SKYWATCH

A beginner's guide to clouds

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from *Sailplane & Gliding*

IF YOU HAVE TIME TO SPARE waiting for a launch or walking over open fields, try watching the development of individual clouds. The pilots who regularly make long flights and compete successfully are usually very good at reading the sky. Beginners may not notice all the indications of lift or sink. Once airborne it is much harder to see what all the clouds are doing so it is worth watching them from the ground to learn their ways.

What thermals may look like before a cloud forms

Experiments in a glass sided water tank made the thermal bubble a popular model. Liquid thermals do look very like inverted cumulus clouds, but the model cloud is initiated by inverting a cupful of denser liquid and thus starts with a hemispherical shape.

Most real thermals start from a fairly flat surface. The warm air can be thought of as forming a wide but very shallow disc; the height may not be more than about 20 metres. If one specifies an excess of temperature of 2°C this disc should accelerate upwards at 0.067 m/sec^2. This value is derived from the density difference multiplied by gravity divided by the absolute temperature (9.81 x 2/293 assuming a surface temperature of 20°C). At first glance this seems unimpressive acceleration but if there was no mixing or drag to slow it down it would reach a speed of 40 m/sec (nearly 80 knots) after ten minutes.

Figure 1

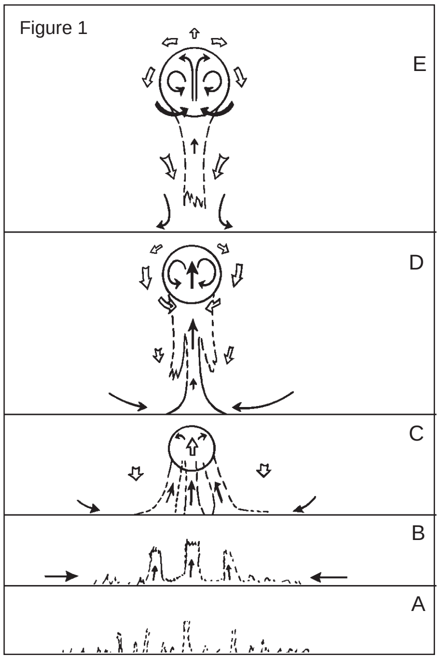


Figure 1 shows some of the stages in transforming a flat disc into a tall thermal. The disc cannot lift off vertically like a flying saucer; the form drag would be enormous. What seems to happen is that little tendrils of air start rising like steam from a hot bath (A). One can sometimes see these misty thermals after a forest has been drenched by rain. When the sun comes out again the forest sometimes sends off tendrils of mistiness which rise very slowly. They show no sign of changing into bubbles before the mist evaporates. Presumably the process is much too gentle. Another example is "arctic smoke"; wisps of mist or fog rising off warm water during a very cold spell.

Until these tiny wisps become more organized they cannot rise far. To form a thermal the tendrils must amalgamate into small plumes which in turn join up to form wider columns (B).

Plumes which combine to make a good sized cylinder usually go on to form a dome shaped top (C).

As the air is gathered up into the thermal the original disc shrinks and there is an indraft of surface air. This is sometimes strong enough to produce a change of wind on the ground. When it is almost calm windsocks or smoke from bonfires may show this inflow as the thermal takes off.

The dome eventually forms a thermal bubble (D) linked to the dwindling reservoir of hot air on the ground. Finally the link is broken and one is left with a sort of ice–cream cone shape. The air in this cone is eventually absorbed into the bubble.

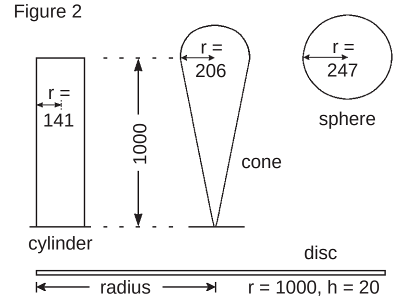
Columns, cones or bubbles? The smoke from a stubble fire suggests how thermals may behave. At full strength when there was a continuous supply of heat, the smoke formed a cylinder with almost parallel sides reaching from ground level to the bubble of cloud at nearly 5000 feet. When the fire went out, the cylinder changed into an inverted cone, and higher up most of the smoke spread out into a roughly spherical shape. The stubble fire is an exaggerated heat source but the smoke gave a good indication of how less violent thermals behave.

Thermal bubbles do not seem to form in all cases. They need enough temperature difference to accelerate the thermal to sufficient speed with enough mass to form a good sized bubble. Some plumes do not grow into thermal bubbles at all, or not until they pass the condensation level and get a boost from the cloud. If the plume has little energy left when it reaches the condensation level it just drifts on to form a ragged puff. Flying through such puffs shows very little turbulence and no sign of a bubble.

Putting numbers to the imaginary thermal

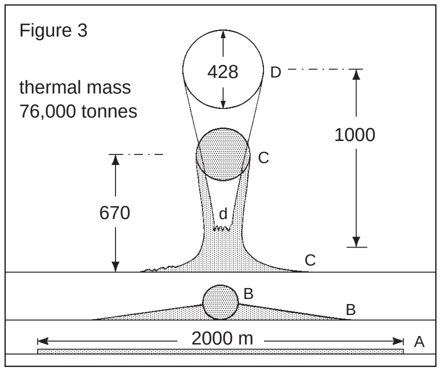
If we start with a disc 2000 metre across (about the size of a big airfield) with a depth of 20 metre the total mass works out to about 76,000 tones. Ignoring any expansion with height this disc would provide a thermal cylinder 1000 metre high by 141 metre wide, or a shape like an ice–cream cone 1000 metre high with a top radius of 206 metres, or eventually a sphere radius of 246.6 metres. Figure 2 shows this series of options.

