06/2013 RVS

Rev 1

Thermalling Helper

Thermalling Helper

Ok, I can now solo; maybe I should learn more and practice thermalling

Forward

Any impression of originality in the following is purely coincidental. This is *strictly* a compilation of some of what has been presented by a number of acknowledged experts, and is confined to just this one of many topics germane to the sport of soaring. I occasionally did some 'paraphrasing' and changed a little 'technician's' wording to my own, while hopefully keeping the same meaning. I strongly recommend doing your own research, starting with the FAA Glider Flying Handbook (GFH) and Wander's 'Art of Thermalling'. In short, what I've tried to do here is eliminate the 'chaff' from the worthy ten references used (Section 7) and still keep it readable. More experienced soaring pilots may understandably take issue with some content. I hope, for every one of those, five *inexperienced* members learn something they didn't know which they can now go out and practice.

The way I generally went about compiling the *techniques* portions of this Helper was to start with the fundamentals best expressed in one of the references and then integrate material from the remaining references, emphasizing the use of pictures/diagrams. Throughout the cut-and-paste nature of this article, it'll be hard to miss redundancies and even a contradiction or two; just more evidence that soaring is at least as much art as science. Note how often the authors used words like, 'may', 'probably', 'sometimes', 'usually', etc. They don't even agree on the spelling of thermalling (or is it thermaling) !?

Another approach: After a few months, I have realized that, as originally put together, this tome can be a bit eye-watering. So, an important purpose of Revision 1 is to offer a couple of quick&easy reads to at least get a start:

1) http://www.gliding.co.uk/bgainfo/aim%20higher/Howtothermalbetter.pdf
2) http://www.gliding.co.uk/bgainfo/aim%20higher/Gettingtothecoreofclouds.pdf

Then, if you still don't feel like plowing into fifty-some pages (although the number is misleading), next go to Section 6, a one-pager.

Rev

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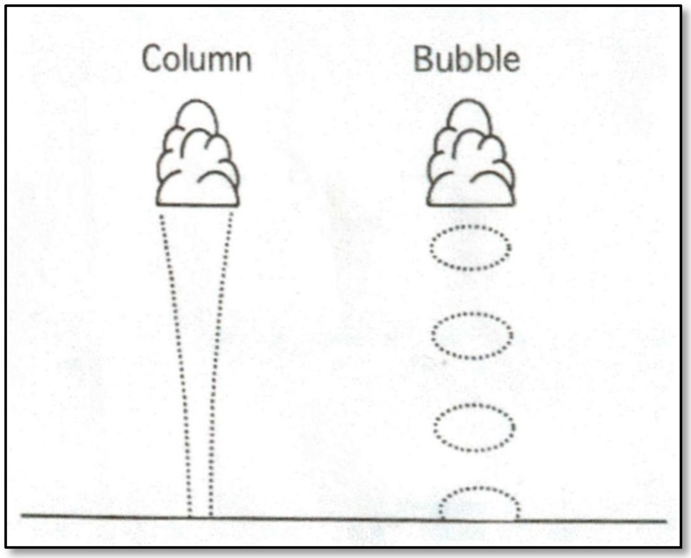


Figure A

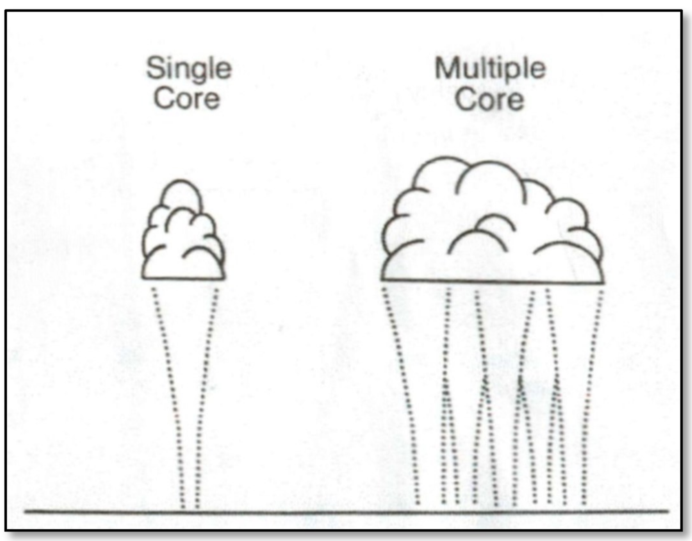


Figure B

Section 1. What are thermals?

"Thermals are like people in many ways. They all share some basic characteristics by definition, but each one is different."

There are conceptual models that help us visualize what a thermal looks like, if we could see it; the bubble model and the column model are two of them. But everything we know about atmospheric flow points toward a reality for which no model is fully accurate.

Experience shows that many thermals act like a column of rising air. But, some thermals behave more like bubbles, where the warm air forms either a single bubble or a series of bubbles (Fig A). Most thermals probably fall somewhere in between these two models.

The 'classical' thermal is under a well-developed Cumulus cloud (Cu) which has specific characteristics (dome shaped and dark base, and sharp, well defined, cauliflower tops). Only one in three (dry day) or one in four or five (humid day) Cu's will have a thermal feeding it.

Thermals over mountains have a larger area to feed them and tend to be steadier and less fragmented; they act more like column thermals, unless strong winds are present which often have the effect of breaking up thermal columns, making them more bubble-like. Also, the bubble model seems to best describe thermals toward late afternoon. Other thermals, especially very large ones, can have multiple cores (Fig B). Keep the conceptual models in mind for guidance, but when actually thermalling, stay loose and nimble so that you can see and feel the signals that the thermal gives you.

For our purposes, let's visualize a thermal as roughly round in cross section – like the hot smoke that comes up out of a large smokestack (except invisible); a vertical column of rising air with a center area that rises rapidly, an outside area near the perimeter that rises less rapidly due to mixing with cooler and denser air surrounding the thermal, and an area of descending air all around the column of rising air.

Now, let's imagine what a thermalling day in the Skyline area might consist of: 1/4th to 1/8th sky coverage of Cu's with bases around 5,000 ft AGL in some stage of growth or beginning decay. Under some of the Cu's will be a usable thermal, leaning a bit downwind, and have a diameter near the top of 1/4th of its height (in this case, about 1,500 ft). Its top diameter is about 50% bigger than down low. Some say that the strongest part of its core is about half way to two/thirds up; others say right under cloudbase.

It's important to remember that the thermal itself is the primary phenomenon, while the Cu is only a secondary characteristic which appears during the life of the thermal and persists after the thermal has already dissipated. Thus the presence of a Cu by no means always indicates a

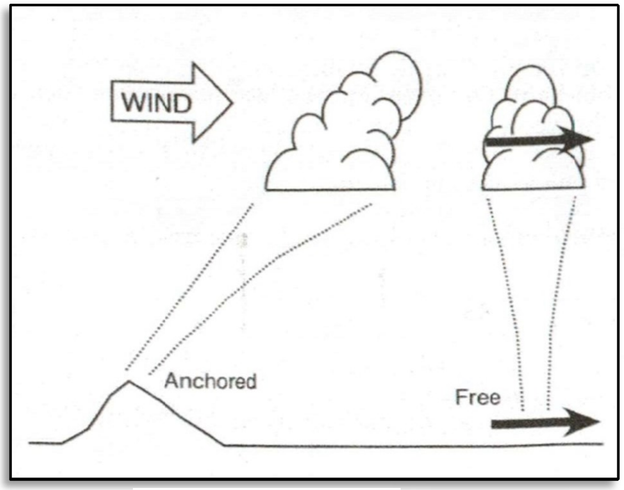


Figure C

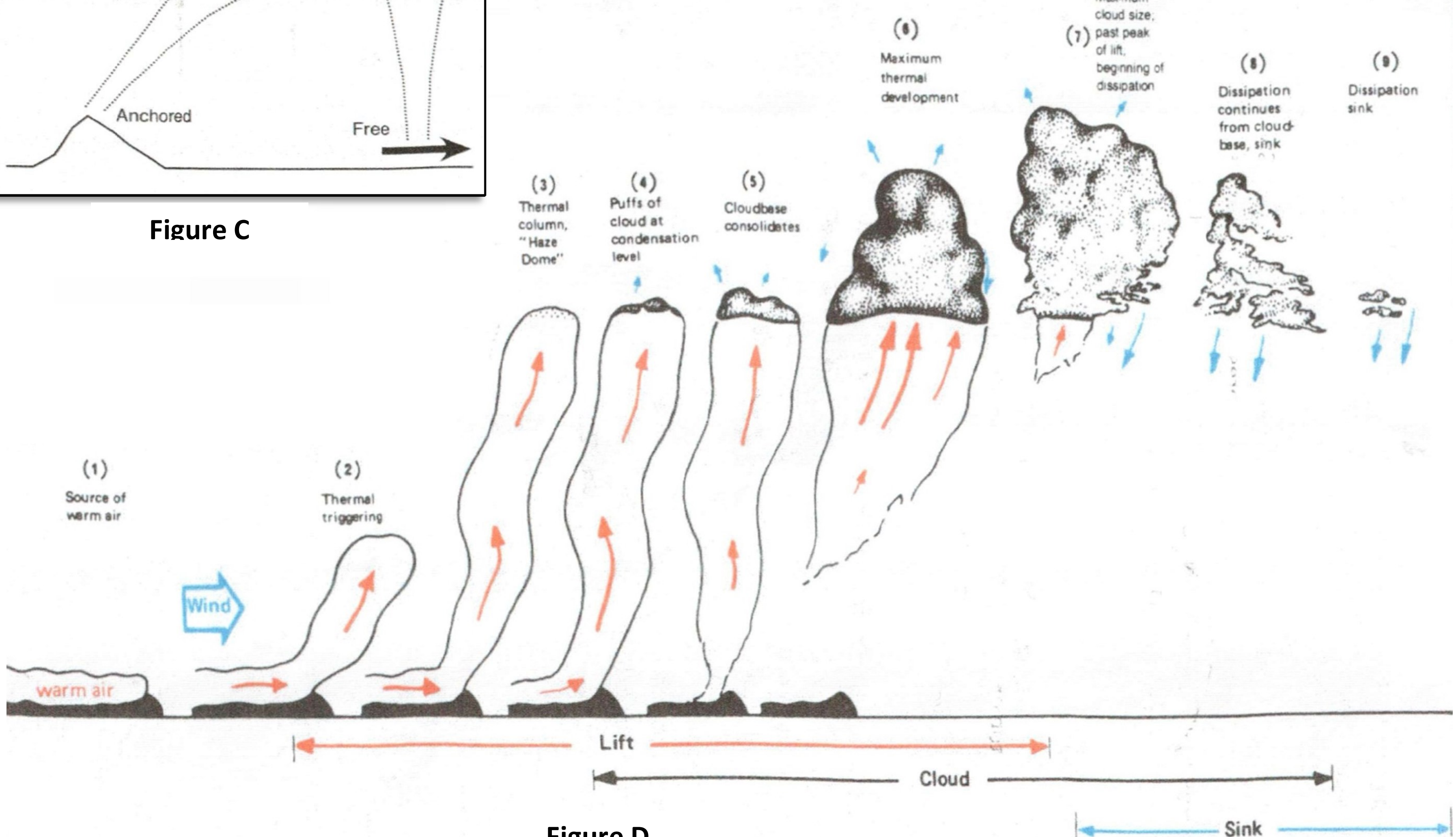


Figure D

thermal beneath its base. *Broadly speaking, the most aesthetically beautiful cloud is at its best stage of development. Dark areas in the base are indicative of cloud thickness and higher local humidity, signs of increasing thermal strength.*

Thermal cross sectional shapes can vary considerably from 'roughly cylindrical'. And, large thermals can have multiple cores and the pilot must decide between circling in only one of them or flying a bigger circle and working several cores until the strongest one is located. Variability also applies to 'leaning'. The effect of wind on thermal shape and 'tilt' is discussed later.

A thermal can either be anchored to a fixed source or it can move about freely, fed by a source of warm air traveling with the wind. Thermals generated by terrain features, such as a mountain top or rocky hillside, tend to be anchored (Fig C). A fire will produce an anchored thermal. Thermals originating over featureless terrain, such as farmland, are often free to move with the wind.

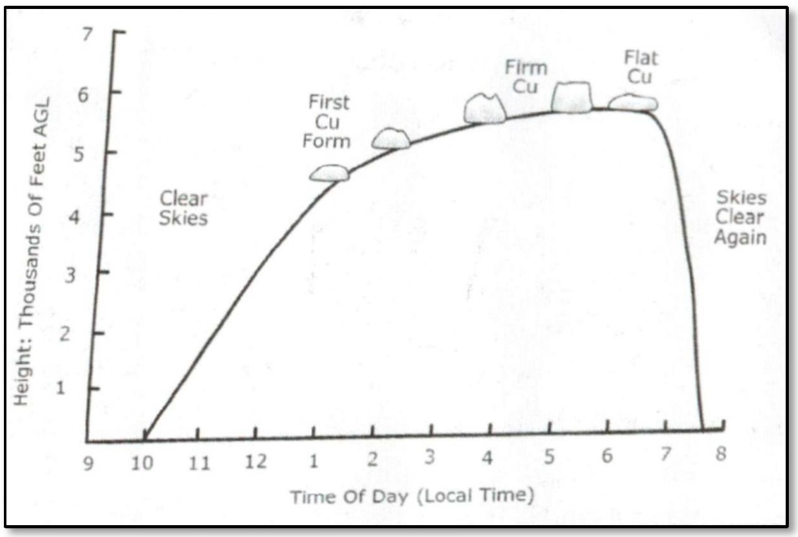
There is a 'rule of thumb' relationship between the height of cloud bases (convective condensation level) and the strength of thermals. For example, if cloud base is 4,000ft, you can expect to find a couple of 4 kt thermals, with the strength of the rest roughly two-thirds of that. Bases of 6,000ft will produce a few 6kt thermals, the rest 4kts, and so on.

Some thermals (not to be confused with Cu's) have a life span of just a few minutes; others for the better part of an hour. A lot can be learned by studying clouds from the ground. The first wisp of a young Cu looks very much like the last wisp of a dying Cu. One expert says that the 'average' life of a thermal is 20 minutes. Cu's live longer as the day develops.

Figure D illustrates a nominal life cycle of a thermal capped with a Cumulus cloud. Note that it begins with a mass of warm air just waiting to be 'triggered' which in this diagram is accomplished by the edge of the ridge line.

[Soaring lore has it that a 'trigger' (impulse) of some sort is needed to give a heated air parcel near the ground an initial push. In fairly uniform terrain any irregularities on the surface can act as a thermal trigger. This is especially true when there's a light breeze (a single row of trees, edge of a wooded area, a farmhouse, differences in soil/vegetation). The process has been compared with the behavior of water drops on a wet basement ceiling, which do not drop off until one touches the ceiling with a finger, at which point a little rivulet runs down one's arm, fed from the immediate area of the ceiling. On this basis, even ridiculously small impulses can set off the mighty process of thermal convection which can lift thousands of tons of air aloft.]

(1) Warm air collects at the surface (largely a function of surface heating characteristics); (2) The thermal is 'triggered' by any one or more of numerous factors, and the warm air begins to rise; (3) A more or less vertical 'cylinder' of rising air is formed. If no further warm air flows in at the bottom, the 'cylinder' can be cut off at the bottom and the air will rise as a bubble.



