Thermals, sources and streets.

My theories as to the development of thermals and streets as the two blend together, I have considered over some years and consistently appear to be proved correct. Most of the ideas are from my personal observations but stem from a concept mentioned in Wallington's Weather for Glider Pilots. The use of the lee side of bush as a thermal source works from the very first think in the Morning to the end of the day.

Many years ago when reading the Wallington's Weather for Glider Pilots I noted the absolute concept of how thermals develop.

a) The sun heats the ground.
b) The ground heats the air in contact with the ground.
c) The air does not immediately rise but is stored for a period of time in the form of a hot air reservoir for a period of time until some function causes it to break away from the surface.
d) The depth of this layer of hot air depends upon the environment.

So what governs the depth of the hot air reservoir? If the air is over an area of rock, or road the layer will be very thin, you can see it as a mirage when driving on a hot summer day. Over some grass the layer is a little thicker, in crop the layer can build up to the depth of the crop and finally in bush the layer can be deeper still.

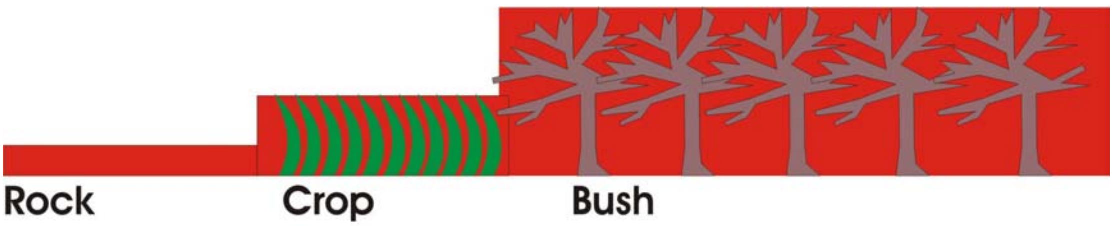


Fig 1

There is another influence that will affect the depth of this layer and that is the wind. If the wind is strong it will tubulate the hot air adjacent to the ground and force it to break away and rise. If the wind is light the hot layer can build up to a greater depth until it has reason to break away. We will see what causes it to break away later.

Let us picture a day where the wind is blowing from right to left. When the wind meets the bush it will slow down to a light breeze through the bush. This light breeze will assist in filling the bush up with hot air. In addition the sun will still be adding to the reservoir of hot air within the bush. Thus the layer of hot air will build up within the bush over a period of time. Now when hot air comes to the lee side of the bush, where it may border some crop or even better some rock. There will be a large volume of hot air flowing out of the bush that can not be sustained over the rock, remember point d) above. Therefore this huge volume of hot air that has been stored up in the reservoir of the bush will have to escape. It will tend to do so in a continuous stream from the downwind edge of the bush. Similar situations occur where a rocky environment exists in the middle of the bush.

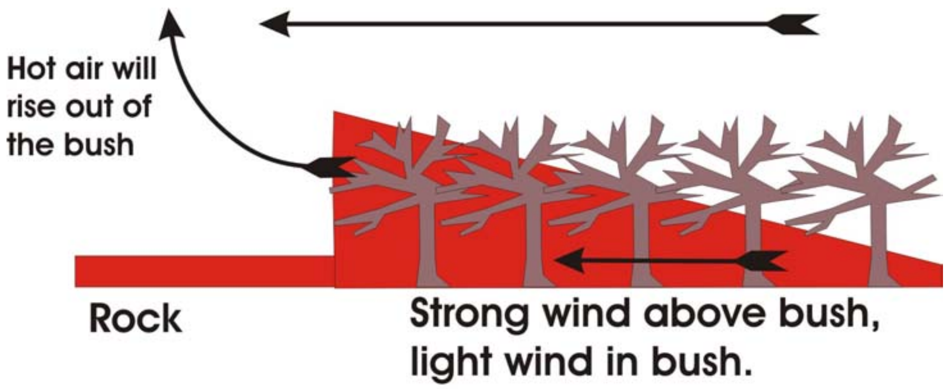


Fig 2

So now we see that the leeward side of bush will give a good thermal source, it works nearly every time for me. Now what happens down wind?