Figure 2



Large and powerful thermals probably do produce a tall cylinder of lift at least for a time. When the heat source is exhausted the cylinder changes into an inverted cone. Finally the

Figure 3



cone is drawn up into the expanding bubble. When there is only a finite source of heat which soon becomes exhausted the thermal shape probably goes through the stages in Figure 3. This shows a simplified version in four stages, A to D. Each is a cross–section of a circular volume of air, starting with a shallow disc and ending up with a sort of ice–cream cone. The cross–sections are drawn to contain the same mass of air throughout. B shows the region where a bubble might start off with a very flat cone of warm air feeding it. C shows the expanding bubble at the top of a cone with its centre at a height of 670 metres (about 2200 feet). D shows the whole mass now detached from the ground. The reservoir of hot air is exhausted and has been converted into a bubble and cone about 1000 metre tall. The bubble itself has expanded from 200 to over 400 metres in diameter.

Do gliders weigh down a thermal?

If the thermal is as massive as suggested its ascent is not likely to be seriously hindered by a few sailplanes circling inside it. However, when circling in a rather weak thermal one does wonder if it will really support any more sailplanes. I had great sympathy for the 15 metre pilot circling in a tired thermal when he was pounced on by a gaggle of Open class monsters. Picking up his microphone he said “Go away! This is only a Standard class thermal”.

Entrainment The example in Figure 2 is not the full story. Water tank models show that thermals grow in size by being diluted with the environmental fluid. This process is called “entrainment”. The tops of big cumulus consist of a large dome which is made up of hundreds of smaller domes. This region of different sized domes is where the environmental air is folded into the thermal. At first most of the entrainment occurs at the cap but as the bubble grows some of the outside air sinks round the side and is pulled into the bubble from underneath as well.

Entrainment cools the thermal

Entrainment makes the bubble expand and dilutes the warm air, so reducing the difference in temperature. When a thermal rises into a stable layer the temperature contrast is changed. The outside of the thermal is warmed by mixing but the faster rising core continues to cool at the original rate. This produces the unexpected result of the fast rising air in the core becoming cooler than the slower rising, or even sinking, edges of the thermal.

So attempts to detect thermals by measuring temperature differences usually fail except near the bottom. Only in the first few hundred metres is the rising air significantly warmer than its environment. In the middle levels there is little difference in temperature and at the top the best lift is actually in colder air. Figure 4 shows the bubble rising on the left with speeds of 2.5 knots strengthening to 6 knots between 1500 and 2500 feet. On the right is the temperature profile through the thermal. At ground level it is 2°C warmer. By 300 feet this is down to 1.5°. In the range from 1500 to 2500 feet it goes from fractionally warmer to a tiny bit colder than the environment. Then at the top where it reaches the inversion the lift drops off rapidly, but the temperature profile shows the core to be 1.4° colder than its surroundings. (This is just one of a number of

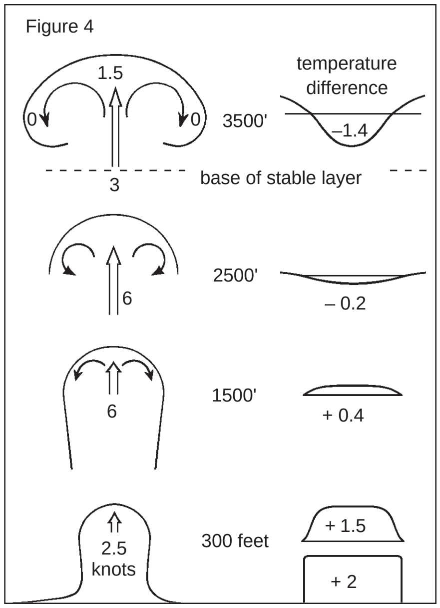


Figure 4

numerical thermals. One can have different figures and in extreme cases the thermal core was 4° colder than the environment before being halted.)

Little bubbles or narrow cylinders are diluted quicker than wide ones

The rate of entrainment depends on the surface area of the bubble but the dilution depends on the internal volume. As the radius of a bubble grows the column increases faster than the surface area. Figure 5 shows how entrainment can stop little bubbles from ris-

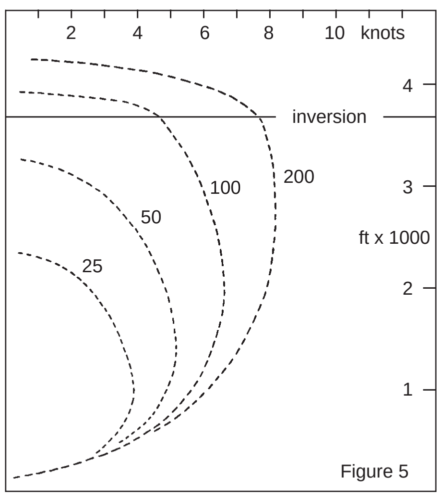


Figure 5

ing far. Initial bubble sizes are marked against the curves. They show that the height reached depends on the initial radius. In this calculation each bubble started with 2°C excess and ascended through an environment which cools off at 8°/km (less than a dry adiabat). As a result thermals smaller than 100 metres initial radius failed to reach the inversion. The larger bubbles rise much further and faster and penetrate the inversion. The curves also show the rate of ascent (marked in knots along the top).