Height: Thousands Of Feet AGL
7
6
5
4
3
2
1
9
10
11
12
1
2
3
4
5
6
7
8
Time Of Day (Local Time)
Clear Skies
First Cu Form
Firm Cu
Flat Cu
Skies Clear Again

Figure E

(4) As the top of the rising air reaches the condensation level, delicate wasps of vapor appear and rapidly become more visible (10 sec – 1 minute); (5) The cloud begins its existence as individual irregular clumps which become thicker and coalesce; (6) The cloud becomes increasingly compact and its edges become more clearly delineated. Above the area of strongest lift, the cloud grows upward in domelike fashion and is blindingly bright with very sharp edges, the darkest part of the base is directly below. These formations, so beautifully aesthetically, are signs of the best development of lift. As pilots, we should also be aesthetes and try to reach the most beautiful clouds at their best stage of development. Especially dark areas at one or another side of the base are where the thermal strength is at its highest. (7) The cloud continues to grow as long as there is warm air available from below. If the reservoir of warm air is exhausted the growth process halts. The edges of the base fall apart as they mix with the surrounding air and their moisture is absorbed. At this point, the 'dome' of the cloud can still appear round and sharply defined, and can even continue to grow a bit.. This phase of a dying thermal is recognizable in that the cloudbase is a bit smaller than the horizontal area of the 'dome'. *The upper part of the cloud should be clearly smaller in area than the base; if it's not, it's a sure sign that the cloud is past its prime.* (8) The contours of the dome become less distinct (a 'fuzzy' appearance) and the cloud falls apart. As its water evaporates, the air is cooled to such an extent that sink develops and increases of its own accord – a 'thermal in reverse.' (9) The remaining bits of cloud dissipate in this downdraft, which in turn persists for a short time after the last visible remnants of the cloud have disappeared. The drier the surrounding air, the more rapid the dissipation of the cloud.

And the greater the sink

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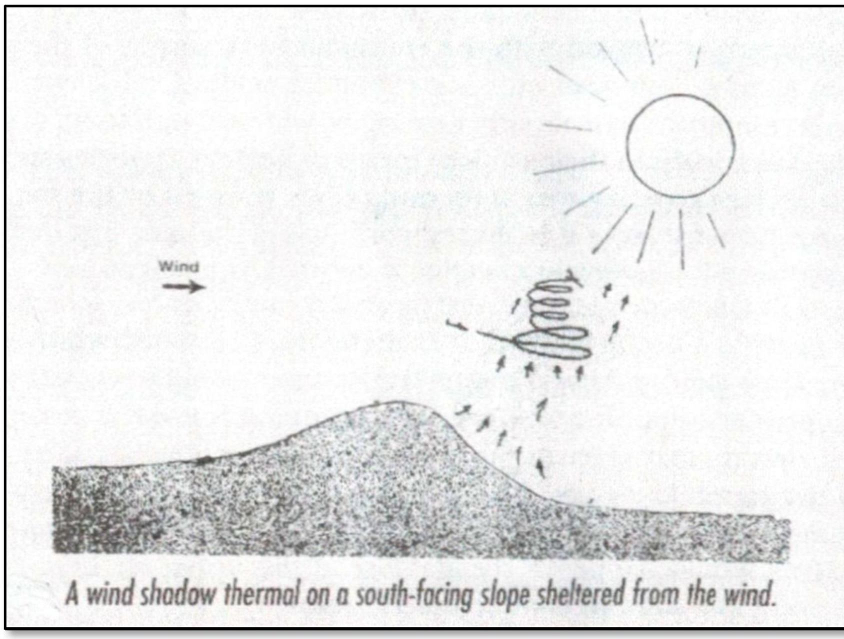
On a typical soaring day, the first few usable thermals are weak and may only extend to 1,000 or 2,000 ft AGL. As the day continues to warm, the thermals become stronger and extend higher. Early thermals may be 'dry' (see next section) for the first hour or two, and then Cu's form when thermals reach their condensation level. On moist days (high humidity), Cu's may form with low bases; these gradually rise during the day. As evening approaches, the last few Cu's of the day look weaker and flatter.

Figure E plots thermal height vs. time for a typical thermal soaring day.



A wind shadow thermal on a south-facing slope sheltered from the wind.

Figure F

Section 2. How do I find them?

"As with people, the potential of any particular thermal is largely defined by the nature of its source, yet its ultimate character is always affected by the interactive world into which it springs." The factors generally accepted as affecting the source of thermal production are:

- The intensity of the heating by the sun and other sources of local heating
- The contours of the ground
- The type of soil, crops, or surface of the ground and the effect of color contrast of them
- Wind strength and direction (on the ground and at altitude)

All of these factors are discussed in depth in some of the references and most are at least touched on later. Just a few remarks here:

Surface heating – the essential condition is that one mass of air should become warmer than the air surrounding it. *The actual temperature of the main air mass is unimportant* and, in fact, thermals can be found in both tropical and artic conditions. When the heat and light waves from the sun strike the ground, some are absorbed and raise the temperature of the surface, but the rest are reflected back into the atmosphere and dissipated. If the heat waves have to pass through an en route layer of cloud, most are absorbed and never reach the ground. During the course of a good soaring day there are often several periods when the Cu's completely cut off the direct sunlight. Then the clouds disperse, followed by a gradual improvement to another peak of activity. This 'cycling', or **over-development** as it is known in gliding circles, spoils many otherwise promising days. It generally occurs when the air is very moist and when forming Cu's are prevented from developing vertically by a stable layer. Usually on a day when the Cu's develop quickly early in the morning, there is more likelihood of over-development, so that the mid-day conditions will have deteriorated. Only the approach of a dryer air mass will prevent this from happening.

Ground contours – Usually high ground or hilly ground is good for producing thermals, and thermals starting from hill-tops are likely to be stronger than those originating from the adjacent valleys. Where the sun and wind are from opposite directions, the air trapped downwind of a hill may remain still long enough to become warmer than in other areas where wind is blowing steadily. When conditions are right, such 'wind shadow' thermals (Figure F) offer remarkably predictable lift, possibly even stronger than the thermals from the windward side of a hill. As they rise, wind shadow thermals may also collect energy from both sides of a hill.

Type of soil and surface – This factor generally comes into play when you're relatively low. Keep in mind that the sun heats the ground. The ground, in turn, heats the air. Look for spots

On the ground where the heating is maximized. Think of taking a mental stroll through the landscape below. The game you're playing is*: If I were a thermal where would I be?* Imagine yourself strolling along the countryside below. Where would warmer areas be? For instance, if you walked from the shade of a forested area into an open dry field, the air would suddenly warm as you stepped into the sunshine. A town surrounded by green farm fields should be warmer. A yellow-brown harvested field will feel warmer than an adjacent wet field with lush green vegetation, since wet areas use the sun's radiation to evaporate moisture, delaying surface heating. *Dark, dry surfaces generate more heat than moist, light ones.* Surface features which are hilly and have a sun-facing side are worth a look. Large, black K-Mart parking lots are frequently excellent heat generators. Rev

The wind – Strength and direction is, as stated elsewhere, an important factor in determining where thermals will be produced in *hilly country*. While, in *open fields*, the effect of wind blowing over a row of trees or other obstructions often disturbs the warm layer of air close to the ground. This is a most noticeable feature at airport sites. Airports are well drained and provide an almost continuous stream of warmed air which is swept by the wind over the obstructions boundary giving a stream of weak lift. This is met on many final approaches and causes some frustration in that the glider is too low to soar but yet the glideslope is upset.

High winds make it difficult for large thermals to exist near the ground, although even on the windiest days there may be strong lift just below cloud base. Since the rising air drifts with the wind as it gains height, unless low, it is often difficult to know the source of a particular thermal. Searching for thermals above about 1,000' becomes a matter of trial and error unless Cu's are developing or a search pattern is used, as discussed below.

When searching for lift, use the best speed-to-fly; that is, best L/D speed plus corrections for sink and winds aloft. This allows covering the most amount of ground with the available altitude.

A robust thermal may accelerate and expand as it rises. Fortunately for us, a thermal that is small and feeble down low, might be very powerful higher up and so large that remaining in it demands only a shallow banking turn and therefore small penalty for circling. This explains why lift is often much easier to find at higher altitudes. Individual thermals that have grown toward each other aloft may even unite near their tops like trees in a canopy forest.

There is normally a uniform band of altitude where the lift is strongest, or at least more prevalent. It usually lies near the top of the useful convective layer, sometimes just under cloud base.

Some people believe that there is a subtle degree of horizontal rotation within thermals, and circling against it limits forward momentum, producing a smaller turn with a flatter bank (too subtle for us beginners). The only pertinent advice provided is that if there are birds in your thermal, give them credit for unerring instinct and follow their lead. And, don't disregard soaring birds just because they're flying straight instead of circling. A bird flying straight at high altitude is probably gliding *away* from lift, while one flying straight at low altitude is apt to be moving *toward* it.

Sometimes the bases of various Cu's occur at different heights, and this itself can help you decide which one to approach. During the early half of a good thermal day the average cloud base may steadily rise, perhaps a thousand feet per hour. If the day is still gaining strength, you can expect stronger lift from newer thermals under higher clouds. Also, regardless of the time of day or any other variable, higher bases imply a greater volume of rising air, and therefore more lift.

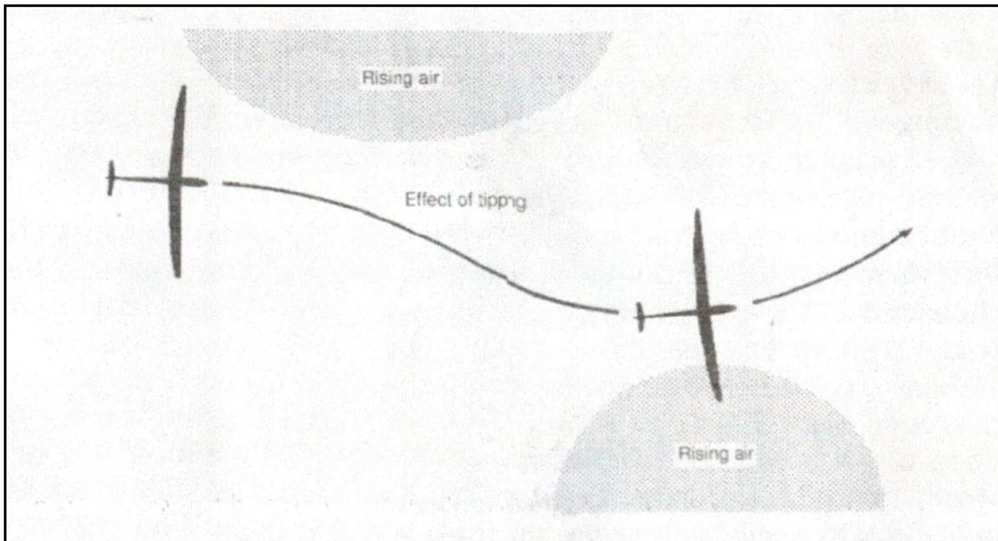
An area of darker gray in the base of a cloud may indicate stronger lift, and several dark blotches near each other could mark a cluster of thermal cores.

In very active conditions, small 'rags' of dark *forming* cloud may appear beneath the base of a Cu. If they are *noticeably growing* or moving upward, they almost certainly mark strong lift. Be careful; 'rags' that are similar in appearance, but not visibly rising, may mark sink.

On a day that promises good thermal conditions, unusually early growth of large Cu's also indicates a potential for early over-development. Such clouds typically form first over high or irregular terrain, or where converging winds meet. After taking advantage of them, work to windward or sunward before their vertical structures create too much shade and reduce the potential for further convection across wide areas of land.

Broadly speaking, to the pilot the *first* sign of nearby lift is some slight turbulence, and the *second* is an increased rate of sink. On *entering* the thermal, a surge will be noticed – a sensation sometimes combined with one wing being raised.

But here, let's look at releasing early into a thermal while on aerotow: it *can* work, despite the local hex. A few relevant comments: Keep tabs on the rate of climb during the tow - entering 'normal air' after a prolonged stretch of sink could be mistaken for lift; never release when unaware of your altitude relative to the airfield; maintain a steady tow position, so when the tow plane rises above the horizon it is really the tow plane going up and not the glider going down. Watch the tow plane closely; if it hasn't flown through the thermal by the time you reach



Fly in straight lines and watch for signs of tipping when searching for thermals.

Figure G

the edge of it, release immediately, make a well-banked 360 deg turn to the right and start centering (see Section 3).

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Back to assuming that we've had a normal tow release at the pre-briefed altitude. Remember that circling flight *not* within a thermal is a quick way of losing height without searching any new area. During the search, unless using a pattern like the one described below, it's important to fly the glider in straight lines and not let it turn. Otherwise, it will wander or turn away slightly as it is affected by the outskirts of the thermals. Inexperienced pilots often unconsciously let the 'glider fly them' and subtly commence a turn when it is banked almost imperceptibly by lift. In this way the glider will find its way *between* thermals (Figure G). That said, probably the most important fundamental technique is *staying light on the controls* in order to feel what the atmosphere is trying to signal. A death grip on the stick will disguise anything but the most severe updraft.

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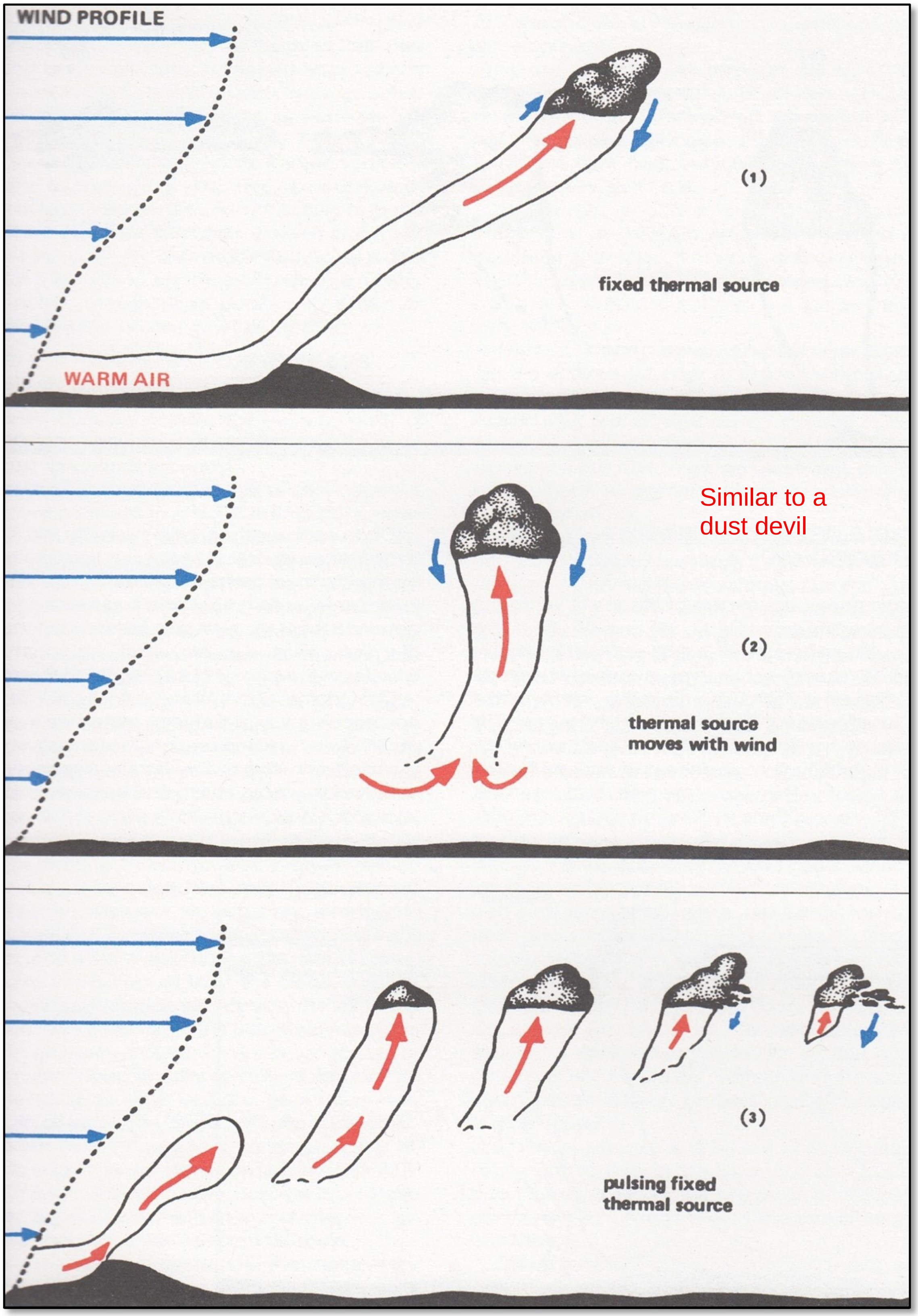
Thermal-search tactics for fair-weather Cu: The art of finding good lift is – at least to a great extent – that of realistically judging the stage of development of those clouds that might come into question. While climbing under one cloud is a good time to practice selecting the next one. And, while gliding between thermals, we have a chance to change our mind and head for a second choice. For those who think that this sort of judgment demands too much of the pilot who's already busy climbing and adjusting his circle, it's a staple of good cross country flying.