We have a large bubble of air rising vertically, but being drifted down wind. The bubble has considerable mass and momentum and will, as it rises creates a low pressure underneath that will suck any residual hot air off the surface of the ground below. Now we can see that the layer of hot air over the rock or crop down wind is not as large in volume as that that has just exited the bush but it will now be persuaded to leave the grip of the earth. The thermal will be continually fed by this energy supply as it drifts down wind.

We can further look at what happens as the thermal drifts down wind being further stoked by the hot air below from the crop that it is passing over. As the volume of air that has been stored up over the crop does not have the volume the strength and size the thermal will be weaker and narrower. In addition as the thermal drifts down wind it will consume any available air to the right and left of track, and as this is a continuous process a thermal street will be created. In addition to the right and left of the thermal for some distance there will be little hot air available to create another thermal, all the hot air having been consumed. As we can see in Fig 3

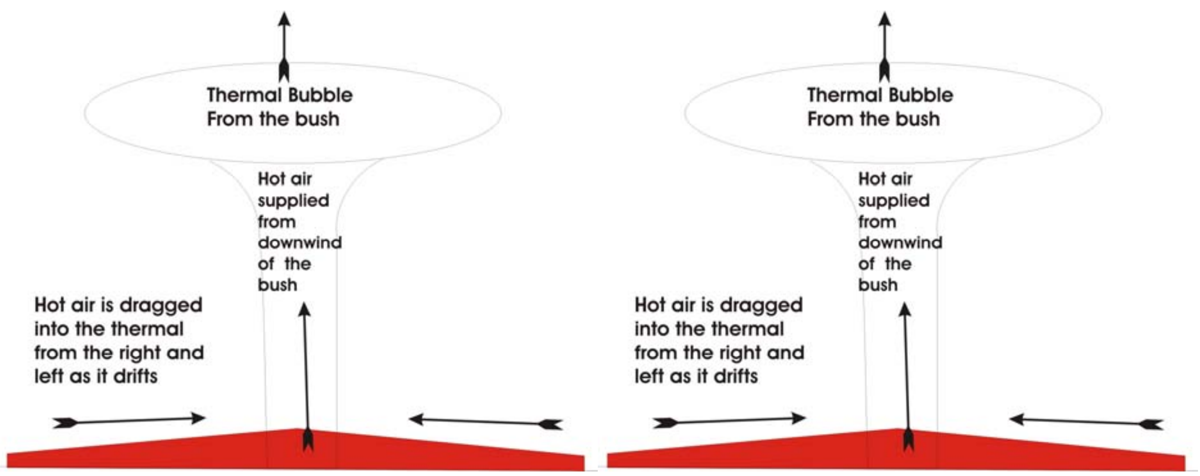


Fig 3

No thermals here

To look now at the situation we have seen develop.

- We have a strong thermal reservoir in the bush.
- The thermal escapes on the lee end of the bush.
- As it rises it draws up further fuel from the paddocks below.
- The thermal downwind of the bush is not so strong.
- The street will be very narrow perhaps 30 metres across
- As the air is drawn from the sides there is little or no chance of other thermals developing for some distance either side of the thermal street.

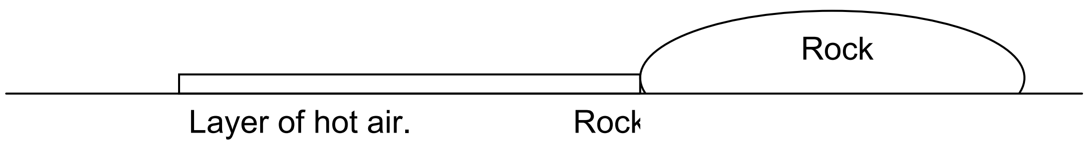
So what do we gain as glider pilots from this knowledge.