Little bubbles expand more than big ones

Figure 6 shows two curves. The solid one is the ratio of initial to final radius. The dashed line shows how high bubbles might go. The initial radius is shown along the bottom ranging up to 140 metres. The maximum height

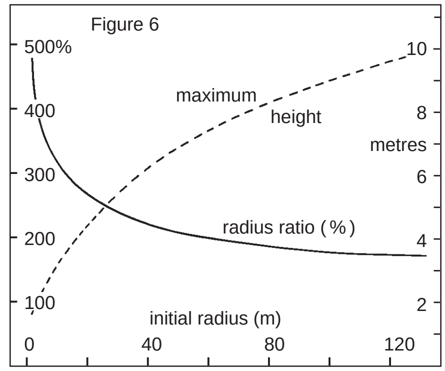


Figure 6

reached is marked on the right and the percentage increase in radius on the left. The solid line shows that the smallest bubbles may have a 500% (or more) increase in radius while the larger ones increase by less than 200% even though they have risen further.

Penetration into stable air When a thermal goes through an inversion and starts to push into stable air, the penetration depends on both the temperature difference and the speed of the bubble on entry. Fast moving thermals can go a surprisingly long way before the deceleration caused by the temperature difference overcomes the momentum. Sometimes his carries the bubble high enough for a puff of cu to form well above the original base of the inversion.

First thermals are usually feeble The effect of entrainment probably explains why the first thermals of the day are apt to be disappointing. These thermals are short lived. It seems as if they lift off before they have a big enough reservoir of heat to draw on. They form small bubbles which are quickly diluted and seldom reach the top of the unstable layer.

The appearance of the first clouds Once the rising thermal has passed the condensation level extra heat is put into it by the release of latent heat of condensation as cloud forms.

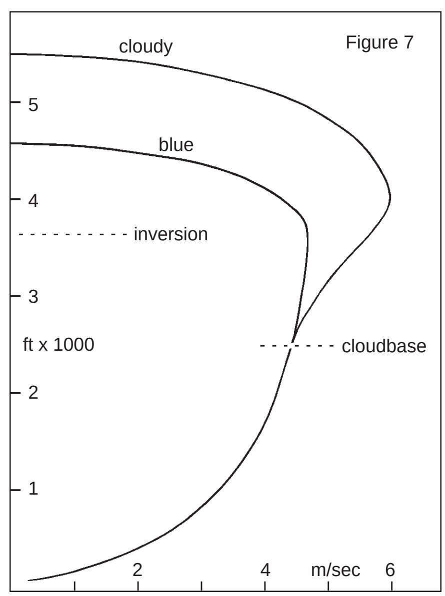


Figure 7

Figure 7 shows how this may change the rate of ascent. The curve marked “blue” represents air too dry for clouds. The upper curve marked “cloudy” branches off the blue curve when the thermal passes the level marked "cloudbase". The heat released by condensation makes the thermal warmer and more buoyant so it accelerates. Being warmer it rises further into the inversion layer. Because it is moving faster it has more momentum too so (in the conditions selected for this example) it ends up about a thousand feet higher. On days of stratocumulus spread out one may climb in a growing cumulus and come out into the blue well above the 8/8 sheet which marks the inversion. Cumulus which penetrate like this seldom survive long. The air aloft is often so dry that evaporation soon cools and destroys them.

Starting puffs Little bubbles which barely manage to reach the condensation level produce short lived shreds of cloud. These do not seem to have any bubble shape when they appear. If a bubble had existed lower down it would have been too diffused by entrainment to retain its shape and circulation. Don't trust such clouds as thermal indicators. By the time they make these puffs almost all their energy has gone and there is no cone of lift beneath. One can tack back and forth trying every cloud in sight and never finding any which work. It is possible to stay up however, because one bumps into blue thermals in between. Early in the day thermals may be small but they are often fairly close together.

Thermals when there is a light wind

A light breeze often stimulates the release of thermals. In really still conditions quite large reservoirs of warm air can build up before something sets off a disturbance large enough to produce a good thermal. If there is a light breeze the warm air is pushed gently across the ground until it reaches an obstruction. Figure 8 illustrates two possibilities. The lower section shows the shallow disc of hot air bumping into a line of hangars and being triggered into releasing a series of plumes which grow into bubbles higher up. As time goes on the entire reservoir is used up and the thermal dies out. The repetition rate depends on how fast the airfield heats up again. It may be a long time when the sun is low.

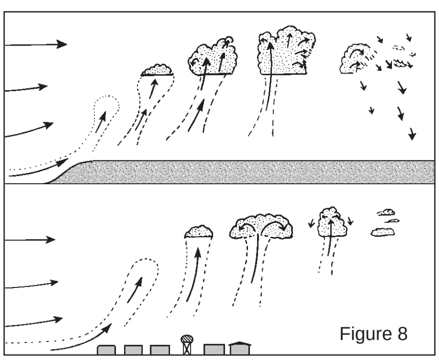


Figure 8

The upper section shows the sloping edge of high ground acting as the trigger. This is often better than a low level obstruction. The slope lift gives the embryo thermal a boost to start it rising and the high ground (being dry) heats up quicker and provides a good reservoir for the thermal to feed on as it drifts along.

An initial boost does not make the thermal much better

One might suppose that being given an initial boost up the hill side would make the thermal grow faster and extend higher. This does not seem to be supported by calculations. The entrainment process depends largely on the rate of rise of the thermal. When it rises faster the entrainment is greater. The result is that the excess speed is soon lost once the thermal has risen clear of the hill side.