Find primary secondary areas to fly to while thermaling

Often the relative size of a cloud can be used to determine its stage of development; this leads to *preferring smaller clouds with well-defined bases*. If scraps of cloud are hanging about near a relatively good looking cloud, they are sometimes remnants of an earlier cloud which has been given a new lease on life by the newer cloud's supply of warm air; usually, though, they indicate only weak lift. If we're faced with a long trip to a cloud of questionable virtue, we must juggle its current stage of development , the general life-span of clouds on that day, and the time it will take us to reach it. Otherwise we'll be treated to a splendid display ahead while cruising but will arrive only to find a wilting cloud and increasing sink.

Searching for thermals directly below cloudbase: Here the objective is *to aim for the darkest part of the base.* The sun angle can also sometimes affect the area of strongest lift by providing additional heat to one side of the cloud. Of even greater importance – and unfortunately unknown to us without specialized electronics – is the wind profile at cloud altitudes, which tend to displace the best lift against the direction of wind shear. If, for example, the wind speed at or near cloudbase increases, the *best lift will be found on the upwind side – especially if this is*



WIND PROFILE
(1)
fixed thermal source
WARM AIR
Similar to a dust devil
(2)
thermal source moves with wind
(3)
pulsing fixed thermal source

Figure H

also the sunny side. Once it's determined that the best area of several clouds is consistently on one side, it can be assumed that will be the case for almost all clouds on that day. If a fixed point on the surface triggers a continual thermal from a large reservoir of warm air, the rising air will lean downwind.

Searching for thermals at medium altitude: The higher we are the more dependability we can base our decisions on cloud forms. As we slowly lose altitude, we should on no account forget the fact that even active clouds may not have lift for more than a few hundred feet below their bases if they're being 'fed' primarily from the side. This is particularly applicable to those Cu's of somewhat 'overripe' appearance.

Searching for thermals at lower altitudes: *The lower we get, the more attention should be directed toward the ground and possible thermal sources.* If there is wind, it will be much more difficult to locate the often curved or tilted thermals. There are many ways in which wind can affect the shape and direction of thermals; Figure H shows three of the most common cases.

(1) If a fixed point on the surface triggers a continual thermal from a large reservoir of warm air, the rising air will lean downwind.
(2) It the terrain is regular, the low, turbulent area will trigger thermals without any particular surface feature. Such thermals are relatively vertical although, of course, they drift downwind with the airmass along with the cloud above them.
(3) A further possibility is that of a surface triggering feature that produces a pulsating , rather than steady, flow of warm air. In this case, each pulse - which can be of several minutes duration – will form a thermal which will separate from the ground and behave as an isolated thermal as in case (2).

These three different types of thermals can appear next to one another in appropriate weather conditions; the question of which form will appear where is a difficult one whose answer depends largely on surface features and terrain. *The best chance of finding lift once it is lost is to fly directly up – or downwind.*

Searching on Cloudless days: Just because there are no Cu's doesn't necessarily mean there aren't any thermals. If the rising air is too warm or too dry to permit condensation and the formation of clouds, the conductive flow will remain invisible to us. Of course, all the mechanisms of thermal development already discussed remain. These **'dry thermals'** (also called *blue thermals*) can be almost as strong as their Cu-topped brethren.

But, without the Cu markers, how do we find thermals? There's the hit and miss technique, or random, technique which works well if you like buying tows. Or, try the local 'house thermal' ('the Rocks'). Remember that a house thermal will likely be downwind of its typical spot on a windy day.

Don’t dismiss the signals you may get while ‘cruising in the blue’. *If you feel definite lift, go ahead and try a circle*. If the sailplane climbs respectably, stick with it, assuming that its ‘ripe’ stage is yet to come.

Look for another circling glider. Circling hawks are excellent markers. On blue days, thermals may be found at the higher levels of upward sloping terrain facing the wind. A long ridge with the spine sloping up on both sides to a crest (like the Masanutten, being weary of the valley) can be used to good advantage, even in light winds, or when the wind is parallel with the ridge. On some days there will be thermals along such a spine, often spaced close enough to permit straight cruising.

Ridge starts the thermal

As the air from the lower levels moves up the slope to higher elevations with cooler surrounding air it becomes unstable – fertile ground for thermals. At times these thermals stop just short of reaching the condensation level, but get close enough to form domelike ‘bulges’ in the top of a haze layer which can be good markers. To spot subtle thermal signposts, such as haze domes and other faint or distant indicators, some pilots like sunglasses. Some like polarized lenses. Others prefer orange tint that block blue wavelength light. Still others have several types of sunglasses and use them according to the weather – blue blocker lenses for hazy days, bottle green polarized lenses for bright sunny days, and so on. Use caution when selecting expensive Polaroid glasses which are susceptible to an interference effect with plexiglass canopies (and are broadly *not* recommended for pilots).

Features on the ground itself can be useful, even if you’re still fairly high. From several thousand feet up, we’re not necessarily looking for a specific trigger point, but rather land-surface features that should be conducive to thermals.

When low remember, contrary to popular belief, that the air is not heated by the sun, but by the ground. Ground that almost completely reflects the sun (e.g. snow) is never a good source of lift. Glider pilots need to identify which areas are absorbing heat energy. These are the hottest spots and the most likely thermal sources. A few hints:

1) Start to look at the ground during the launch or straight after release.
2) Imagine walking barefooted over the ground below.
3) Direct the flight over and slightly downwind of areas assessed to be the hottest.

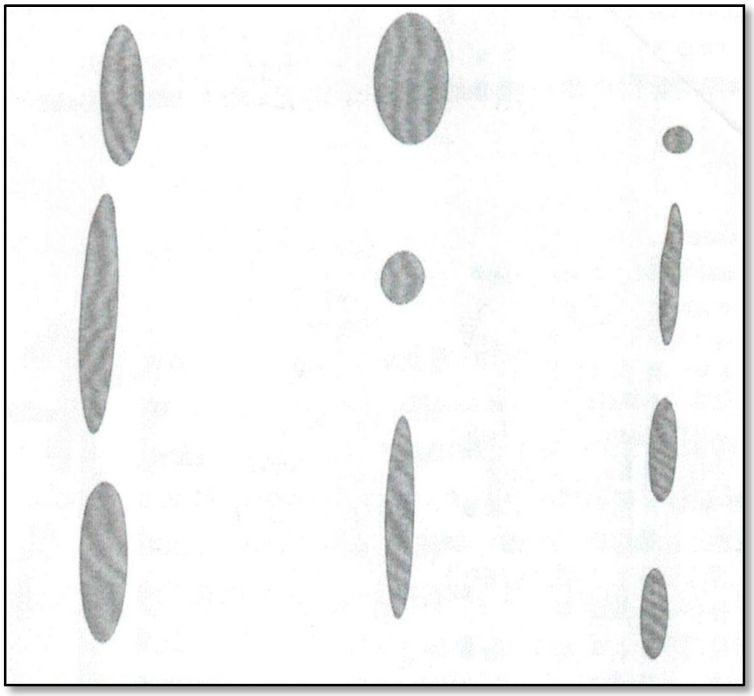


Figure I

If you fall out of a thermal, fly up or downwind to search for more

The presence of variable breezes from many directions on the surface (carefully observed while hanging around the airport; maybe disparate wind sock indications) almost certainly will produce usable updrafts.

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A very large number of Cu's certainly need not mean that there will be a large number of thermals. On the contrary, the usual case for many Cu near one another is that the humidity of the surrounding air is high enough to slow significantly the process of cloud dissolution. Due to the increased cloud shadows in such an over-developed situation, good lift may be quite difficult to find.

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Thermals often seem to organize themselves into very predicable patterns. Knowing the pattern and knowing how to look for evidence of the pattern gives you an edge in your search.

One such pattern is caused by the wind tending to sometimes organize thermals into long lines of consecutive thermals called **thermal streets**, as long as ten, twenty or even more miles. Figure I shows Cu's in linear formations which frequently earmark these 'streets'. Many of the clouds have an almond shape to them, with their long axes aligned parallel to the wind, which is blowing from the top end of the diagram. The glider pilot looking for a thermal would do very well indeed to look within the confines of one of the three streets pictured. That's where the lift is, in the streets – why look elsewhere? But since we know that what goes up must come down, where's the sink? Just where you might expect – between the thermal streets are sink streets which generally have much more area than the thermal streets. If you must cross them, do so at something close to a right angle and at the appropriate speed-to-fly while penetrating the sink. (Skyline pilots should know that we have a common exception to the wind-parallel adage. When there is even a light west or northwesterly wind at or near ridge top levels, streets will form parallel to the ridges on the Massanutten, Blue Ridge, and even the Alleghenies. These streets can be virtually perpendicular to the wind direction.)

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A term you will hear, generally associated with 'street-flying' is **dolphin flight (**or **porpoising)**. While this technique can be quite academic in nature, as can many others affiliated with the sport of soaring, for our purposes it'll simply be defined as the process of flying slowly through any lift not worth circling in and speeding up when in sinking air.

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4. FIND LIFT: Fly parallel-ish to,the wind

3. ENCOUNTER SINK: Turn roughly perpendicular to your heading but maintain roughly an upwind/ downwind overall direction

2. FIND LIFT: Turn back parallel-ish to the wind

1. IN SINK: fly perpendicular to the wind unless originally established in a street

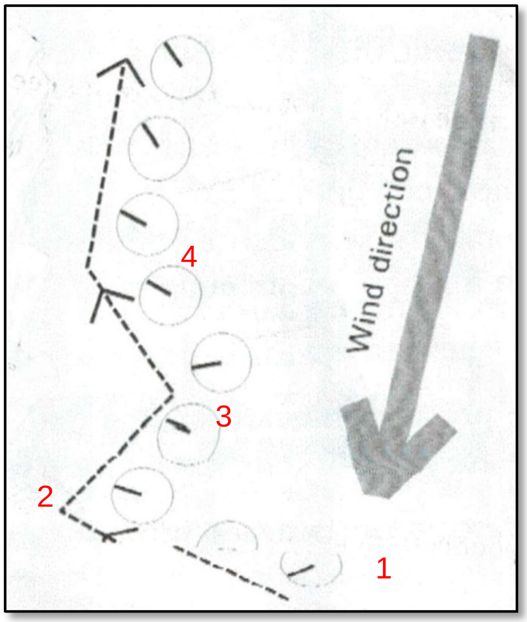


Figure J

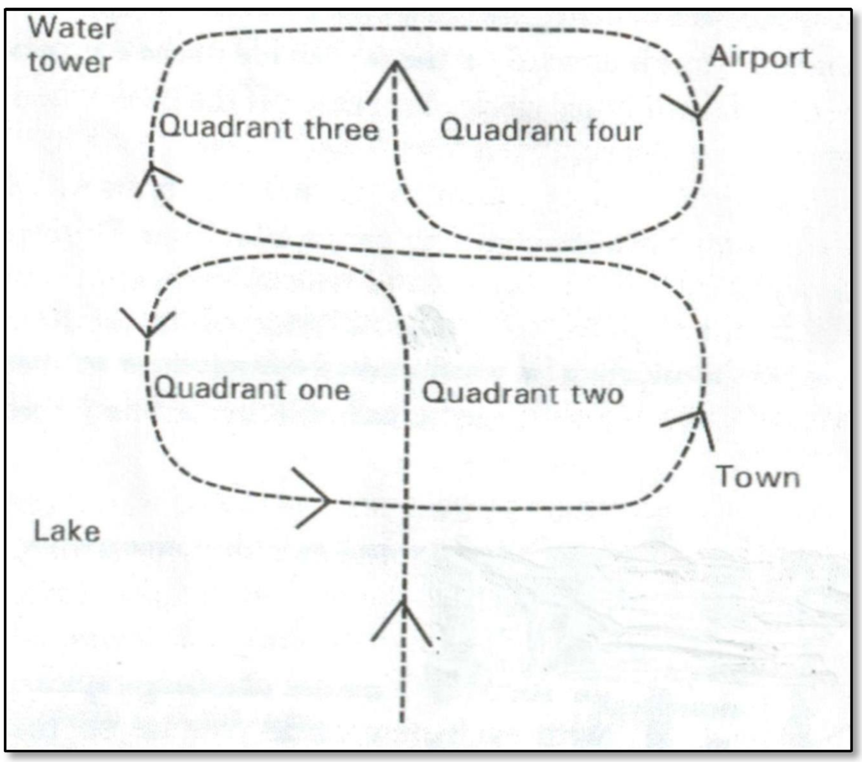


Figure K

The fact that Cu's don't form on 'blue days' does not mean that there are no lift streets or sink streets. Quite the contrary! *Clouds have little or nothing to do with streets.* Clouds don't cause them – they just serve as signposts. One expert proclaims that it's *a rare soaring day that does not have streets and it behooves us to behave as if streets are present even if we can't see them.*

Another example of detecting the presence of something invisible: By search regimen or chance, you happen to encounter some weak lift on a blue day. You center the thermal and climb until it's time to leave. You look all around but still see no visible signs of lift – no Cu's, no haze dome, no soaring birds, no nothing. Just blue. Which way to go? Go in the direction in which you have the highest probability of finding lift, which is directly upwind or downwind of your current position, because that's how you stay in the street. Because you can't see the street, you may have to zig-zag a little to increase your chances and while your doing so, note your Vario and use the appropriate speed-to-fly. Once you find lift again, turn back to parallel the wind direction. Figure J applies.