- On a day with sufficient wind to generate streets we will probably find lift if we fly away from the sink cross wind.
- When we find lift, if it is weak, we will need to fly upwind to the thermal source. Don't turn it is too narrow, you will fall out the side.
- This part of the street may be narrow broken and turbulent, so fly with all your senses switched on straight into wind.
- Do not turn until you find the thermal bubble that is stronger and smoother. This will be the bubble that has left the lee of the bush.
- Once you have gained sufficient height if you leave into wind you will probably run out of lift very soon as you leave the main thermal bubble. So pick up speed before you leave the lift

As a picture tells a thousand words I have created a simple movie that can be viewed on Quick Time Player. Select Thermal Movie to download on the page Articles.

Just some further comments, you may willy willys run down the side of bush. One of our clubs in Western Australia has a runway that is located against an area of bush, this gives problems of willy willys upsetting parked gliders. I have even noticed small ground turbulence running down the border of cut and non cut grass.

The explanation of the layer of hot air explains why large rocks are not good sources. Let's look why.



In this case we see that the hot layer adjacent to the rock is actually sealed in and will only escape by drifting around the side of the rock or in the case of a strong breeze that will push it up over the top.

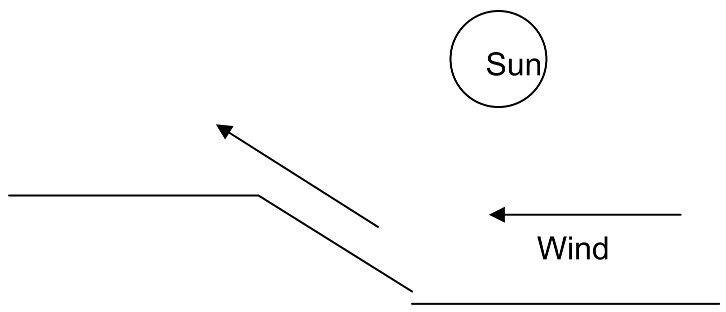
My first thermal

As a child I lived in a large area of woodland, Sherwood Forrest. To the back of our house was an area of cleared land about one hundred meters square. When I was about 8-10 I had a small man with a parachute that I would through into the air and usually he would drift down to the ground with the parachute generally open. On this particular day rather than the man drifting down. The hot layer that had stored up in the woodland must have drifted into the grassy area. (I did not understand that at the time,) But I did understand that my little man was not coming down instead lifted up and drifted off over the trees and horizon, never to be seen again. I suppose from that moment I was hooked.

Humid Air

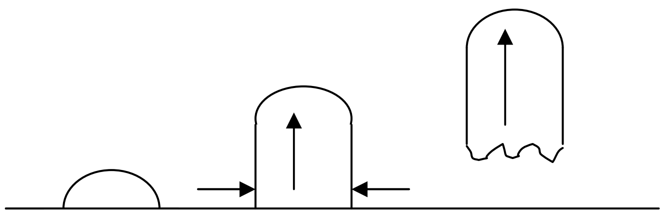
Another interesting point to remember is that water vapour is actually lighter than air. Hydrogen having an atomic weight of about 1, Oxygen of 16, therefore H^2O being 18 whilst nitrogen that is the largest component in air has a weight of 14, N^2 therefore having a weight of 28. It is however also important to remember that water requires a lot of heat to raise its temperature. So areas like salt lakes that reflect the heat and absorb much heat will not be a good source in the early part of the day. With the high water content they may be good in the evening, as they will have stored up a lot of heat energy over the day. In addition being more humid will be inherently more buoyant.