The vacuum cleaner effect Some flat regions can build up a huge area of hot air just waiting for a trigger to release a thermal. Once a thermal has lifted off it is drifted along by the wind picking up more warm air. The air may rise as an almost continuous column or in a series of closely spaced bubbles plucked off by the thermal passing above. The result is a very long lasting thermal. The inward flow towards the base of the thermal can bring in air from several directions. If the surface air has a slight rotation initially the concentration under the thermal greatly increases the spin. Eventually this sets off a whirl visible as a dust devil. In desert regions dust devils can amble across the ground for many minutes and extend up to 7000 feet or more. In the UK where solar heating is less powerful most dust devils are very short lived and rarely go up high. I have known them appear before anyone had realized it was soarable.

Strong winds Strong winds cause turbulence which diverts the horizontal flow so that some of the fast moving air comes down to the ground. Then thermals seem to be torn off the ground before they are really ready to go. As a result they seem unable to get properly organized until much higher up. There are very narrow and irregular bits of lift low down but seldom anything useful. Higher up thermals are apt to be narrow and usually rough too. Up at cloudbase thermals may be just as strong as on light wind days but low down they are too broken for circling. Sometimes flying straight into wind gives better results than turning.

Figure 9

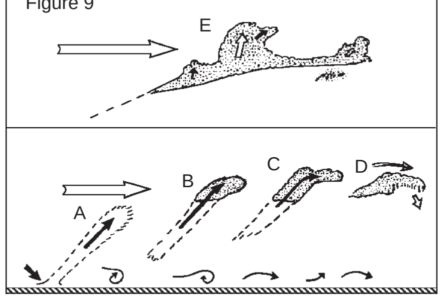


Figure 9 shows thermals being pulled off the surface by the turbulent flow near the ground. They do not seem to form bubbles, at least not low down. The air goes up as a ragged column, much too narrow for circling. At B it produces a scruffy patch of cloud. At C it loses momentum and the cloud is bent over and at D it decays. In the upper section cloud E has passed the condensation level with more energy and been revived. The odd bubble may push up from this cloud. With early thermals it is quite common to find the cloudbase slopes upward. On the windward side a tail marks the end of the plume. Tails are a feature of strong winds and weak thermals. I have not found any useful lift in these tails.

Life span of a cu cloud There are a number of garrulous glider pilots who delight in telling their companions how good the lift is. Information about a particular thermal may boost the morale of the pilot astern but is seldom of practical use unless the two can see each other. Few thermals last long unless they are capped by big clouds which everyone else can see. On blue days a call saying "There is 8 knots over Cowley" is seldom much help to the pilot leaving Didcot. This splendid thermal will usually have departed long before you get there.

How long a cumulus lasts seems to depend on several factors:

1 Volume of the cloud. The bigger the cloud the longer it will last.

2 The aspect ratio, or cloud height divided by width, low aspect ratio clouds last longer. For example a tall thin cloud with an aspect ratio of 4 tends to have only 1/4 the active life of a flat cloud with much width but little height. If you contact a thermal feeding a high aspect ratio cloud just as it starts you may be quickly whisked up several thousand feet, but only if you can stay in the bubble.

3 The time of day. Clouds have a shorter life in the morning than in the afternoon and the longest lasting thermals seem to be found in late afternoon.

4 The cloudbase. The bigger the thermal bubbles and the cone of lift underneath the higher it can go. High cloudbases usually go with tall cones of lift and big bubbles on top. If the cloudbase is below 2000 feet, as it may be when the first early morning cu appear, the bubbles are usually small and the clouds have a brief life. Little clouds may be dead in a couple of minutes. (But you will still see the remains five minutes longer.) On summer afternoons when the cloudbase is more like 5000 feet the cone of lift can often be found a long way below cloud and the bubble on top is much larger than in the morning. Such large thermals have a long life — a quarter of an hour or longer.

Towards evening, even on days when the cloudbase is so close to the inversion that the cloud itself is very shallow, one may find small flat cumuli working for half an hour or more. At this stage of development, the active clouds are nearly always much further apart than in the morning.

Group effect When talking of cloud life one needs to distinguish individual cells from the groups or lines of clouds which last very much longer. Large clumps of cloud consist of many cells. The outside ones have a short life because they are exposed to erosion from the surrounding air. Cells near the middle of the group live a more sheltered existence. The outer ring of clouds protects them from erosion by contact with dry air so they can grow much larger. One can usually head towards a large cluster of cu with confidence that there is bound to be lift somewhere underneath, even if it takes fifteen minutes to get there. Isolated clouds are far less reliable. They may look good from a distance but too often start to expire just as you reach them.

Semi permanent thermal sources

Another system of clouds has a very long life. These have an underlying supply of warm air which doesn't become used up. In fairly calm weather a group of cu anchored to a mountain may stay there for hours, often until the sun goes down, provided the cloud does not grow so big that it puts the mountain slopes in shade. However, if you watch these orographic cu you will usually find that the individual towers have a short life; the bank of cloud remains active because it consists of a large family of cu all growing over the same region. As one tower collapses another rises nearby to take its place.

Cumulus streets These usually have a long life too, but this is due to the special circulation where the air follows a helical path. Once again individual cells do not last much longer but the street is continually replenished by new cells so that its effective life is long.

Signs of active cumuli One should look for two features:

1 A well defined domed top with little domes superimposed on larger ones shows that there has been a good thermal underneath. (But it may not be still working below cloudbase.)

2 The appearance of the base usually shows if a thermal is still feeding the cloud. An almost level base, flat for several hundred metres, nearly always shows that a thermal is still entering the cloud from below. Soon after the thermal has ended the base loses its level appearance. The top may continue to grow for several more minutes after the base has begun to decay.

