challenges for the soaring pilot in several ways. By their turbulent definition, they are variable in direction, speed, and size. Terrain undulations or irregularities lead to the development of eddies on the windward side of the hill in areas that one might otherwise expect smooth uplift. Wind eddy presence also poses a danger in the form of wind gradients across the wingspan of gliders operating in proximity to the terrain. Similar to terrain providing lifting action and possible eddies on the windward side of a ridge; the lee or downwind side of a ridge provides for downdrafts and leeside eddy currents. Again, by definition, a stable atmosphere is one where air disturbed from its original altitude will want to return to that altitude. Because of the neutral to stable conditions of the atmosphere that provide ridge-lift conditions, soaring pilots need to plan for heavy sink on the lee side of a ridge as air tries to return to its original

altitude before it was lifted on the windward side of the ridge.

In summary for our weather-to-fly, Slope soaring courtesy of the World Meteorological Organization's *"Weather Forecasting for Soaring Flight"* cites three factors that help to determine ridge lift conditions: 1) The stronger the wind flow, the greater the tendency for air to flow over rather than go around a mountain barrier; 2) Air with neutral stability has a greater tendency to flow over a small barrier while stable air would seek to flow around a such a barrier; and, 3) Air flow tends to go over wide barriers, while it will seek to flow around small or narrow barriers. More insight is provided from Helmut Reichmann in *"Flying Sailplanes."* Favorable terrain features are also where the terrain undergoes a gradual steepening of the slope from the valley floor and there are no obstacles to the wind-flow upwind of the slope. The smoothest ridges also provide the best flights using ridge lift. Varying amounts and heights of trees or irregular slope features on the ridge slope affect surface friction. With this increased friction, eddies form that weakens the ridge lift. The greater the turbulence, the deeper the layer of eddies and disturbed flow along the slope. For more information on mountain flying in respect to ridge lift, suggestions can be found for soaring in and around complex terrain in Dale Masters' book, *"Soaring Beyond the Basics."*

(*) The Dry Adiabatic Lapse Rate is a physical constant. From the *Glossary of Meteorology*, it is defined as "the rate of decrease of temperature with height of a parcel of dry air lifted in an adiabatic process through an atmosphere in hydrostatic equilibrium." The decrease in temperature with altitude in this atmospheric constant is 3-deg.C./5.4 deg.F. per thousand feet or in the metric system 9.8 deg.C. per kilometer. [Author's note: A parcel of air is a fixed mass of air. Within an initial volume no energy is added to or taken away from the parcel's mass as it moves vertically (up or down) in the atmosphere.]

Acknowledgement:

Thanks to pilot *John Good* in providing background and comments on a fine example of a long-distance soaring flight using primarily ridge lift on the Appalachian Ranges on April 4, 2006, in which he set a U.S. Standard Class Record. John Good, Richard Kellerman, and John Seymour flew from Eagle Field to Tazewell, VA, and a point south of Charlottesville, VA, for a 1049 km triangle. Karl Striedieck also flew long distance on the day.

References:

"Glossary of Meteorology." American Meteorological Society, Edited by Ralph E. Huschke, c.1959.

"Flying Sailplanes," Helmut Reichmann, Thomson Publications, c.1980.

"Meteorology for Glider Pilots," C.E.Wallington, John Murray Publishers, c.1961.

Library Build:

"Glider Flying Handbook," FAA-H-8083-13, FAA/ Gov't Printing Office, 2003

"Soaring Beyond the Basics," Dale Masters, c. 2006

"Weather Forecasting for Soaring Flight," World Meteorological Organization Technical Note #203; WMO-No.1038; c.2009.

How Do I Know When to Expect Ridge Lift?

Understanding the conditions necessary for ridge lift development, go to the following web locations to grasp the synoptic scale weather situation and upper air temperature profile:

– NOAA/NWS Aviation Weather Center, www.aviationweather.gov
    – On the Left Side Menu, under "Forecasts": Click ***Prog Charts"***
        – Choose the time period for a surface chart forecast at your flight time
– Unisys Weather Data Site, www.weather.unisys.com
    – On the Left Side Menu, under ***"Analyses",*** click ***"Upper Air Data"***
        – In the menu that shows on the right side, click ***"Upper Air Sounding Plots"***
            – Choose the upper air site upstream and likely to be representative of the post-frontal air mass for your intended flight area
    – You may also use this URL/Web Address to look at current upper air plots of the observed weather at specified pressure levels of the atmosphere.