Although I fly in predominantly flat lands it is worth noting how hills will help us. If a hill faces into the sun it will absorb more heat than the surrounding flat land. If the wind is blowing up the slope it will assist the now hot air break away. I can assure you that if the wind is blowing the opposite way to the diagram it could still work, I have experienced this fact, and the logic is as follows. The lea side of the hill is sheltered by the wind allowing a thick layer, reservoir, of hot air build up in the shelter of the hill. As this layer builds up and drifts down wind it will eventually break away as a large volume of air.



Breaking away

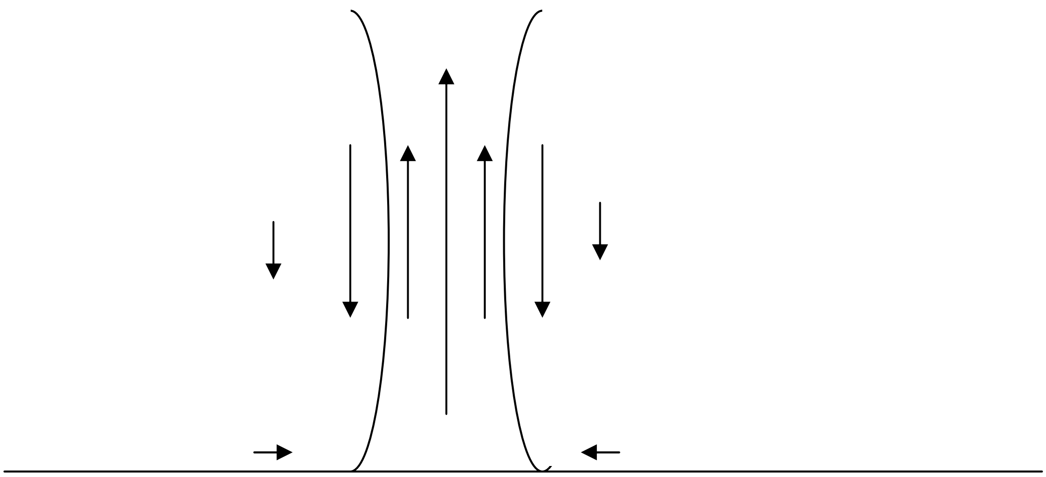
We have looked at how the air is heated up now we should look at what happens as it breaks away from the ground. Let us initially assume no wind.



The thermal rises and in doing so drags in hot air from all sides. It will continue to rise and increase its cylinder length whilst being supplied with more hot air. This will depend upon its local environment. If there is a large area of available hot air in the vicinity the thermal column will be tall, if however there is little available air due to a thin hot layer, adjacent cloud shadows, other thermals in the vicinity, the height will be less. Once the hot air supply has run out the bubble will be cut off leaving the bubble to rise. One thing to note is that the top of the thermal has a smooth contour, whilst at the bottom of the column it is turbulent. When you are flying if you find a smooth thermal it may be the top of a new bubble worth hanging on to. If alternatively it is rough then you may have arrived too late. We will see later however that it is possible to climb through the bubble, i.e. climb faster than the bubble its self.

Thermal Structure

We should be aware of the basic structure of a thermal, once fully developed. Note that in the case drawn it is a classic thermal with no wind shear and assuming a nice column length. At the bottom the thermal is dragging in surrounding air, remember this when you are low you will get dragged into the core. It rises but due to the friction between the rising column and the surrounding air the core will rise faster than its edge. As the rising air has to be replaced a down draft will develop adjacent to the rising air. The friction between the sinking and rising air will develop turbulence that is noticeable as you enter the thermal from the side. As the thermal reaches the top it is spread out by the inversion and will try to push you out. If you are continually trying to recentre at the top this could be why, may be its time to go. You should be able to see from the diagram why the core is so much stronger and therefore why it is necessary to turn quite tight.