Steer well clear of any cu when the top breaks off and the base turns ragged. There may soon be a waterfall of invisible sink.

Single and multicell clouds
The first puff of cu in the morning is often formed from a solitary thermal which just managed to reach the condensation level. The original thermal may only have a life of ten minutes from start to finish. These puffs of cloud are often dead within a minute and vanish within two or three minutes. Even a large single cell cu has a short life, probably not more than fifteen minutes. Once the cloud has formed it may persist twice as long but unless it is refreshed by the arrival of more active cells the lift soon dies out.

Later in the day the majority of cumulus clouds are formed from several cells (bubbles, columns, etc). Some follow up the same path as the original bubble but others rise on either side and combine to form a wider cloud.

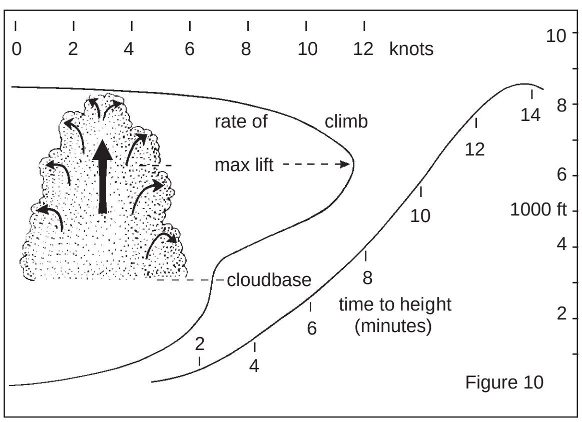


Figure 10

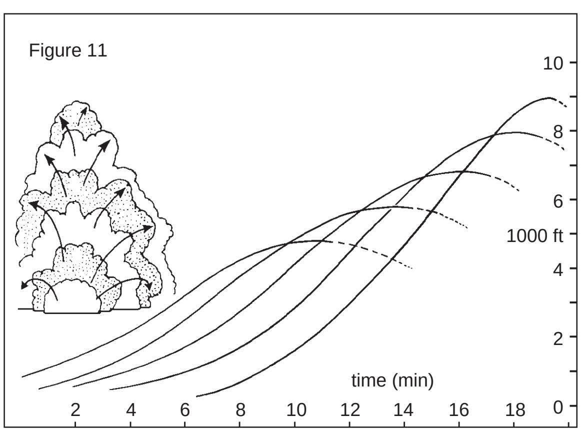


Figure 11

Figure 10 shows calculated climb rates (the left hand curve) and a time/height curve for a very large single bubble. After cloud has formed the rate of climb shows a big increase reaching a max. of about 12 knots in the upper half. The time/height curve shows the maximum lift occurred just after a 10 minute ascent. This bubble stopped rising just before 14 minutes had elapsed. These figures are for one set of lapse rates and temperatures. By altering the initial conditions one can find a whole series of different curves. The results are similar for quite a range of starting values.

Figure 11 shows six outlines of a growing cloud with the time/height curves for five successive bubbles following up to boost the original one. Each added more mass to the cloud so that it grew both upwards and sideways. Most bubbles tend to turn away from the vertical as they lose energy. In some cases one may be able to see part of the cloud edge turn downwards and begin to descend.

Looking for lift under cu One can fly a long way looking for lift under a large multicelled cumulus. Even though it has a good looking flat base and a well domed top the lift only enters over a small area. Thermals feeding the cloud do not all follow the same track and the flat base does not decay the instant the lift ceases. Wispy bits (tendrils) below the main base are one sign of lift and a step in the cloudbase is another. The best lift is usually found very close to, but not actually in the tendrils or step.

Tendrils The longest tendrils appear when two airmasses converge as at a sea breeze front. Figure 12 shows A, a cross section of a sea breeze front with cool moist air coming in from the left. One does not see thermal bubbles in this damp air; when it rises it produces ragged tendrils well below the main cloudbase. Bubbles form in the warmer and drier air on the landward side. B is a sketch looking at a convergence line with patchy tendrils beneath. The dashed line shows a winding route following the lift. Heavy dots show where the main lift was found.