Assume streets exist

Alternatively, let's say that you've just released from a routine aerotow on a perfectly blue day with no visible signs whatsoever. Figure K illustrates one method for systematically searching all quadrants around your flight path. It can be practiced by walking through it on the ground. Leg distances and turn rates can be varied but should be sized so that one circuit doesn't consume the entire flight. If nothing else, you'll get good practice using landmarks for orientation. Of course, entry into any lift encountered would be handled at the time as described in Section 3.

—

Unless you find certain lift and decide to circle up or you find heavy sink and opt to hurry away, complete the entire search pattern. As with actual thermalling technique, *attitude* control is essential to maintaining a uniform flight path. Use quick, little coordinated turns, either to maintain direction or to lean into every lateral impulse, and you may gradually 'sniff' your way right into the best lift around. Otherwise, most of these impulses will push you further away from the strongest lift. (This is also the technique required to optimize linear lift zones such as streets or shears.)

When there is evidence of lift nearby but not enough indication of where it is, a turn into the wind is the best bet. That windward quadrant is where the lift is rising *from,* so even if you turn the wrong way, you may still descend *into* the lift rising from below.

????
Pg 29

Unless you are over flat terrain where the thermal is behaving like a dust devil

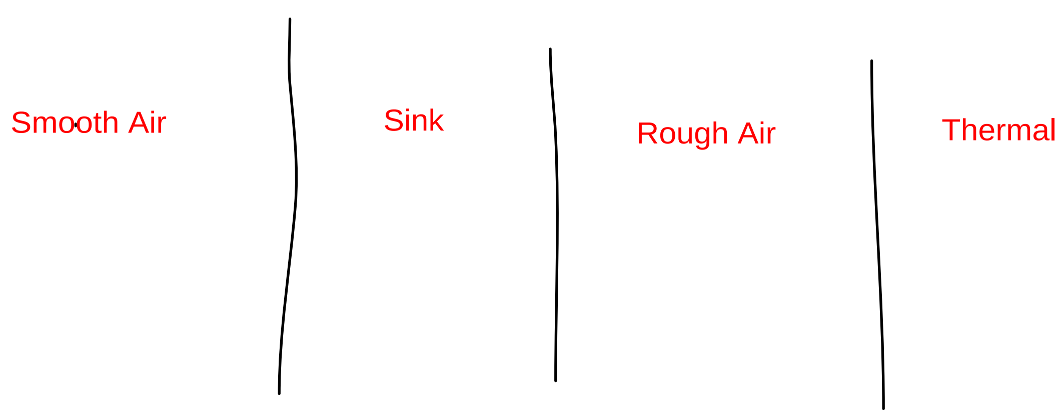
Many times you will fly through lift and beyond it before turning. The temptation to go back and dig around for it can be great, but if you do you may lose more altitude than you can afford. Understand that you're descending already , and turning back will increase your sink rate and stop your forward progress. If you don't locate lift very soon, the thermal *sink* you'll be wandering in can result in a terribly rapid shoot-down. Often it's better simply to admit a lost opportunity and continue on.

Back to more traditional 'thermal hunting':

When you expect a thermal, or where you know there is one and hope to core it, slow your glider and fly as lightly as possible on the controls, feeling for any perceivable sense of dynamic. Merely wandering can be very counterproductive, for it allows the lift to do the one thing lift nearly always tends to do: push an undirected sailplane away and into sink. Instead, try some sort of logical search pattern (such as the one shown in Figure K). This will keep you oriented so that you can return to any particular place within the circumscribed search area.

As emphasized earlier, an increase in sink rate and a bumpy, disorganized feel to the air are *key signs* that you've found your thermal.

We're tooling around in relatively smooth air, wings level, at a speed-to-fly of 50-55 kts with the Vario showing a sink rate of 1.5 kts. After a few minutes of this, we note an increase in the sink rate to 4 kts. A few seconds later, we begin to feel a little chop in the air – it has become bumpier and the sink rate has increased to 5 kts. When this sink gradually turns into weak lift, cruising speed is slowly reduced in anticipation of good things to come. Then suddenly we feel an upward surge and hear a slight 'whoosh' sound. The Vario starts providing pleasing noises and turning clockwise to its climb side and as we continue, we see a climb of 2 kts, then 4, and then 5 kts. When reaching the peak lift, we roll into a 40 deg bank, turn into the rising wing (if there is one) and start climbing! If it was only that simple!



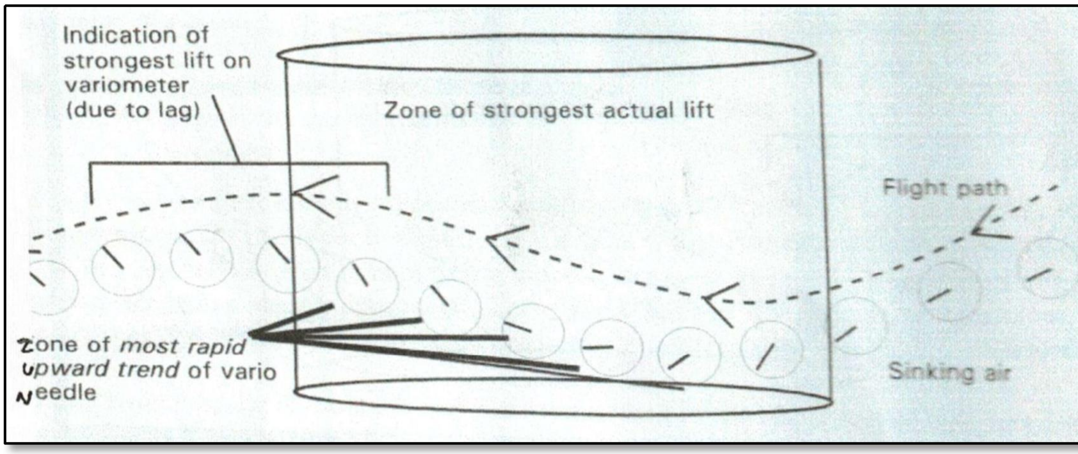


Figure L

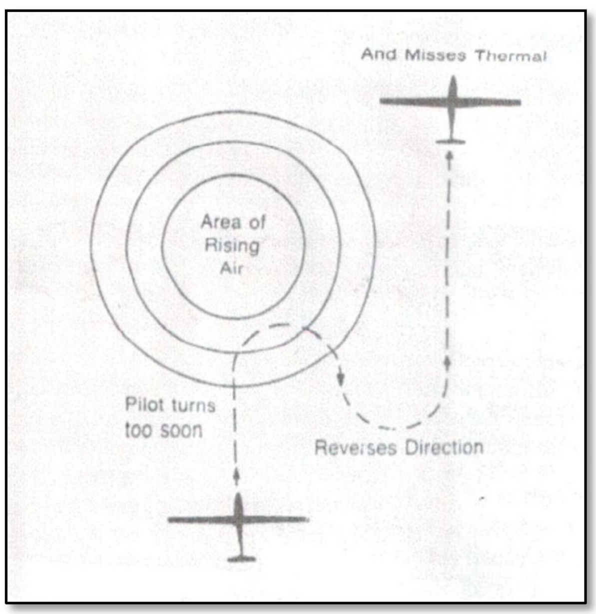


Figure M

Section 3. What do I do now?

Well, why ain't it that simple? ….. just center as quickly as possible and maintain optimum climb rate until it's time to leave!

1) For starters, *opinions differ regarding how long to wait after encountering lift before rolling into the thermal*. Some advocate flying straight until the lift has peaked. Then they start turning, hopefully back into stronger lift. It is imperative not to wait *too* long after the first indication for this maneuver. Other pilots favor rolling into the thermal *before* lift peaks, thus avoiding the possibility of losing the thermal by waiting too long. Turning into the lift too quickly will cause the glider to fly back out into sink. There is no one right way; the choice depends on personal preference, altitude, and the conditions on any given day. Timing is everything and practice is key.

2) Unquestionably, for several reasons, *there is a lot of lag in what the Vario is telling you*. As often as not, when you *feel* a strong surge and hear a 'whoosh' is the time to be banked, circling in your thermal climbing mode. Some of us depend on the Vario to *locate* lift, which is unfortunate because it's usually pretty far behind the action; some say, *at best*, on the order of three seconds (about 250 ft at 50kts, and about equal to one-third of that 'typical' Skyline thermal radius described in Section 1). So, Vario lag can lead you astray. In Figure L if the pilot begins to circle only when it shows *peak* lift indication, the circle will be in heavy sink, not lift. This figure makes the point that the *trend* (toward improving or worsening conditions) of the Vario needle (or Audio) is more important than the actual position of the needle on the face of the dial.

   [Maybe an arguable conflict lies in Vario 'trend' vs. needle position vs. seat-of the-pants ? Looking at Figure M, if the pilot immediately considers the first positive indication of the Vario as the 'first encounter of lift', he might overshoot the 'zone of strongest actual lift'. If he had delayed 3-5 seconds, he might have been ok.   Hopefully, whichever technique is used for the initial turn, things will eventually get sorted out by using the techniques discussed below (and remembering the 'more art than science' preamble). What is not addressed in Figure M is that your 'body sensors' produce a response time close to zero. Feeling the subtle 'kick' and seeing the beginning of an upward Vario 'trend' is the best of two worlds.

   Seat pressure ('seat of the pants') provides almost instantaneous feedback. (Confirm this yourself – force yourself to consult the Vario only upon feeling a change in seat pressure – with the Audio off, of course. You'll find that even occasional lift is sensed more quickly by your 'seat'). Realize that your personal sensor (butt) is only good for detecting *changes* in vertical airspeed, but can't interpret the *rate* of climb (think about the sensations on an elevator in a tall building).   But, the Vario remains critical as an indicator of thermal *strength*.   As always, a light touch on the stick, a keen eye, and a sensitive 'backside' trump a death grip and staring at the instruments.

   Secondly, re when and how to turn: Most say that usually a swift turn is the correct course of action at low altitude, but when high it is almost always best to delay the turn for a while after you've felt the peak surge. Once again, no firm rules here – just keep practicing thermal entry and make a conscious effort to refine this important skill. Which direction to turn is addressed later.]

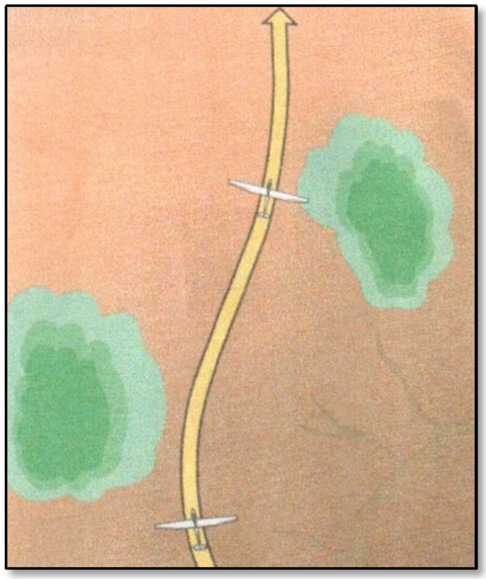


Figure N

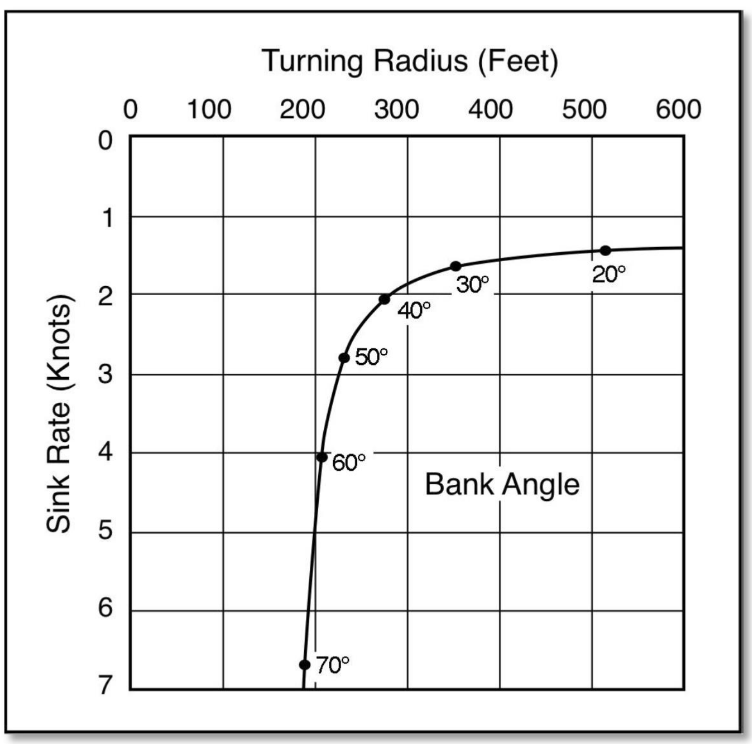


Figure O

Because this Section is the 'core', so to speak, of this 'Helper' , it has a loose order to it:

General – commonly held notions and platitudes; miscellaneous 'pearls of wisdom' offered by one or more of the experts.

Initial Centering – The beginning actions after the first signs of thermal lift are felt.

Refining the circle – Maximizing all you can get, once you're, more or less, in lift at least during *part* of your circling.

General:

Of course, once a thermal has been located, the very first objective is to enter it properly, so as not to lose it right away. Once again, the sequence of indicators is: increased sink; positive G-force (subtle or obvious, depending on thermal strength). 'Seat-of-the –pants' is the quickest indicator. Speed should have been increased in the sink adjacent to the thermal hence, as the positive G-force increases, reduce speed to between L/D and minimum-sink (V min sink). Note the *trend* of the Vario needle (should be on upswing) or the Audio going from droning to excited beeping and, at the right time in the anticipated lift, begin the turn. If everything has gone perfectly, the glider will roll into a coordinated turn, at just the right bank angle, at just the right speed, and be centered perfectly. In reality, it rarely works that way.

To help decide which way to turn, determine which wing is trying to rise (e.g; when entering the thermal and the glider is gently banking to the right, clear and turn left). A glider on its own tends to fly away from thermals. Figure N. Sometimes the thermal-induced bank is subtle, so be light on the controls and sensitive to the air activity. At other times there is no indication from either wing. In this case, take a guess. As discussed later, even a turn *into* the rising wing often creates the impression that it was the wrong way to go.

Optimum climb is achieved when proper bank angle and speed (i.e; pitch attitude) are used after entering a thermal. The shallowest possible bank angle at minimum speed is ideal. Thermal size and associated turbulence usually do not allow this.

Consider first the bank angle. The glider's sink rate increases as the bank angle increases (Figure O). However, the sink rate begins to increase more rapidly beyond about a 45 degree bank angle (you can calibrate yourself for 45 degrees by aligning two diagonal cockpit instrument mounting screws parallel with the horizon – generally, you're less step than you think you are). Thus a 40 deg compared to a 30 deg bank angle may increase the sink rate less than the gain achieved from circling in the stronger lift near the center of the thermal. As with everything else, this takes practice, and the exact bank angle used 'will depend'. Normally bank angles in excess of 50 deg are not needed, but exceptions always exist. In particular, the smaller size of thermals at low levels require steep bank angles. As you climb higher the bank angle can often be shallowed.