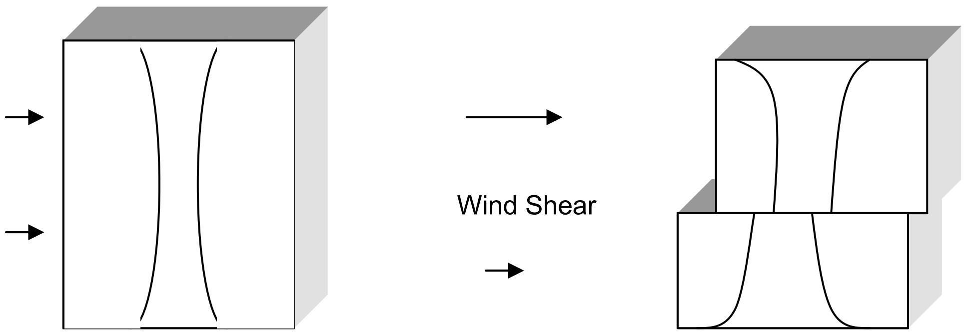


When considering a bubble rising you will be aware that the core of the bubble will be going up at a higher rate than the edge of the bubble. Therefore the rate of assent of the whole bubble will in fact be lower than the core its self. Bearing this in mind it may in fact be possible to out climb the bubble. This could indicate why some climbs start well, a little rough as you climb through the bubble, the climb rate then drops off but becomes smooth as you have reached the top of the bubble but continue to climb on the top of it.

Thermals bend with the wind, or is it against?

As we have seen from all the descriptions above the thermal will form a vertical column. Just look at a willy willy and you will see its vertical tendency. Thermals do not bend into wind or down wind. There are some cases where kinks may occur in a thermal.
They may also lean as they exit the thermal source on the basis that the air leaving the ground is still and the upper air will be stronger so the rising air will need to accelerate, and having mass this may take time.

Wind Shear, When considering what happens to a thermal column you need to think of it in a box of air that is travelling down wind with it. The bubble will be rising vertically in the box and so forming a vertical column but the whole box is drifting down wind. The problem arises when the box is moving at a different speed down wind at the top as the bottom.



We can see on the figure on the right that the wind shear will move the upper column down wind.

Shift into wind or down wind.

When you have lost the core of the thermal you will have to recentre on the assumption that you have not lost it due to inaccurate flying. The general comment is move into wind. This is good when you have reached the top of the thermal, or fallen out of the bottom. Move into wind to find the original thermal source. If however there is a wind shear, usually wind gains strength with height it is necessary to move down wind, i.e. with the shear. You can see from the diagram above that if you are at the top of the bottom half of the thermal, to move back into the core you need to move with the shear to get into the bottom of the top half of the thermal. On this basis it makes sense to examine the weather report in the morning.

Cumulus

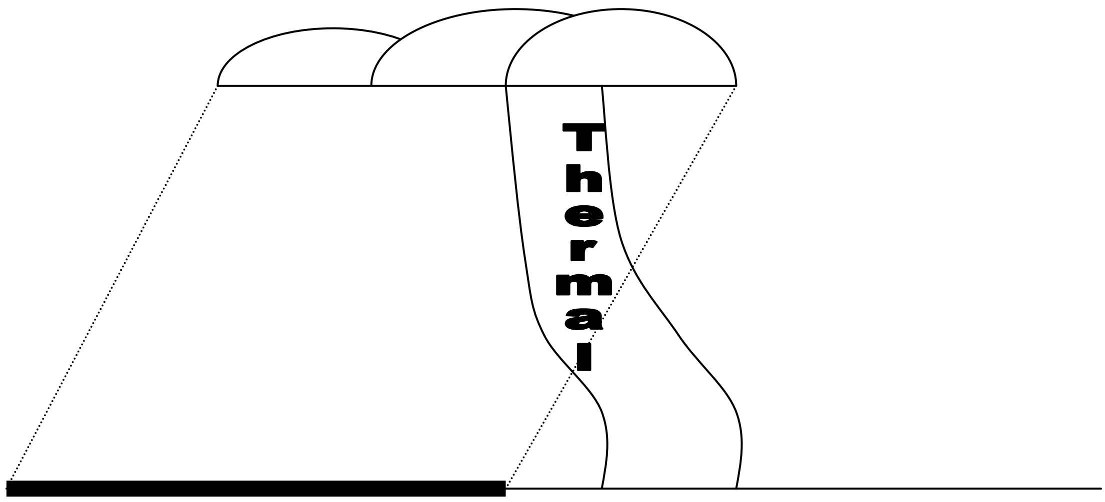
If we are lucky enough for cumulus to be formed cross country speeds will be increased dramatically. You can see the thermals so are able to fly like stepping-stones across the sky from one to the other. With careful observation you can see the core as you approach. In addition the thermal strength is generally stronger under a cu to that in the blue for the same thermal height, normally 1-knot strength per 1000-ft height band, I have also heard 1 Knot per 1000 ft minus 1. This makes a little more sense.