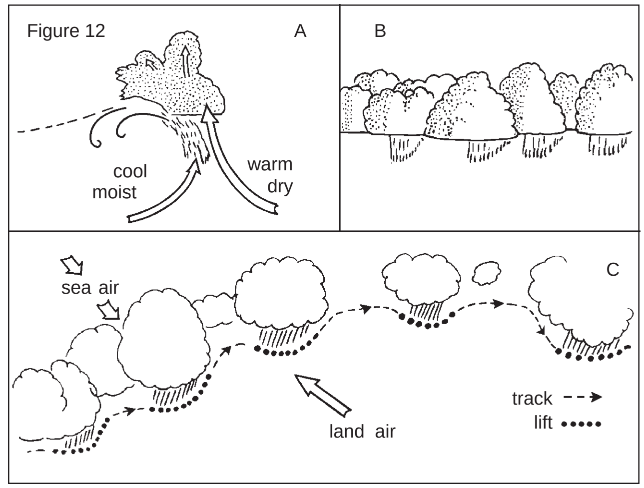


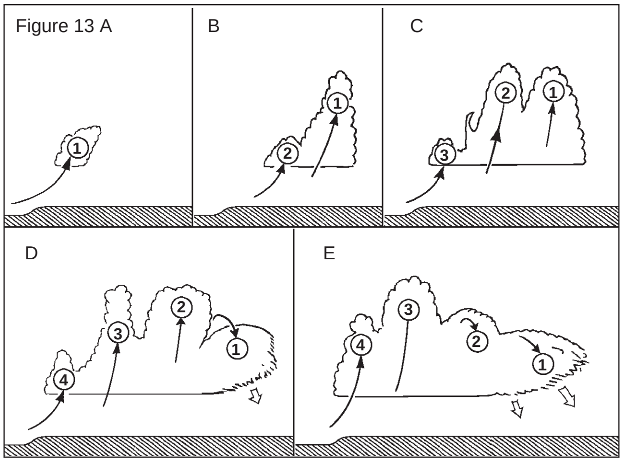
Figure 12

Tendrils often occur under clouds which have nothing to do with sea breezes. If you approach a big cloud from several miles away you may see small tendrils hanging from the cloudbase. One needs to look for these whiskery bits long before reaching the cloud. At a distance they may be silhouetted against brighter objects but they are much harder to see when looking up towards the grey base. The tendrils frequently (but not invariably) mark the edge of strong lift. The best lift is usually a short distance away. Tight circles which graze the tendrils seem to give the best rate of climb. If the tendrils stretch for some distance horizontally you may do best by flying along the line making tight turns either end. If you find sink try the other side.

Steps in cloudbase Occasionally the level cloudbase is interrupted by a step. Steps come in a wide range of sizes. The most impressive occur under cu nim. (The Americans sometimes use the term “pedestal clouds” for the stepped down section under a thunder cloud.) The best lift is almost always close to the step and under the higher base. One reason for the step may be that two airmasses, one warmer and drier than the other, have joined to set off a cloud. The warm dry air usually produces the larger plumes or bubbles of lift. On the dry side the thermal rises higher before forming cloud. The lower cloudbase may also give some lift but it is usually much weaker. Do not waste time circling in weak lift if the base steps up nearby. Head for the higher base.

Large variations in cloudbase occur when weak cu starts to rise out of a damp valley while the hills alongside set off stronger and much drier thermals. In some extreme cases the tops of the valley cu are level with the base of the hill cu. Valley cu are rarely much use at this stage. They may look acceptable but are dismally devoid of lift. Later in the day when the two cloud systems meet to form a single cloud one may see the step marking the change in lift.

It is generally true that the higher the cloudbase the stronger the lift. Like most rules in meteorology there are exceptions which are mentioned later on. When heading from one cumulus to the next you may run through a strong blue thermal. These are usually worth investigating. Quite often the lift is much better than under older cu and the new cloud (when it forms) has a higher base.



Successive cloud cells Some clouds grow on the upwind side and decay at the other end. Figure 13 shows a series of cells which developed over the Cotswold edge (about 800 feet asl) and grew as they travelled downwind. A shows the original cell. B through to E show how each cell rises to a peak and eventually collapses near the downwind end. The diagram shows only four cells but long lived cloud banks are built out of many more. On days like this it pays to head for the upwind end of each cloud and keep well clear of the sink near the downwind end. Topographical features are not essential for starting a cumulus line. Some grow very well over the ocean.

One often finds that nearly all the cumulus have their best lift under a particular side of the cloud for much of the day. The windward end is often the best end to head for; if it happens to be the sunny side too there is an even better chance of finding lift there.

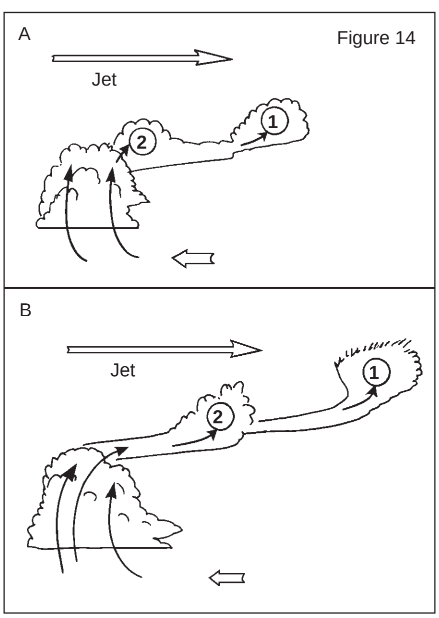


Figure 14 shows an extreme example of what can happen when the tops of cumuli push up into a much stronger wind aloft. As the bubble loses momentum the jet stream whisks it off downstream, still bubbling weakly. The same effect may often be seen with lesser cumuli in smaller wind shears. The sheared off section maintains its domed top and for some time there is a flattish base too. This is one case where the higher cloudbase is not the one to head for first. The lift beneath it has usually been cut off. Look for the main cloud mass from which these cells have been detached. The best lift should still be there under the more solid part.

Wind shear and cloud hooks Thermals may often rise into a stable layer which slows them down and eventually kills all lift. Inversions are powerful thermal stoppers and there are often layers where the wind changes too. The wind shear above an inversion distorts thermals which rise into it. A strongly rising thermal may have its top bent over into a hook like shape. The hook is usually very short lived but the best lift is nearly always below the upward pointing part of the hook. Avoid the area where the point of the hook starts to turn down. That is where the sink develops. Hooks show you where wind shear has been concentrated. Little backward curling hooks sometimes briefly appear on the upwind side of a growing cu. These hooklets show local shear produced at the boundary between fast rising cloud and slow moving air outside. It can be a sign that there is strong lift just inside the cloud.