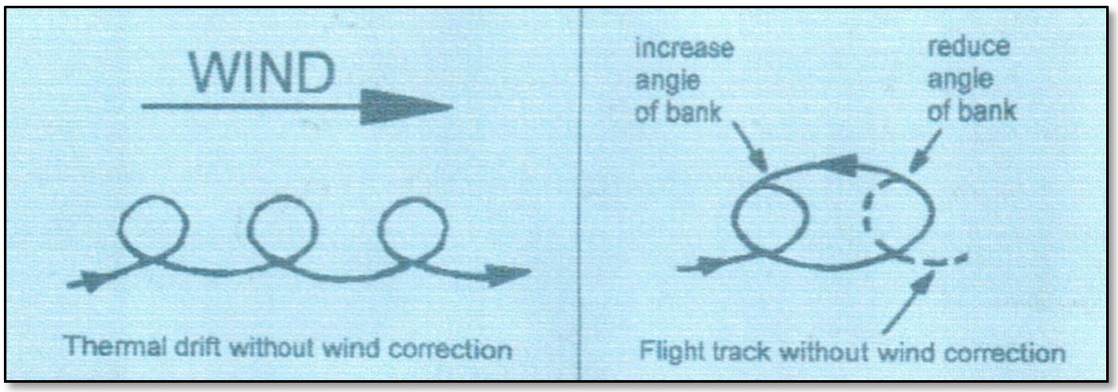
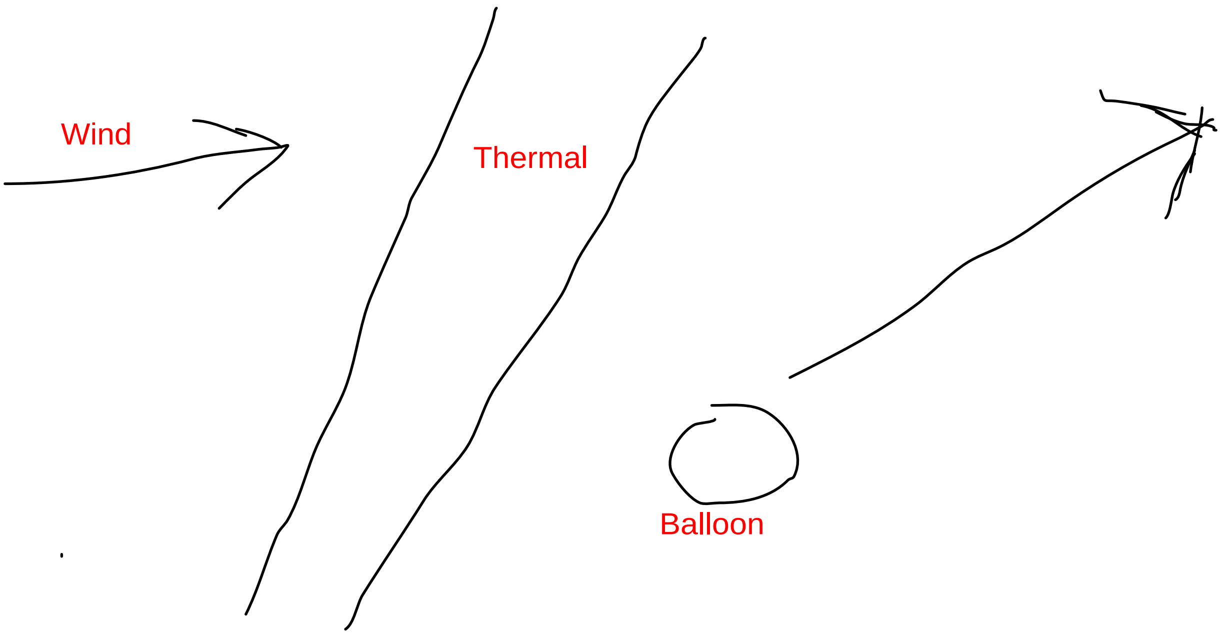


Figure P

Thermals do not always travel at the same speed as the wind. Glider pilots must make adjustments during thermalling turns to remain in the core. Pg 22, 28



Now to airspeed: If turbulence is light and the thermal is well formed, use V min sink for the given bank angle (refer to your cockpit card). This should optimize the climb because the glider's sink rate is at its lowest, and the turn radius is smaller. As an example, for a 30 deg bank angle, letting the speed increase from 45 to 50 kts increases the diameter of the circle by about 100 ft which, in some cases, can make the difference between climbing or not. (More circling performance data are contained in Section 5). Some gliders can be safely flown several knots below V min sink. Even though the turn radius is smaller, the increased sink rate (and marginalized control responsiveness) may offset any gain achieved by being closer to the thermal's center.

Once located, many thermals are maddeningly tricky to work. Although in very weak ones it's not always possible to maintain a continuous climb, 'boomers' present problems of their own. Even very experienced soaring pilots are sometimes unable to maintain position in the strongest thermal cores. So, don't get discouraged! Loss of concentration, contacting a level with severe vertical wind shear (see Section 5), or a simple thermalling mistake are common reasons for the loss of a thermal. This is not a problem as long as we have a fair idea of which direction we need to fly to find it again.

Although thermals drift with the wind, they seldom travel at wind speed, and hardly ever adopt the wind speed at altitude. By contrast, a circling glider tends to drift at the speed of the surrounding air.
Pg 22 Consequently, it will move downwind faster than the thermal itself. Without taking corrective action,
Pg 28 the thermal will be quickly lost in windy conditions. To avoid this, we need to adjust the angle of bank. This is essentially the same maneuver that power pilots call 'turns around a point' and results in an oval-shaped flight path, which is exactly what is needed in this sort of situation. Figure P.

When thermals are rising steadily from a stationary source but the wind is strong, a tentative figure-
Ridge eight is sometimes useful. It eliminates the weaker, downwind half of each circle by turning into the wind each time you're headed across the wind, and is safer than full circles near a hill.

Do not assume that turning is always necessary. On 'street' days you might be able to take full advantage of lift while simply porpoising on course with only an occasional zig or zag.

Initial Centering:

A common lament of inexperienced soaring pilots is: *'I find what feels like a good thermal and turn, but then it seems to be all sink!'* Sometimes that is what happened, but more typically the neophyte has turned too gradually and flown *around* the lift in thermal sink.

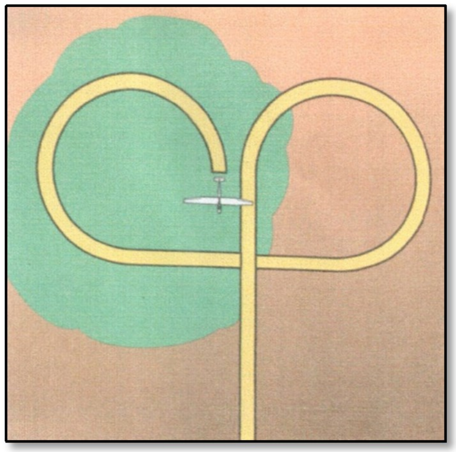


Figure Q

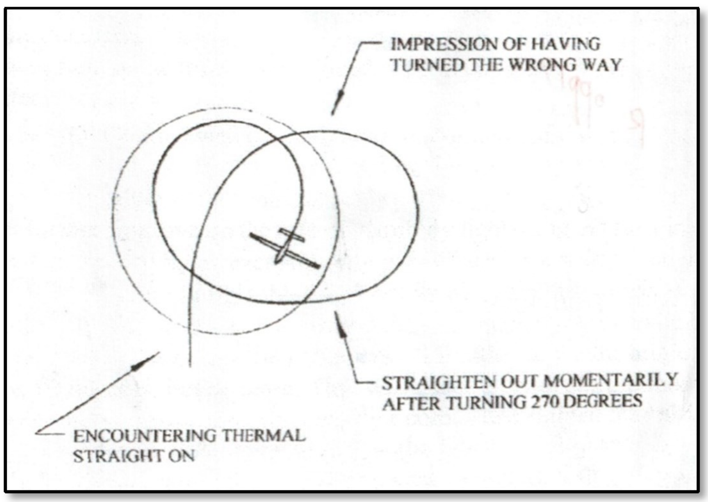


Figure R

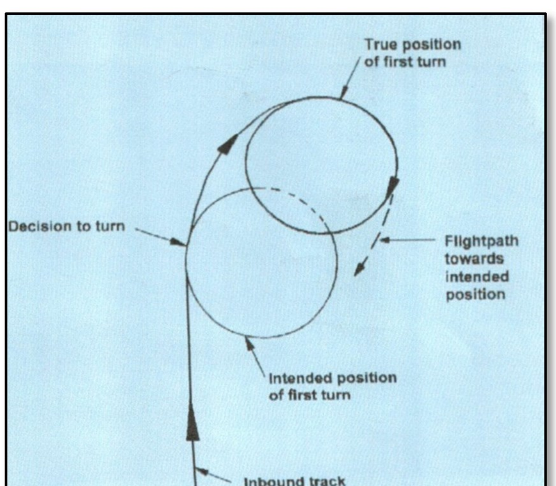


Figure S

Unless there is evidence that the thermal is very wide, make your initial turn a steep one to pinpoint where the lift is and avoid flying away from it. In good lift, a turn that is steeper than necessary does not bring much penalty, but a shallow turn can cost the 'conservative' pilot gobs of altitude per circle.

A very common mistake is not banking steep enough. Thermals vary a lot in size and in gradient lift distribution, but it's a good bet that a good initial turn should be in the 35-plus deg bank angle range to stay within the size of thermals in the eastern U.S. On the other hand, be aware that a 60 deg bank angle works only in *very* strong/tight cores since it imposes a dramatically high glider sink rate of its own (figure O again). Shifting from a 20 to 40 degree bank angle increases the sink rate about 30%: Shifting from 40 to 60 degrees increases sink by 100%.

Usually upon entering a thermal, the glider is in lift for part of the circle and sink for the other part. The goal of centering is to determine where the best lift is and move the glider into it for the most consistent climb rate.

One centering technique is known as the "270 deg. Correction" (Figure Q). The pilot rolls into a thermal and almost immediately encounters sink, an indication of turning the wrong way. Complete a 270 deg turn, straighten out for a few seconds, and if lift is encountered again, turn back into it in the same direction.

[*Even when you correctly turn toward the rising wing you will, in all likelihood, get the impression of having turned in the wrong direction*. There is a logical explanation for this: the path from where the turn was initiated to the point where the circle is established is not circular but elliptical. Thus, even though we turned in the right direction we may come out the side, creating the impression that we went the wrong way (see Fig. R). This is the reason it is most often necessary to straighten out completely for at least a second or two after 270 degrees of turn. Then, when back in the lift, tighten the turn again. As always*, it's important to try to form a mental picture of lift distribution as soon as possible.*]

Regardless of turn direction, pilots often assume that the first turn is tangential to the direction of flight. However, even in the most agile of single-seaters it requires about two seconds to roll into a steep turn. The result is a flight path as per figure S (with the slower roll rate of a training aircraft, this time is about .???? doubled). As a result, the first full turn is usually completed a fair distance away from the intended position. It is therefore often advisable to level the glider momentarily after completing 200 deg of turn. More often than not this moves us closer to the core, which is usually indicated by the air becoming smooth or the amount of turbulence decreasing markedly. Often this coincides with improved control responsiveness and a reduced noise level.

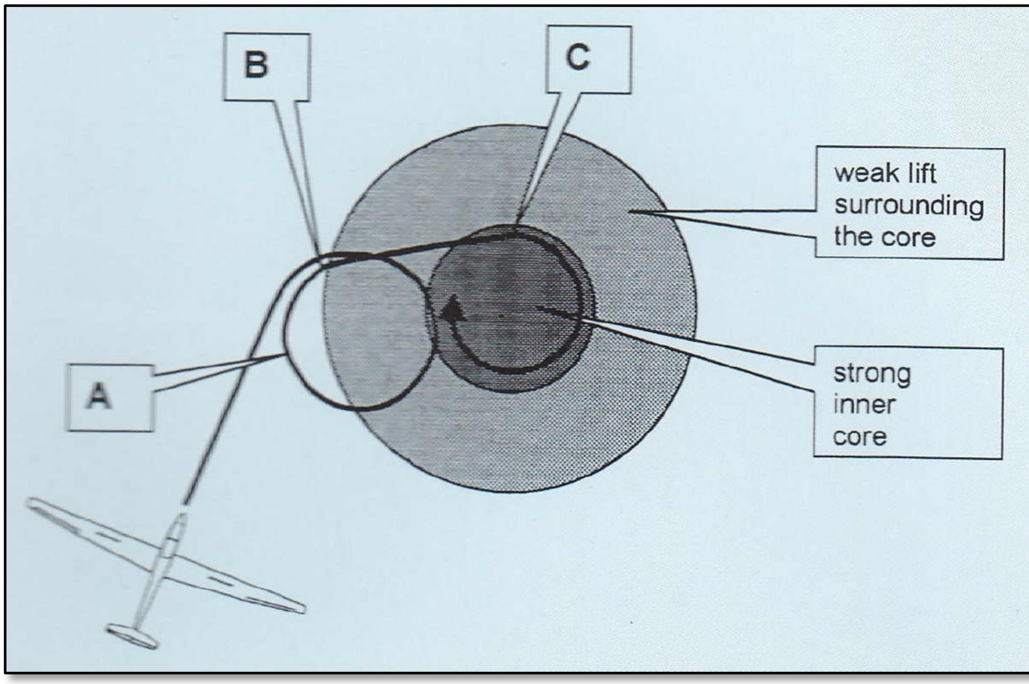


Figure T

Figure U

If we find ourselves relatively distant from the center of the thermal, the Worst Heading Method may provide a means of substantially moving your orbit. This centering method requires that we make a mental note of our worst position in the thermal (Point 'A' in Figure T) and wait for almost a quarter turn before leveling the glider completely (Point 'B'). After a short while, the glider is rolled back in the same direction (Point 'C') and should now be positioned significantly closer to the core. Whatever leveling time we decide on depends on the diameter of the thermal, our speed, and our distance from the core, but the maneuver needs to be repeated as long as subsequent turns are still partly in sink.

Make crisp turns

While flying at 50 kts, we travel about 85 ft/sec, which means that leveling the wings for two seconds theoretically shifts our position by 170 ft. However we also need to consider that the distance consumed while rolling out of and back into the turn can easily account for the same distance again. A two-second leveling of the wings, therefore, results in a position change of approximately 340 ft. Significantly larger corrections are rarely required unless you're dealing with a monster of a thermal or have drifted quite a distance from the core.

___

True

[Another approximate point-of-reference: Realize that if you are flying a 45 deg banked turn while circling, it'll take about 6 seconds of straight flight to fly a distance equal to the diameter of one of your circles. Thus, roughly speaking, if you fly straight for more than 6 seconds, you will be flying in completely different air and have a high chance of losing the thermal.]

___

The timing of control inputs is very important. Leveling our wings too early or too late makes the glider point in the wrong direction and possibly towards sink. For this reason, most experienced pilots use a *reference point as they're forming a mental picture of the thermal and its lift distribution.* The reference point may be the position of the sun or some feature on the ground. Sun position is preferable when flying over featureless terrain.

Always remember, by paying close attention to the 'feel' of the air, we get useful clues about the location of the core. A short moment of smooth air should make us shift position towards this smoother patch. Equally, sudden turbulence indicates a position close to the edge of the thermal and a need to move toward the opposite side of the thermal. In other words, we must update our position in the core all the time, using firm and precise control inputs.

___

Avoid reversing the direction of turn. The distance flown while reversing a turn is more than seems possible and can lead away from the lift completely (Figure U). A commonly held notion is that a beginner often starts turning too soon – when lift is *first* encountered, rather than delaying the generally recommended 3-5 seconds. This technique causes the glider to immediately leave the thermal. Thinking the initial turn was made in the wrong direction, the pilot then tries a turn in the opposite direction. No lift is found in this direction and the pilot logically assumes it was only a small bump rather than a real thermal.

