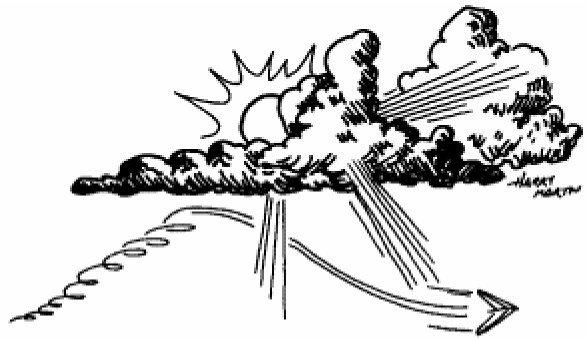
Thermal Lore - Part 1

by Dennis Pagen (copyright © 2002), published in USHPA's publication "*Paragliding*" November 2002.
All illustrations and figures are from USHPA.

Soaring pilots live and dream under the thrall of thermals. Sure, ridge lift lets us zoom around and play local hero, waves are a gift from the gods and convergence is a magic carpet when you find it. But only thermals are consistently present and readily exploitable by even newly fledged novice pilots. Thermals are intriguing because they are mostly invisible and they can take us to dizzying heights, in some cases higher than big brother wants our tender wings to go.



Another aspect of thermals is that they reward the development of certain skills, but involve an element of dumb luck. Just as with fishing or picking up a new romance at a party, you can never be 100% sure about what you're going to come up with when you go trolling. It is that element of expectation and surprise that adds spice to the endeavor. With thermals, we cast our net based on knowledge and how much height we have to spend, then hope for the best. The fact that it so often pays off is a tribute to our glider's performance, the wealth of knowledge that has accumulated in the flying community and the abundant lift that nature affords. Many of us wish that fishing for seafood or mates had such a high rate of return.

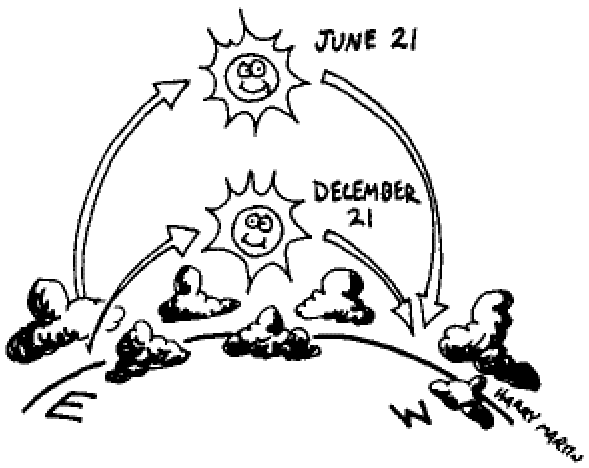
This series of articles is intended to illuminate the many aspects and peculiar behavior of those elusive entities we know as thermals. The idea is to promote better flying through knowledge. Hopefully pilots of all skill levels will find some nuggets to carry with them into the wild blue yonder. My approach will be to try to avoid too much technical detail, but offer references for those who wish to delve deeper. I believe this format is appropriate for the vast majority of pilots, since much of thermal flying is (and should be) intuitive. But we do need a solid groundwork on which to let our intuitive nature roam free.

Much of what we discuss will come from conversations with the world's top pilots, but also an important source has been research papers written on micrometeorology. These papers most notably appear in the OSTIV publications, which is dedicated to the technical aspects of soaring (sailplanes). In the last decade or so there has been much interest in micrometeorology because of the development of drones, surveillance aircraft and other small flying objects. I’m dubious about the uses of these craft, but grateful for the advancement in understanding.

In the course of this series we will visit the subjects of thermal development, shapes, behavior, types and ways to exploit them. We will also look at special thermal situations such as the cause of cloud suck, the “dead zone,” high-pressure thermals, East and West differences and inversion encounters. Hopefully we will touch on some of the very core material that will make each of us a better thermal pilot, or at least informed enough to know why we hit the ground while others are scribing taunting zeros high over our heads.

THE THERMAL DAY

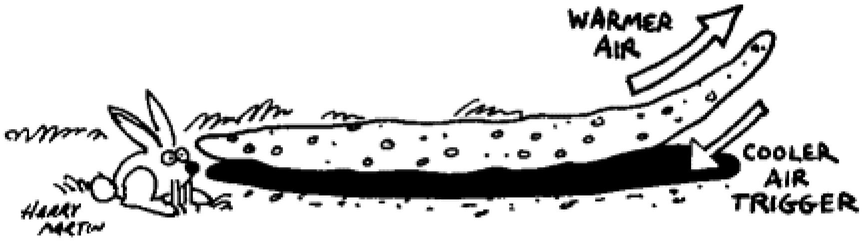
Without going deeper into matters such as lapse rate and insolation right now, let’s look at the broad picture of how a thermal day develops. Most of us know that the air mass sitting over our area must be relatively unstable for thermals to exist in abundance or usable form. What we mean by unstable is a certain temperature change in the air with changing altitude. On an unstable day, thermals rise spontaneously once solar heating gets underway and heats the surface adequately. Here’s the sequence:



1) The sun’s energy, in the form of visible light and ultraviolet radiation, mostly passes through the atmosphere and strikes the ground. The solid molecules on the ground catch the solar radiation and convert it to molecular vibrations and much longer wavelengths — infrared. We detect vibrations and infrared radiation as heat, and so does the overlying air. It is the transfer of heat from the sun to the ground and then to the air that allows the creation, birth and growth of thermals. Thus, solar energy gives rise to all life, including thermals that are born in the heat of the day.