Hoops Occasionally, when a small cloud has produced a hook, the main body of the cloud evaporates leaving just the remnant looking like a croquet hoop. These strange formations rarely last long. If you pretend you are a croquet ball and go through the hoop nothing much seems to be going on. All the energy has been exhausted by that stage.

Pileus Figure 15 A, B and C shows the formation of a pileus cloud. Pileus means a cap and these clouds look like little lenticular caps. They first appear above the top of a growing cumulus. A large rising bubble may behave like a barge with blunt bows pushing some of the air ahead of it. The lift above a bubble is normally very weak so the fact that pileus forms at all with such weak lift means that the air was already very moist before thermals began. Powerful cu can grow straight up through the pileus which is left behind as a collar around the cloud.

Pileus is a warning of possible spread out of the cumulus. It suggests that the air is so damp aloft that cloud cover may become 7/8 later on. Cumulus tops take much longer to evaporate when surrounded by damp air; with slow evaporation much of the ground remains under shadow and the good thermals are then much further apart.

Wave like effect of pileus
Pileus may be evidence of weak wave like lift

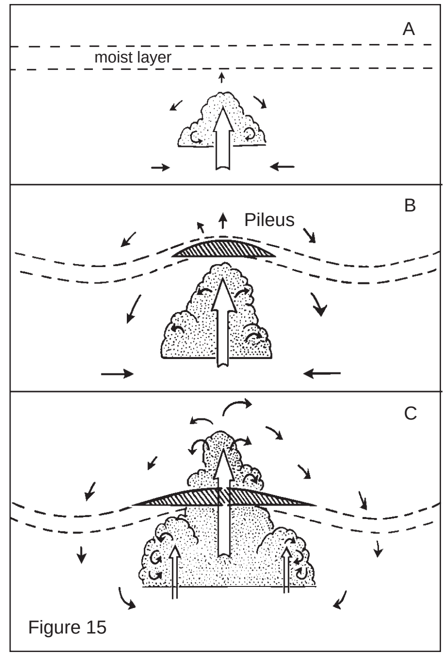
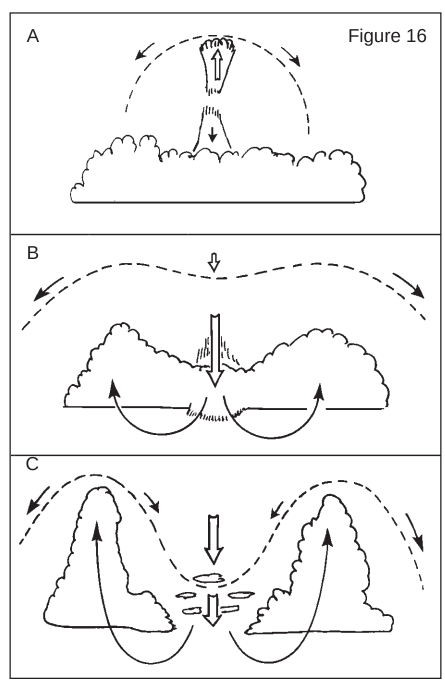


Figure 15

just outside the growing cumulus. Even when there is no visible pileus one can occasionally experience very smooth lift in clear air alongside a growing cu nim. A line of heavy cu may also produce a similar effect.

Lift alongside big cu lines On most occasions one only finds lift under or inside a line of big cu. The clear air outside is usually sinking but there are days when the convergence produces very weak lift just outside the cloud. The lift is apt to be too weak to give a worthwhile climb but it does allow one to go many miles into wind without circling, keeping close beside the cloud. On rare occasions one may even be able to go over the top. This kind of lift is deceptively like a lee wave, but since it extends many miles into wind the wave is probably due to the growth and expansion of the cu line. One usually has to fly very close to the cloud to keep in this weak lift. Pilots in a hurry may not notice it at all.



Cloud collapse and rebuild
There are some days when the air aloft is very unstable but also very dry. One or two cloud cells then shoot upwards with extra speed so fast that they break off from the main body of cloud. The detached bubble evaporates quickly in the dry air. Figure 16 shows three stages in the process. A is the break off of a bubble. The pecked line marks the expanding wave produced by this rocket like ascent. Rapid evaporation in the dry air soon dissolves the detached bubble making the air much colder. Then the whole column falls back producing holes and sometimes a wide gap in the underlying cu. The wave effect spreads outward (B) and new cells start to grow on either side of the gap (C).

Castellanus   This word just means turreted, like the popular idea of a castle. The term can be used for cloud turrets which rise very fast out of a cumulus as in Figure 14A. Castellanus clouds do not necessarily have any connection with the ground. The lift may be started by high level convergence and boosted by the extra energy released when clouds form. If so there is no lift beneath them. Ordinary cu have invisible roots formed by thermals coming off the ground. Castellanus may not have any roots. During a hot spell in summer little puffs of castellanus sometimes appear at 10 to 15,000 feet. These little puffs are called “floccus”. They are a reliable indication of thunderstorms within 24 hours. Few people are fooled when they see these tiny puffs. They look far too high to be due to thermals. When they come from Europe across a cool sea it is obvious they cannot have thermals underneath.

I have found castellanus confusing when the base is 6000–8000 feet and the clouds look substantial. I have wasted aerotows below such clouds only to find the air at 2000–3000 feet totally inert for many miles.

Cumulus lines and streets   Many cumulus clouds tend to form up in lines. Some lines may be an isolated phenomenon, caused by a group of mountains or a peninsula extending into wind, but an orographic source is not essential. Lines of cumulus also form over the sea. If these broaden to downwind and end up in clumps of stratocu they are not true streets. Proper cloud streets form a regular pattern which can cover vast areas with evenly spaced parallel rows of cloud. These streets are formed when there is fresh convection under a well marked inversion. Streets can develop in cloudless conditions too.