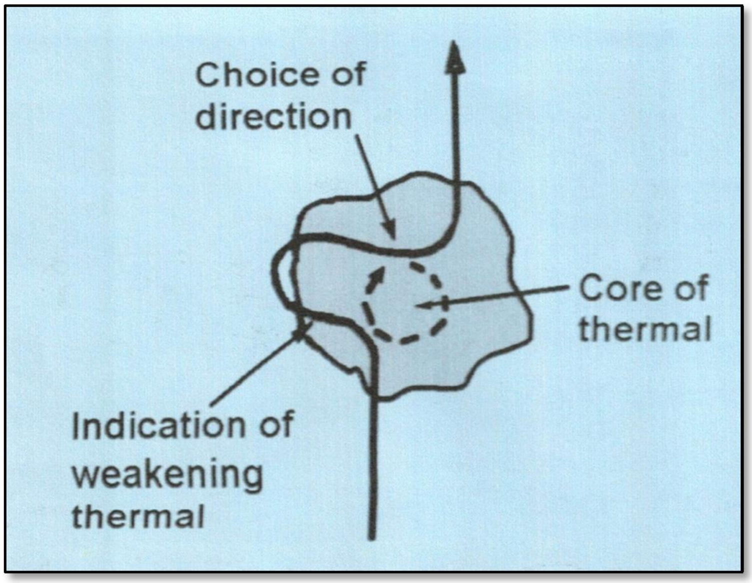


Figure V

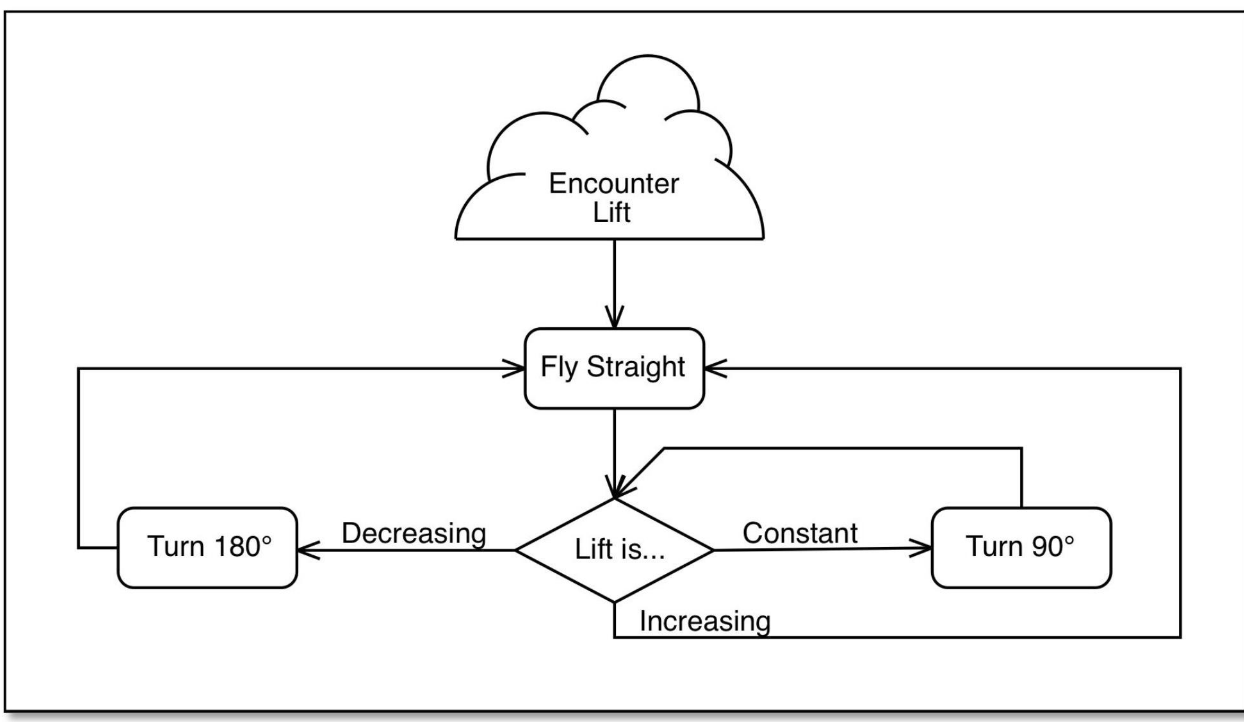


Figure W

[Changing direction of turn is virtually always a mistake. In the rare instance where this maneuver is successful, it is generally attributable to pure luck by stumbling into another core. As a means of centering, this strategy is totally useless. If you lose a thermal completely, you might consider making one shallow 360 deg circle, then tighten the turn if and when you re-enter.]

___

Not withstanding the words immediately above, effective *centering in blue conditions* (if maintaining a specific track is important) may require turns in opposite directions. In figure V, upon feeling some lift, if we have rolled the glider in one direction and see that we have turned into sink, we must decide between continuing the full circle or changing the direction of turn. The expert's advice: perform a decisive 180 deg turn in the opposite direction and then wait until the Audio indicates strong lift again. Then the pilot may start circling in lift or if the lift remains unsatisfactory, turn to the original course.

___

Several other concepts relate to the *initial* thermal turn. If you find lift head-on and the wings remain level, you may feel a sequence of bumps as you proceed from the surrounding thermal sink into the strongest lift of the core. As air rushing out from the core creates a sudden increase in *indicated* airspeed, it might simultaneously raise your angle of attack and reduce the actual velocity of the moving sailplane. In other words, an *indicated* 'speed-up' could accompany an *actual* 'slow-up'. A corresponding loss of control effectiveness will soon follow, but you can easily counter this with a slight pitch-over before initiating your thermal turn.

Upon entering a thermal, the standard rule of thumb says postpone that initial turn three or four seconds. This brings you farther into the rising air rather than immediately turning away, while also allowing time to decide if the lift is really worth stopping for. Generally, it's best to wait until the lift peaks before turning and, depending on a thermal's size, this waiting period *could be* ten seconds or more.

When you're cruising *into the wind* any newfound lift will be rising toward you from ahead on course, making it possible to delay the initial turn indefinitely. If you were to turn too soon you'd immediately
Pg. 28 be *below* the rising air, and need to move farther upwind to rejoin the thermal at a lower altitude.

When running *downwind*, it pays to turn more quickly. The faster you're moving, or the stronger the wind, the sooner you might shoot through the lift and into sink downwind of it.

If you're flying *across the wind* and find a thermal, but are unsure which side it's on, turning into the wind by default will result in success more often than not.

___

One author uses an algorithm approach to entering and centering a thermal: Figure W applies for a classically shaped thermal. As you encounter lift, you should keep flying straight until reaching the 'seat-of-the-pants' point of maximum lift. Then you should enter a turn. If after 90 deg of turn, the lift has

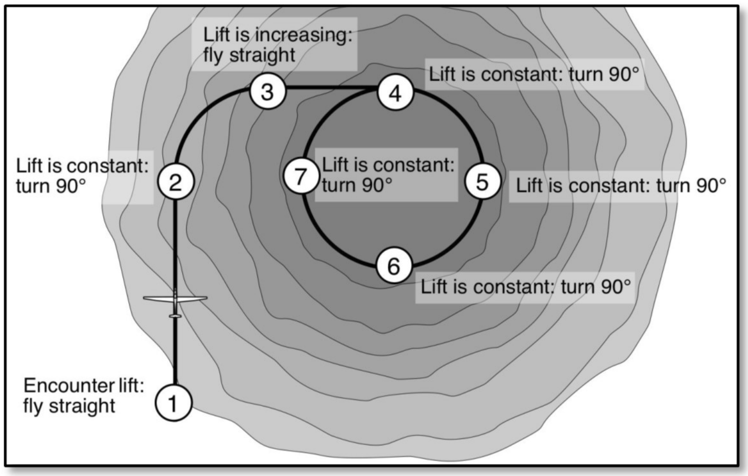


Figure X

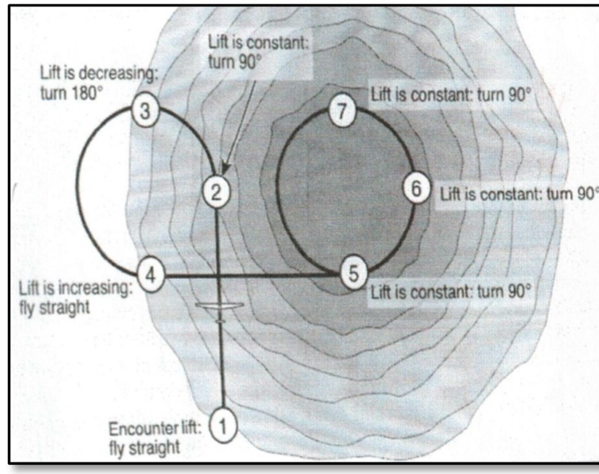


Figure Y

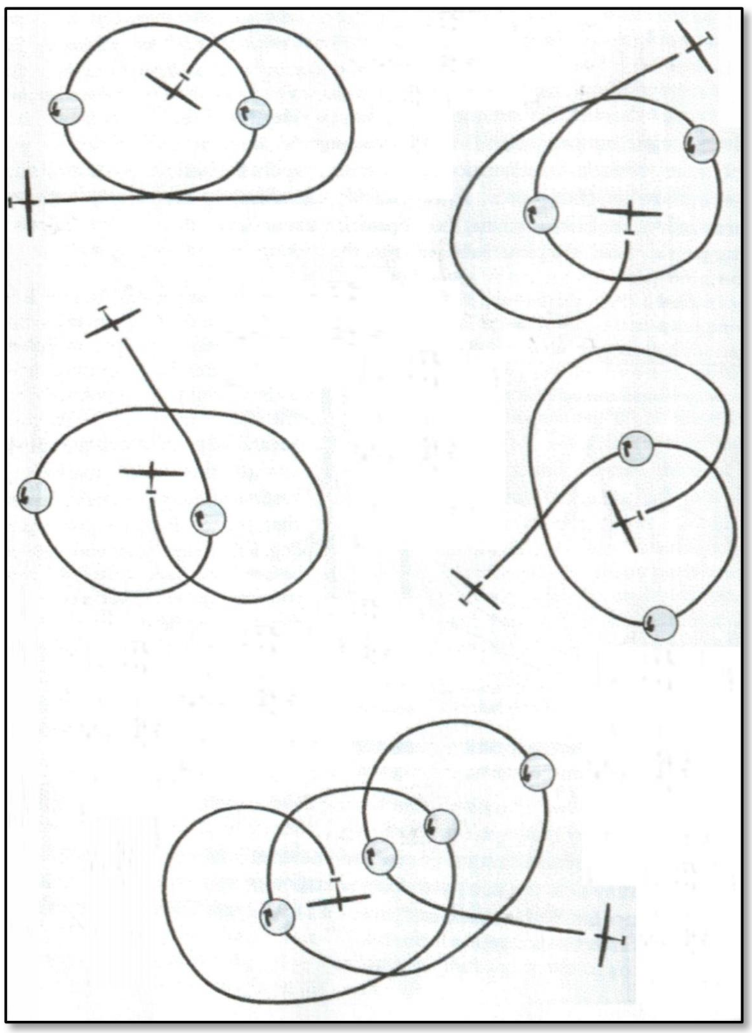


Figure Z

stayed constant, stay in the turn. If the lift has increased, level out until it peaks again, then turn again in the same direction. If your lift has decreased after the first turn, stay in the turn for another 180 deg, the level out and wait for another peak in the lift, then start another turn in the same direction.

In Fig X you encounter lift at #1, so continue to fly straight. The lift peaks at #2 so a 90 deg turn to the right is started. During the turn the lift is increasing, so you level out at #3 and flies straight. The lift peaks again at #4, so you enter another 90deg turn in the same direction. At #5 the lift is constant, so you maintain the turn.

Fig Y shows the algorithm applies equally when the initial turn is made in the wrong direction. Note that the first 180 degree turn doesn't immediately bring the glider back into the strong lift, but as the turn ends the lift will be starting to increase.

Application of the algorithm to the case when you're 'almost centered' is illustrated in the next sub-section.

If you're not thoroughly saturated yet with fundamental thermal entering concepts, follow each glider in Figure Z through its paces, noting the *trend* of the Vario and the pilot's reaction to the trend. Note the pilot is always shifting the center of his thermal circle toward the strongest lift.

So, now let's assume that, if fact, you have mastered the initial centering task to the point that lift is present throughout your circle, but stronger on one side than the other (remember the Vario is a valid indicator of thermal *strength* – but not a timely indicator of peaks).

Refining the circle:

Even the best glider pilots do not get *exactly* into the core on the first turn and need to shift or adjust their centering. Two basic rules help greatly when it comes to moving the glider closer to the center of the lift:

Rule 1: Never ever fly twice through the same patch of bad air.

Rule 2: Continuously shift your circle towards the stronger part of the thermal.

Rule No. 1 needs no elaboration. It's a basic mistake that is repeated over and over again and applies to all facets of thermalling – not just 'refining the circle'. Just don't do it!