2) In the morning, as the air overlying the surface gets heated, not much happens as a thin layer thickens and grows warmer. A slight sloshing around may occur here and there, but no real thermal activity happens until suddenly, all heaven breaks loose — thermals happen everywhere. What’s going on here? The answer is that ground inversions stop the release of thermals until they have penetrated to the top of the inversion (we’ll discuss the nature of inversions in a later part). However, once this penetration occurs, the thermal release comes all of a sudden and from widespread sources.

3) The abundant release of thermals may continue for half an hour or so, then frequently it shuts down for a spell before thermals reappear in earnest. After that, a more sparse but regular production of thermals occurs. This is when the thermal day sets in properly and we are apt to be successful when we cast our fate to the wind. The mechanism that causes the thermal production pause, then the more regular succession of thermals is as follows: The warming ground in the morning heats a large area (almost the entire layer) of air over the surface. Thus, there is a large reservoir of warm air to go up as thermals. But this air can't release because of the ground inversion. When the bonds of the inversion are broken, the thermals release with a vengeance. These early thermals may not be all that strong because the sun isn't yet beaming down all that hard, but they come in rapid succession and often are fairly continuous streams as the warm air on the ground seeks restitution aloft.



But when the warm air is depleted, it has been replaced by cooler air from aloft that takes time to heat. So we have a pause. In addition, without the presence of the widespread ground inversion, the thermals that do build can release when they grow to a certain size, or they are induced to do so by triggering mechanisms. The most common triggers are downdrafts impelled by the rise of other thermals in the area. Thus, we have a picture of a steady-state growth and release of thermals as long as the sun's heat continues in sufficient strength. The size of the thermals depends on (among other things) how long they sit on the ground and grow before release. The initial release, then pause in thermal production, is often seen in the ridge and valley systems in the eastern U.S.

4) As the day progresses, thermals tend to climb higher and peak in strength just a bit after the peak solar heating. Then they dwindle in strength and frequency but still retain their maximum height. Finally, only a few anemic old-maid thermals rise as the sun wanes and our soaring prospects dim. In the end, only dreams of the day's glory remain unless special situations occur that continue to result in the artificial release of heat from the surface. (The artificial matters may be buildings with internal heat sources, fires or water heated by some means other than the sun's rays.)

5) As evening falls, the moon rules and the earth loses what it has taken from the sun. The heat re-radiates off as infrared, and this effect sustains the warmth of the air for a while, but with no new solar heat to tickle the earth's surface, the surroundings soon grow colder. Then, the air stills, chills, and a ground inversion layer develops. This layer thickens throughout the night until the sun again peeks over the peaks and warming begins again. The cycle is complete.

ADDING DETAILS

Ground inversions can be anything from a few feet to a few thousand feet in thickness in extreme cases. The thickest inversions occur in deep valleys in desert conditions. The reason for this situation is that desert conditions result in rapid and extensive radiation of heat from the surface because of the clear, dry air, and thus a much colder overlying layer. The high mountains surrounding the valleys drain these layers of cold air down into the valleys all night long until a blanket of cold air is pooled deeply in quiet repose.

The thicker the ground inversion layer in a given area, the longer it takes to reach trigger temperature, which is where thermals break through the inversion in the morning. However, in desert conditions the sun's heating is comparatively more intense, so trigger temperature is reached relatively sooner than in humid areas. In addition, thicker inversions often result in a longer initial release of thermals, and in this case there may be no pause between initial release and the onset of regular thermal production. The reason for this latter factor is that the thermals developing in a thick inversion are already rising high enough to promote the vigorous downdrafts that can trigger other thermals building on the ground. Thus, once the thermals begin their initial rise to full potential, the process continues unabated. This situation is often noticed in the Owens Valley and the Alps.

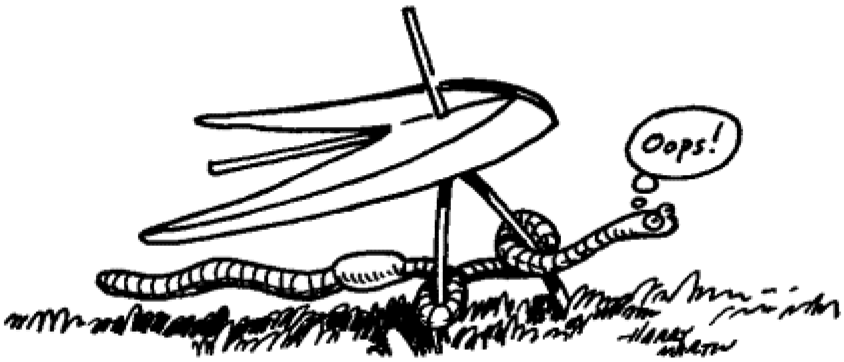
THERMAL STRENGTHS

There are a number of factors that affect thermal strength. These are in two main categories: the temperature profile of the air and the intensity of the solar heating. Let's look at the heating factor first.