Why does a cumulus increase the lift?

- When you boil a kettle you have to put in energy to convert the water to water vapour. Knowing Newton's law "For every reaction there is an equal and opposite reaction." If you convert water vapour to liquid water, you get energy back.
- Air can only hold so much water vapour, the cooler it is the less it can hold.

So as the thermal rises cooling at 3° per 1000ft. It will eventually reach a point where it has cooled to a point where it can hold no more water vapour, this is the due point. The water condenses, and as we have seen above we will get some heat input into the thermal. There will now be an added boost to the thermal, once the cloud has developed sufficiently it will actually begin to suck air in. If you can keep in contact with the cu's there is a great advantage.

When flying on a cumulus day it is worth noting how it will affect the thermal sources. If the sun is high in the sky, in effect producing shadows directly under the cu. This will cut off the thermal source, so the thermal will not last for long. Well this is what we may think at first. On the basis that the sun is on the ground adjacent to the shadow producing the hot layer of air, that will now become thicker than the air above the ground in the shadow. Another thermal will rise but to the side of the cloud along the shadow line. It will tend to rise vertically and then shear to one side so as to be directly under the sucking Cu. If there is any wind we can assume that the thermal column will not be up wind of the cu as it will already have consumed that air. If the sun is other than directly overhead there will be a tendency for the thermal source to be on the sunny side of the cu as this gives the least path of resistance to the rising thermal.



Wave

Wave is a phenomenon that we get more often than we recognize, although there are sometimes we recognize it when it is not actually there. On the flat lands we fly the wave is generated either by wind shear or by a frontal system to the west. The wave can be visible by producing wave bars in the form of lenticular or cumulus with smooth tops. The effect of the upper level wave will affect the thermal activity right to the ground. The secret is to recognize it and act accordingly.

When the wave is on the up stroke there will be a tendency for the wave to pull thermals from the surface, they will break away smoothly and tend to achieve higher altitudes than the day would normally expect to achieve. That is under the cloud and towards its windward edge, that being the upper wind.

When the wave is on its down stroke it will tend to depress the thermals. If the thermal rises due to the reasons mentioned previously it would in turn be depressed by the upper wave. On that basis you will tend to get large areas of air trying to gain height but in turn being depressed. In other words areas of rough thermals going nowhere. The danger is assuming the thermals are no good and pushing on when all you are going to run into is further subsiding air. The wave length may be many many kilometres.

Remember that it is unwise to go cross wind in the down part of the wave. Better to push into or down wind find the best part of the wave before going across.

Rogue Thermals

We have a term called rogue thermals. These are thermals that are considerably stronger, smoother and go higher than others found on a given day. The problem is recognizing them. And being aware that the day has not actually improved. The tendency of the glider pilot having taken this say 10 knot climb is to push on hard leaving the 6 knots he would had previously taken behind, until he starts calling Kilo Uniform Landing out. I do not know the reason for these forming and would dearly like to know how to track them down. Don’t confuse them with the sea breeze front, which can have a similar effect, but has in addition a strong wind and no thermals behind it!

James Cooper