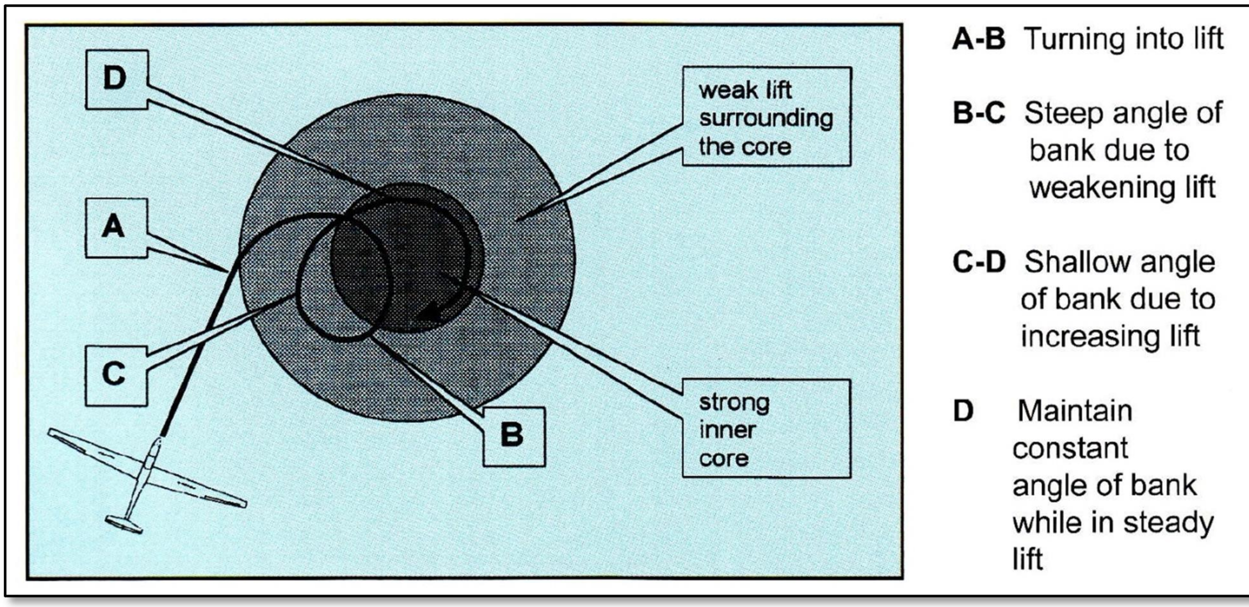


Figure AA

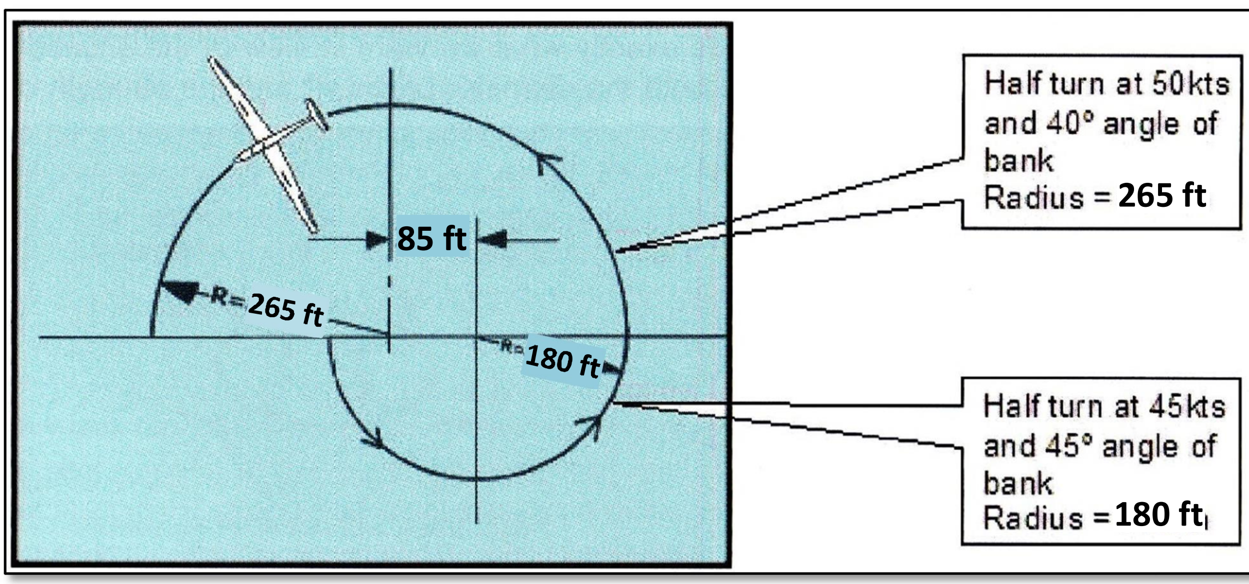


Figure BB

Obeying Rule No. 2 is easier said than done. However, it becomes much easier if we increase the angle of bank after the peak as the lift decreases (think of it as minimizing the time spent in a bad condition) and decrease the angle of bank as the lift increases. Figure AA.

Centering a thermal by varying the bank angle is *only* advisable when just slightly displaced from the core. In fact, bank angle is the single most important factor in terms of extracting the maximum rate of climb from a given thermal.

—

There is an exception to the methodology of Rule No. 2. Once established in a circle with some climb rate all around and reducing bank in lift and increasing with decreasing lift, *IF you feel a sudden surge and exceptionally pronounced boost in your hindquarters*, dig the wing in right there and hold a tight turn as long as the lift is solid. A strong core will have the tendency to push you out of it; when that happens, tighten the turn even more, if possible. The instant the lift tapers off a little reduce the bank angle slightly. This will cause a small adjustment either bringing you back to center or in contact with another core.

—

The situation in which a turn is partly in sink is addressed in the Initial Centering sub-section above ('Worst heading' method in particular). Note that those techniques (when the glider is *not* close to being centered) include shallowing when in weak lift or sink ….. quite different than Rule No. 2 above.

—

So, getting into the 'sweet spot' of core is one thing; staying there is another. What's the answer to 'how can I *stay* in the core of a thermal?' The answer is surprisingly simple. *Fly accurately – very accurately, or better still, very very accurately indeed.*

Flying accurately simply means maintaining airspeed and angle of bank appropriate for the current thermal. Not even minor inaccuracies can be tolerated if we want to hang on to the core – where we can extract the maximum rate of climb. As soon as we tolerate fluctuations of only 5 kts and 5 degs in bank angle, we run a risk of losing the core, and the result is a struggle with the thermal's outer fringes.

[For a given bank angle, the radius of turn varies with the square of airspeed which demonstrates that it is important not to fly faster than necessary (pitch attitude; not ASI).]

In Figure BB, for half a turn a pilot is circling at a 45 deg bank angle while flying at 45 kts. For the other half of the turn he allows the airspeed to increase to 50 kts while simultaneously reducing the bank angle to 40 degs. How far will the will the aircraft move away from the center of the original circle?

As we can see, a circle flown at 45 kts/45 deg would result in a circle diameter of 360', whereas a circle flown at 50 kts/40 deg would increase the circle diameter to 530'. Not only has the pilot increased the circle diameter by 170' (or close to 50%) but he has also moved away from the center of his original circle by 85'.

As emphasized, the basis of good technique is flying a *round* circle *concentric* with the area of lift. Most circles in lift should be banks of 30 to 40 degrees at the minimum sink speed for that bank. Speed control is essential to keeping any circle truly round, and the key to that is holding a *constant attitude.* Perhaps the single most common error in all areas of soaring technique is moving the stick far too much while neglecting to use the rudder precisely. Think critically about the way you handle your aircraft. It is not possible to maintain a constant attitude while jerking the stick. The effective way to work a thermal is to lightly *hold* the stick (insofar as possible), using it to steady the aircraft, while controlling direction as much as possible with positive pressures from both feet.

Once a particular thermalling turn is established, use the attitude of your ship's nose on the horizon to fix all three axes – roll, pitch & yaw – as solidly as possible. Concentrate your vision for several moments (not minutes!) at a time *straight ahead* as the sailplane turns across the horizon. When the bank angle is flattened by lift beneath the inboard wing, you can see it and instantly react with momentary aileron into the turn. If you're skirting along the edge of a thermal core you may see your rotation across the horizon slowed or even stopped by the stronger lift even while the angle of bank remains constant, demanding a moment of inside or 'bottom' rudder to maintain a constant turn rate. On the other hand, if the lift weakens momentarily, a bit of 'top' rudder can prevent the sailplane from falling into a steeper turn than necessary. As you turn into stronger lift the nose may rise, calling for a moment of forwards stick to maintain speed and control effectiveness. If you fly out of stronger lift, the nose will drop, requiring a moment of back stick to avoid increasing speed and moving out of position within the thermal. Keep in mind that although frequent, quick control pressures are necessary to hold your position firm against the constant changes in airflow around you, it is most important to remain *steady*. Make a point of sitting straight in the cockpit (not leaning to one side), with the yaw string directly in the middle of your field of view, so it can be observed and reacted to instantaneously. That string is the only instrument that always tells the truth! After a full circle or two, look around for traffic and other information such as position over the ground and under clouds, and drift in the wind, but then return to looking straight ahead and fixing your attitude on the horizon. If you consciously practice thermalling this way, results will improve immediately, and you will soon be capable of the same subtle reactions even while looking all around all the time, as you should. Any time you're having trouble with a thermal, holding constant attitude is a major part of the solution, and the key to that is looking *straight ahead, through the yaw string*, to the horizon.

Many pilots have an unconscious habit of looking almost constantly sideways in the direction they're turning. Some have been taught to, rightly, to watch for traffic. But when circling, the one place you're least likely to see traffic is inside your thermal.

Of course, you must always look before beginning any turn, and you should also look straight down to establish a reference point on the ground. Looking mostly straight ahead, though, will give you a continual scan across the horizon every thirty seconds or so. Add to that a gradual up-and-down movement of the eyes, and you have the best possible way to confirm that the area around your circle is free of approaching traffic - while also maintaining attitude and coordination by reference to the horizon and yaw string. Then, while circling, only an occasional look into the turn is called for, to check for other sailplanes in the thermal and note the direction and speed of wind-drift over the ground.

Good soaring pilots cultivate a near obsession with climbing as fast as possible in any situation. In large, powerful thermals, this may mean forsaking gentle circling techniques in smooth, easy lift for the challenge of working a turbulent core to achieve measurably better climb rates. Flying in only the strongest lift, staying in it longer, climbing quicker and higher: one thermal at a time, these small triumphs facilitate further improvement in every other area of soaring.

Any turn can be made in more than one way. For a circle of a given size, the steeper you bank the faster you need to fly, or conversely, the slower you fly the less bank is required to remain the less bank is required to remain within a given diameter. The flatter/slower turn allows a lesser sink rate, and therefore a higher rate of climb. However, in situations where the lift is very narrow, or when slow speed is impractical (turbulence, proximity to terrain or other sailplanes), compromise is necessary. In such situations you must fly fast enough to ensure full control, paying an unavoidable penalty in greater sink rate, while doing your best to stay in the strongest lift and optimize your climb.

Even in the center of a strong thermal, if you lose contact with the strongest lift, you have probably been ejected by the turbulence of the core. When this happens, it will usually push you out the downwind side as your thermal boils up through stronger horizontal at higher altitude. New lift from the same source will arrive *upwind* of the position to which you have drifted. So, here too, in the absence of any other indication, and especially if the climb seems to have slowed with unexpected suddenness, moving upwind will often bring the climb back to life.

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Thermal behavior is far from an exact science, but examining theoretical issues is helpful in real-time situation. In a practical sense, what we know for sure is that efficient thermalling is almost always a combination of constantly shifting/adjusting the circles toward the better part of the thermal and tightening the turn in *pronounced* surges … a never ending process. You're unlikely to experience a fixed rate of climb all the way around for very long. Whenever the rate is slightly different in part of the circle, you need to take action. It ain't going to improve on its own!

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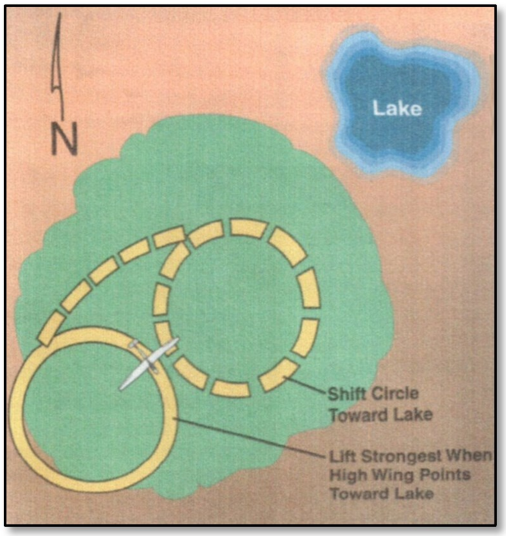

Figure CC

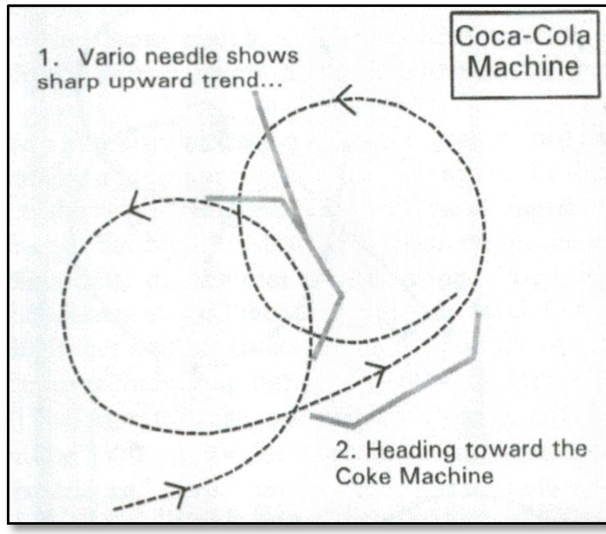

Figure DD

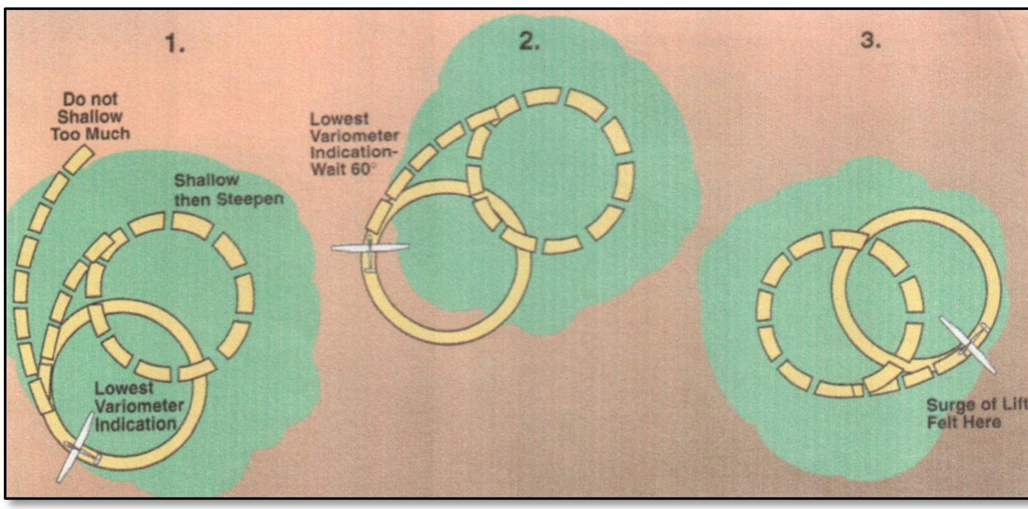

Figure EE

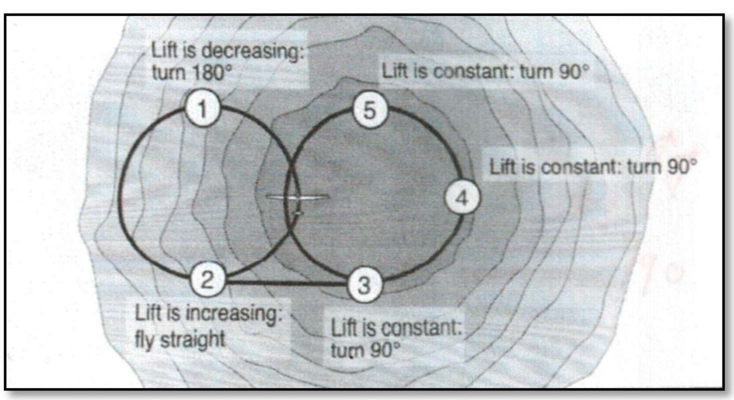

Figure FF

Most books on soaring discuss various ways to make adjustments once near the core and, although they're all valid in one situation or another, many of those descriptions are confusing. *Fortunately, the simplest method is very effective for almost any situation*:

A specific example: In figure CC, let's say the thermal is the strongest toward the northeast or toward some feature on the ground. To help judge this, note what is under the high wing when in the best lift. On the next turn, adjust the circle by either straightening or shallowing the turn toward the strongest lift. Anticipate things a bit and begin rolling out about 30 deg before actually heading toward the strongest part. This allows rolling back towards the strongest part of the thermal rather than flying through the strongest lift and again turning away from the thermal center. How long a glider remains shallow or straight depends on the size of the thermal.

[This can be practiced on the ground: In Figure DD, walk a 15 foot diameter circle at a slow and steady pace. Use ether compass points (north, south east, west) or 'landmarks' (inside - sofa, picture window, TV, etc: outside – hangar, picnic table, sun, parked car, etc.) to orient yourself.