The more readily a surface on the ground is heated, the more it imparts this heat to the overlying air. Thus, we should expect to get good thermals above such surfaces. Take a barefoot walk across the landscape on a sunny day and see what you feel. Did your feet get burned on that blacktop? Did you enjoy the cool of the grass? How about the medium heat of bare dirt or fields in crops? We know from experience and common sense that the surfaces that heat most are more likely to produce the best thermals. But we also know that no surface stands alone. Everything is affected by everything else surrounding it, because the atmosphere is a dynamic system. It is moving and three dimensional, so sometimes an area that would normally be excellent for thermal production is constantly being swept with cooler winds or stable air and thus does not live up to its potential. One such situation is beach areas. We have all burnt our feet on those littoral sands, but beaches are rarely great thermal producers because the constant inflow of the cool, stable sea breeze attenuates the effects of the heated surface.

A big factor in intensity of heating is the humidity in the air. When the atmosphere is dry, the solar influx goes right to the ground with nearly its full power. But in humid conditions, a good portion of the solar radiation gets scattered by the suspended water molecules, so the air itself takes up heat and less is available to heat the surface. You might think, "That's okay, what we want is heated air and we just bypass the surface exchange in this situation." Unfortunately, that's not true. What happens in the case of humid air is that the sun's beaming heat is scattered deeply throughout the air's layers, so we don't have the potentially unstable situation of a warm blob at the bottom of cooler overlying air pressing down. In fact, the hot, humid, summer doldrums are what we Eastern pilots dread, because the few thermals that do develop are weak. In the case mentioned here it should be apparent that there are many factors that affect both the amount of surface heating and the lapse rate.

Two more factors that affect the solar heating of the surface are the sun's position and the amount of cloud cover. We acquire an almost unconscious knowledge of the sun's diurnal variation. We all know that only mad Englishmen and dogs go out in the heat of the day in the heart of Africa. So we know that the peak heating at the peak of the day provides peak thermal production. But put a little fudge factor in there because there is a lag in the whole process, so peak thermal production usually occurs a half hour to an hour after maximum sun height. Speaking of sun height, we should all be aware that June 21, when the sun is at its peak height, and December 21 when it is at its low point, are the acme and nadir of thermal production, all other factors being equal.



Clouds affect solar heating of the surface and thus thermal production simply by blocking the sun's rays and scattering or absorbing the energy. Cumulus clouds denote thermals rising, so we are happy to see them around as long as they don't throw a wet blanket on our fun by overdeveloping into sunshine-robbing shrouds. Clouds in general reduce the strength of thermals, as well as their abundance. They also alter thermal behavior. A broad, weak, stratus cover may make the day less punctuated with thermal exclamation points, but also make the thermals more regular as the thermals spend more time building on the ground and are less interrupted by vigorous, cool downdrafts. We've also seen it happen that the approach of a stratus layer is accompanied by pre-frontal unstable air, so the thermals actually get stronger even as the solar insolation weakens. So, you can never talk absolutes in this game, which is what makes it a game in the first place.

WHAT YOU CAN USE

This article speaks mostly in generalities in order to set the stage for our later discoveries. However, we can still glean a few straws of learning from the general discussion. Perhaps the main point to recognize is that at many sites it is a normal process for the first thermals of the day to happen in the morning, anywhere from 10:00 AM to 11:59 AM. Then, after a flurry of thermal activity, things die down and nobody stays up until a bit later when the thermal day begins in earnest. It is important to recognize this occurrence, because you don't want to be the early bird who gets to be in the landing field feeling like a worm. Learn to understand the behavior of your own site(s) in this regard. Does it happen nearly every good thermal day? Does it never happen? What are the conditions when it does happen? (Hint:

Clear nights with little upper wind, so a deep ground inversion forms. Note that these are the same conditions conducive to dew and frost formation.)

Once you have figured out your sites, carry your newfound awareness with you when you visit other sites. As you gain knowledge and experience you will perhaps be able to predict thermal behavior at other sites. It is this type of understanding that helps create great pilots, for after all, a great pilot is just like you and me but with more skill, more knowledge and more luck. I just wish there were some way to work on the luck factor.

We bypassed the discussion of lapse rates to avoid over-complicating this first installment. But next time we will give the subject its due, because it is important to the understanding of how thermals really work. For more information on the matter of solar heating, and thus thermal production daily variation, see *Understanding the Sky*, beginning on page 189.