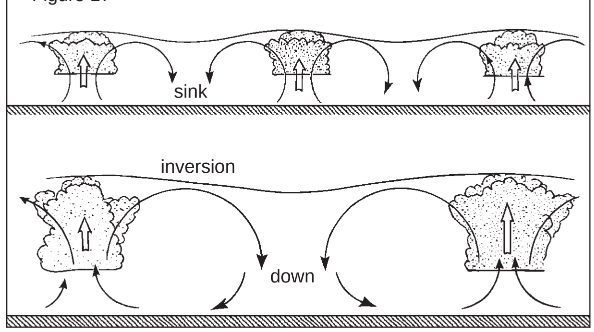
When there are streets the airflow develops a helical pattern. The air goes up under the clouds, spreads out sideways under the inversion and dips down in the gaps. At low level there is an inflow towards the street to complete the circulation. The air is also moving downwind so the motion forms a helix. The important thing is that a complete circulation develops. This makes cloudstreets a fairly long lived phenomena; some extend hundreds of miles.

Cloud streets are aligned parallel to the wind at cloudbase; the spacing is about three times the depth of convection. Thus with 5000 feet tops the streets will usually be about three miles apart (sometimes a bit less). The gap is kept clear by the sink between cloud lines, sink which is distressingly strong. One usually needs to cross gaps as fast as possible and at right angles to the lines.

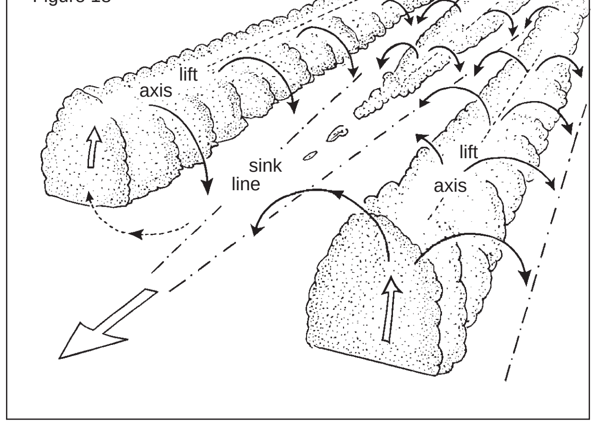
Change of spacing by the suppression of some streets
If the depth of convection increases cloud tops go higher and the spacing has to alter. This occurs not by the streets fanning out but by suppression of some streets and strengthening of those remaining.

Streets are splendid for making progress into strong winds but one usually has to jump across to another street to keep on track or avoid controlled airspace. Watch that you do not head across to the downwind end of a dying street. Choose an unbroken street to cross to. If suppression is taking place the circulation is changing, going higher under the growing street and descending further out into the clear lanes. As the sink spreads out it kills off intermediate streets.

Figure 17 shows a cross–section with three streets forming part of a well developed circulation giving lift under the clouds and continuous sink between the streets. The lower diagram shows what happens when the inversion rises. The circulation widens and the middle line becomes squashed by the outward spreading region of sink from either side. Figure 18 shows a 3–D sketch of the process. The downwind end of a street may lie under this widening region of sink. If you go across at this point there may be only sink under the cloud street. It is heart breaking to have to work miles upwind through miserable broken bits of decaying lift to reach the active part of the street.

Figure 17


Satellite pictures indicate that a stage is reached when the inversion is too high for streets. This can happen in a short distance. Cumulus streets forming near the west coast of Wales and Cornwall can be broken up when the air goes over high ground which sets off shower clouds.

Figure 18


Wave suppression of streets
When the wind speed increases with height it is common to have lee waves at right angles to the cloud streets. The waves often occur in air too dry for any lenticular to appear. Where the wave flow is going up the streets below become stronger and the cloud line may widen too. In wave sink the streets may stop working or even decay. Thus one can find great variations in lifting up a cloud street on a wave day.

Miscellaneous signs of activity

Colour changes
When vigorous thermals first push through the condensation level the cloud droplets are very small and very numerous. They reflect the sun strongly so the fresh new clouds look clean and bright. After a time droplets coalesce, they grow larger but less numerous and reflect less light. The older clouds begin to look a big grimy in comparison to the new cells. Off white clouds are apt to have lost most if not all their lift. However, their appearance also depends on the angle of the sun.

Problems of perception
After flying for a long time in the same direction one becomes used to heading for a particular part of the clouds where there is nearly always good lift. Rounding a turning point alters the appearance of clouds and may spoil the ability to go straight to the best lift.

Cardboard cutouts
Flying down sun it is easy to be fooled by a bright looking cumulus. Arriving underneath one finds the cloud has no depth to it; it is little better than a bit of stage scenery, only convincing when viewed from the auditorium. Looking into sun one can pick out these fakes because they look too transparent.

Fretwork clouds   When cumulus clumps start to decay the rot may start internally; from a short way off they still present a respectable front. The trouble may start from the collapse of a turret which shot up too high and evaporated, or it may be some much smaller feature. On some days very small holes form because the entrained dry air has begun to evaporate the middle of the cloud. Evaporation produces cooling and sink. Sink sets off more evaporation and the cloud begins to fall to bits. Watch for the shadow on the ground. If it starts to look like a piece of fretwork steer well clear. The whole cloud is ready to dissolve into a region of sink. It may still be worth flying round the perimeter to see if the central sink has triggered off some peripheral lift. •