As you walk the circle, think of the trend of the Vario as you pass by each landmark or compass point. On the side of the circle near the Coke machine the Vario trend sharply upward. You note the trend but continue walking in a circle until you are pointed directly at the Coke machine. Now you walk several steps in a straight line directly towards the Coke machine. Next, resume walking in a circle in the same direction. You have shifted the center of your thermal circle several steps in the direction of the machine. Since that is where the lift was strongest, your overall circle is nearer the best climb rate.

With each circle you make, imagine that the Vario indications are changing frequently. Adjust your circle any time you think that doing so will bring you closer to the center of the thermal and the best lift. With a little practice on the ground, you'll find that employing this centering method in the air is easy and natural.]

Other (more complex) variations complementary (and/or repetitive) with some others described herein include the following (Figure EE).

1) Shallow the turn slightly (by maybe 5 or 10 degrees) when encountering the weaker lift, then as stronger lift is encountered again (feel the positive G, Vario needle swinging up, Audio beeping) resume the original bank angle. Shallowing the turn too much can cause flying completely away from the lift.
2) Straighten or shallow the turn for a few seconds 60 degrees after encountering the weakest lift indicated by the Vario. This allows for Vario lag since the actual weak lift occurred a couple of seconds earlier than indicated. Resume the original bank angle.
3) Straighten or shallow the turn for a few seconds when a large seat-of- the- pants surge is felt (verify with Vario needle or Audio). Then resume the original bank angle.

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Applying the algorithm approach introduced earlier to the 'refining the circle' situation: The glider shown in figure FF is in a thermal but not centered. You'll note decreasing lift at #1, increasing at #2, and peak where the glider is shown. The pilot should level the wings as the lift is increasing at #2. Notice that the wings should *not* be leveled when the lift is at its maximum. As the lift peaks at #3, the turn should be resumed in the original direction. At #4 and #5 the lift remains constant and strong, so the turn should be continued …. Along with the near constant 'adjustments' described earlier.

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In the broader sense (more than 'tweaking' near-perfection) flying 'accurately' also includes making the glider do exactly *what* you want it to, *when* you want it to. Once in a thermal, how we incrementally displace our thermalling circle so that it is exactly concentric about the core isn't too important. What *is* important is that it's done quickly. Once we know where we want to go, we should not be overly concerned about performance losses caused by hard maneuvering or full control deflections (presuming you're not near stall nor above maneuvering speed). If we can save ten seconds getting into two knots of better lift, it is worth it.

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Don't be satisfied with an uneven climb rate in a thermal and tolerate it as long as there is a net gain in altitude. For example, a pilot might climb at four knots for part of a turn and find himself in only one knot just moments later. Experience indicates that, in such a situation, the pilot is in danger of losing the thermal altogether and adjustments are in order.

Let's trace the steps of a pilot about to fall out of a thermal. Initially his glider is a constant distance away from the center of the thermal and the Vario indicates a fairly steady rate of climb. The pilot has managed to keep the core almost exactly opposite the inner wing and can at least momentarily relax in the knowledge that he can't do much better.

This ideal situation changes rapidly when the Vario begins to indicate varying lift strength with a minimum on one side and a maximum on the other. Obviously the glider's orbit is not centered on the core any longer. Without correction, the very next turn could well see the glider pass through the exact center of the lift. Although the pilot would momentarily enjoy a greater rate of climb, he is likely to be in sink at the exact opposite part of the turn. If this happens, the alarm bells should ring because subsequent circles are likely to be displaced further, perhaps even to the extent that the outer wing moves through the center of the lift. This has the unwanted effect of accelerating the glider away from the core and eventually into the heavy sink nearby. The glider can be thrown out of the thermal by the forces meant to lift it up.

As a result, the thermal is lost. Our pilot could have avoided this situation by taking corrective action as soon as the rate of climb started to fluctuate. Instead, he failed to shift his position early enough and this procrastination not only led to the complete loss of the thermal but also to contact with heavy sink. Experienced pilots react differently. They make corrections as soon as the sound of their Audio changes. For them, climbing has become second-nature. They center and re-center their glider without really thinking about it. More often than not, their early response is a gentle variation of bank angle, just enough to steady the rate of climb again.

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While advancing to more aggressive techniques, be sure you fully understand the fundamental aerodynamics involved. Remember that the steeper an aircraft is banked, the more up elevator is necessary to raise the angle of attack and maintain slow speed, and the more opposite aileron you need to prevent rolling into a steep spiral. Also, slower speeds require more rudder when steepening or shallowing a bank. Strong or narrow thermals demand more small, short-term adjustments to the airflow in all three axes of control to achieve a round circle flown with a constant attitude. Making the most of strong, narrow thermals requires walking on the edge of stall or spin in turbulent air.

Section 4. When should I leave?

Now that we know how to find and center thermals, the next question is – how do we know when to leave them? In general, might as well leave when, despite your best efforts, the thermal strength decreases markedly. It’s seldom worthwhile to work up to near cloud base if the Cu is somewhat flattened. Keep an eye on the Cu you may be circling under – is it dissipating, maybe indicating that it’s not your centering that’s the problem?? It’s excellent practice to locate another promising thermal to go to when this happens.

More specifically, there are several other reasons to leave, even if you’re still climbing. The first one is that you’ve had enough for one day and want to leave, or need to return the glider for someone else to use.

If you’ve climbed beyond the best ‘usable band’ of lift for the thermal, or you’re just getting too close to cloudbase, regardless (Class E: 500’ < 10,000’ MSL cloudbase & 1,000’ > 10,000’ MSL)

While practicing for cross-country, you may want to leave one weakening thermal to transit to another promising one en route to your imaginary checkpoint.

And, if you’re in a gaggle (not discussed herein) having more gliders than you can safely track.

Or, if you’re becoming fatigued, sleepy, dehydrated, or excessively hot or cold.

Last, but not least, don’t get so wrapped up trying to climb and simultaneously drifting downwind, that you lose sight of when you need to knock-off in order to make it make to within one nautical mile of KFRR at the required 2,000’ MSL.

Section 5. Other thermalling-stuff it might be handy to know?

Audio variometer: It's probable that a major portion of your primary flight instruction was with the Audio turned off. Break that habit as soon as you can. Audio systems make the job of finding and centering thermals much easier, as their use frees up time for scanning and air mass movement and keeps the head out of the cockpit.

The mechanics of simple glider flying: It's not far-fetched to envision someone getting so wrapped up practicing thermalling that some fundamentals are neglected – like geographic orientation; clearing before turning; collision avoidance, particularly in gaggles; not chasing the ASI in thermals; and not getting slower than the appropriate V (min sink) while circling.

Flying circles: The ability to maintain thermal center depends on flying nice round circles in the sky – aptitude in making well banked, coordinated and steady speed turns …. In *both* directions.

Looking at the effect of doing otherwise, using an approximation of our two-seater performance:

At V (min sink) in a 40-45 degree banked turn (at, say, 50-something kts), the turn radius is about 250ft and the glider sink rate is about 2.5kts. Varying either bank angle or airspeed can have a major effect. As shown earlier in Figure O, there isn't a great effect on sink rate in the 20-40 deg bank angle range, but the curve quickly steepens above 50 degrees. That's why a bank angle of a *true* 45 degrees is usually considered the 'standard' *steep* turn. Figure GG takes a bit of study, but it shows a glider with an inherent sink rate of 1.5 kts superimposed on the profile of a moderate thermal with 4 kts airmass lift and diameter of about 1500 ft. In this particular case, you can see that a bank angle of 30-35 degrees produces the best climb rate.

It will be necessary in almost every thermal to change the bank angle – and hence the airspeed, glider sink rate, and circling radius – in order to maximize the climb for the changing characteristics of the thermal with increasing altitude. Often thermals require bank angles of 40-50 degrees in their lower regions, while the upper third requires only about 25 degrees. Only if there is a *very* steep climb-rate gradient between the edge and the core is greater than 50 degrees of bank warranted, despite its inherent inefficiency. Flying at 60 kts when you should be flying at 45-50 will increase your turn radius by a bunch, to say nothing about what happens to the sink rate - unless you're in a *really* strong, tight thermal when it may be worth it. Figure HH puts several interdependent relationships together for a Sprite-type of glider.

Naturally, clean and coordinated flying is a prerequisite for decent thermalling. The yaw string is an irreplaceable and ultrasensitive 'instrument'. Nevertheless, it is more important to center the thermal rapidly; the most gorgeous textbook circle is of little practical use if only half of it is

Figure II

in the updraft. Therefore: First, center the thermal, *then* be sure you are flying in a clean, coordinated manner.

Speed-to-fly while circling: When a glider is in turning flight, the load factor, or 'G', increases. This increase in 'G' requires that the minimum sink speed must be increased. In fact, the minimum sink speed for a given 'G' increases as the square root of the increase in 'G'. For example, if the straight-flight load factor is doubled to two 'G's, the wings-level minimum sink speed must be multiplied by the square root of 2, or 1.4. So, for another example, if the wings-level minimum sink speed is 40kts, it would be 56kts in a very steep 60 degree bank. The Club's Cockpit Cards have a table of Min Sink Speeds by Bank Angles that you should be familiar with.

The MacCready Ring: A simple speed-to-fly concept that remains the basis of what all the latest cockpit computers provide. It can be used in two ways: one for conservatively maintaining optimum altitude, and the other for maximizing cross-country ground speed.

The device consists of a movable ring surrounding the face of an ordinary variometer, with an index mark and several numbers around the bottom half of the ring (See metric-system calibrated figure II). In the conservative mode, the one we're interested in, (zero MacCready) the index is left at zero on the Vario and you fly the speed indicated on the ring wherever the Vario's needle is pointing. In cross-country mode, the index is set *up* to whatever rate of climb expected in the next thermal, and then the ring is used in exactly the same manner.

Wx Forecasting Tools: This topic could be the subject of a paper the length of this one. Two of the frequently used services available via the Skyline Web Site are XC Skies (www.xcskies.com) and the Skew-T/Log-P Chart (Winchester). The former is quite user-friendly and is described in depth by Mike Ash in the April 2009 issue of Skylines. The latter is a collection of what seems to be a random mix of groups of lines and is frequently considered one of the most important tools for assessing soaring conditions. There is a good explanation of it provided by the GFH; for those who want more in-depth discussion, references 4 and 7 are recommended.

Wind shear: Soaring becomes even more interesting if there is vertical wind shear in the winds. This simply means that the wind changes speed and/or direction with altitude. Wind shear is very common. Generally, the wind strengthens with increasing altitude, and undergoes direction change as well. The stronger the shear, the rougher conditions become.

Suppose the wind is southerly from the surface to 2,000' AGL, slowly turns to westerly between 2,000' and 3,000' AGL, and then is westerly from 3,000' to the base of the Cu's at 4,500'. A thermal starting from the ground will first drift towards north, then higher up it will drift towards the northeast or east. The exact path taken depends on both wind speed and direction at various levels.

Figure JJ

Figure JJ is a photo taken on a day with strong wind shear. The wind blows from right to left and increases with height. Note that the cloud tops are sheared off towards the left, and clouds have a tattered appearance. Some thermals may be fairly strong on days like this, but cores will be small and rough. Most thermals will be unusable, or at best, provide short climbs.

If the shear is strong, turbulence it creates can even break thermals apart. Thermals will be tilted steeply, so it may be difficult to judge where the best lift is in relation to the Cu's. Vertical shear doesn't always increase or decrease at the same rate . If it's strong, the shear Layer becomes the maximum height for any thermalling activity.

What value of shear is strong enough tp cause problems for thermals? It depends on the size and strength of thermals on any given day. If the wind increases 10 kts or more over 1,000 or 2,000' of altitude (moderate shear), expect thermals to become somewhat difficult to work. If the wind increase over 1,000 or 2,000' is 20 kts or more (strong shear), expect thermals to be completely broken apart.

An example: The forecast calls for surface winds to be northerly at 5 to 10 kts. At 3,000' AGL the forecast wind is northerly at 15 kts while at 6,000', the wind is northwesterly at 35 kts. Based on the forecast winds, you would expect thermals to be difficult to work above 3,000' and may break apart before reaching 6,000'.

E**stimating Cu cloud bases:** A rule of thumb using only surface temp. and dew point temp (in C):

(Surf Temp – Dew Point Temp)/2.5 = height of Cu cloud base in thousands of feet.

Example: Surface Temp 26C; Dewpoint Temp 14C …… (26 – 14)/2.5 = 4.8, so Cu cloud base is estimated to be 4,800 ft AGL.

Thermal Index: A measure of atmospheric stability/instability; just a number that represents the difference in temperature of air rising from the ground (a thermal) and the air it's passing through. Obviously, for thermalling we want the rising air to always be warmer than the surrounding air, so a negative TI is desirable (-3 to -4 is 'good': -5 or better is 'excellent'). This concept is pretty subjective in nature and there are much more thorough weather analysis methodologies available such as the Skew-T/Log-P diagram, which takes practice to use efficiently and is addressed in detail in several of the references.

Condor's thermalling simulation: For those who enjoy playing with simulators, the author of Condor Corner (Soaring magazine) has produced an interesting video clip about working thermals (http://www.youtube.com.watch?v=gs61CxgryU8). This clip just demonstrates one of many Condor capabilities. Unfortunately, lacking is the so-important seat-of the-pants aspect.

Section 6. Suggested Take-aways

- Use your solos productively: Study, practice, and don't get discouraged. Good thermalling is essential to everything from 'pleasant floats around the airport', to serious cross country flying.
- As a beginner, it's important to stay with basic procedures. If you over-complicate things, a thermal can be easier to lose than it was to find.
- Make use of the Audio a habit.
- Use sketching and walk-throughs as an important part of your studying
- Study the sky while you're sitting around the airport.
- While practicing, don't forget the pre-solo fundamentals of ordinary glider 'aviating' (and navigating and communicating). Among the basics, include rapid turns into precise circles – in *both* directions - in smooth air.
- Establish a mental picture of lift distribution.
- Never go through the same sink twice
- Don't over control. Control movements must be timely but no more than needed
- Do not become mentally lazy during a thermal climb. Always work toward 'perfection'.
- When puzzled or something didn't work as expected, talk with the Clubs' experts.
- Keep in mind the 'art vs. science' principle; there's seldom only one 'book-way' to do things.
- To test your thermalling progress, consider the SSC 32 nm within-gliding-distance 'round-robin' circuit or a variant of it.
- Develop the habit of checking the forecast, including winds-aloft, prior to traipsing to the airport.

A few common errors:

- Too shallow a bank angle, resulting in too large a turning radius
- Flying too fast in thermal
- Failure to maintain constant bank angle and airspeed
- Failure to continuously clear for traffic while thermalling
- Ignoring winds aloft

Section 7. Plagiarized References

1. FAA 2003 Glider Flying Handbook
2. The Art of Thermalling Made Easy (Wander)
3. After Solo (Knauff)
4. Glider Pilot's Handbook of Aeronautical Knowledge (Holtz)
5. Flight Training Manual for Gliders (Holtz)
6. Gliding, A Handbook on Soaring Flight (Piggott)
7. Advanced Soaring Made Easy; Revised & Extended Third Edition (Eckey)
8. Soaring Beyond the Basics (Masters)
9. Gliding Mentor – Thermals (Hertenstein)
10. Cross-Country Soaring – Revised Edition (Reichmann)