LESSON 1 – THERMALLING TECHNIQUES

Thermalling Techniques

- Where to go?
- Finding Thermals
- When to Thermal
- Height Bands
- Summary

Where to go?

- Identify signs of thermal streets, [clouds]
- Establish relationship of optimum lift to clouds, sunny side, upwind?
- Follow path of short cycling wisps
- Stay upwind of course line
- Follow cloud streets even if 30^{o} off track [<15% longer distance]
- On blue days use gentle zig-zag on course to find blue thermals
- If long region of sink, turn 90^{o} to avoid sink street. Do not make 180^{o}

Where to go?

•Watch conditions while circling and plan ahead. Use cloud shadows to estimate distance to clouds. Glide ratio roughly 5nm/1000’

•Identify prime areas of lift, baked bare ground, high ground, sun orientation, ridges

•Avoid areas likely to have sink, e.g. downwind of lakes or irrigated areas.

•Watch for soaring birds, sailplanes, fires.

•Keep track of wind from thermal drift, smoke

•Constantly monitor and stay within range of landable terrain

Finding Thermals

When you're high … fly the sky

- ***Cu, wisps, haze domes***
- ***Birds, debris, gliders***

When you're low … look below

- ***Terrain, junk yards, hay fields, heat source***
- ***Smoke, crop movement, flags, debris***
- ***Spacing is related to convection depth***
- ***Mark and return to excellent thermals***

Finding thermals

- Before even getting airborne on a club day, just after eventualities, you should start thinking where you are going to find your first thermal and what the sky is doing. This will vary depending on cloud quantity, wind, temperature, and humidity and the variation of these four items with height.
- If you take an aero-tow count the number of thermals that you randomly pass through, mentally note their strengths and size and relate them to areas on the ground plus wind and the cloud.
- To find a thermal you need to use the
- Ground
- Clouds
- Other gliders
- Birds
- Feel
- Smell
- Instruments

Buoyancy due to Temperature Differences

- Thermal mass. A cubic metre of air weighs about 1 kg ay sea level. Therefore a thermal which is 200 metres square (easy maths) is 200 x 200 x 200 = 8,000,000 kgs or 8000 metric tons!
- Gas laws state that in there is a constant between pressure, temperature and volume.
- As the temperature increases, the number of molecules in any volume will therefore decrease (assuming the air is free to expand) and the density will therefore reduce, making the air more buoyant.
- PV/T = constant.
- To put some numbers in then.
- 1013 (P) x 100 (volume) / 288 (temperature degrees Kelvin) = 351.7361
- Raising the temperature by 1 degree
- 1013 x new volume / 289 = 351.7361
- New volume = 351.7361 x 289 / 1013
- New volume = 100.3472
- So the volume has increased by 0.35%
- Therefore the density has reduced by 0.35%
- Back to our thermal mass at 8000 metric tons then.
- The buoyancy generated will be 28 tons per degree rise in relative temperature.

Dry / Humid Air - Lift
Not hard but helps if you understand

- Gas laws state that in any volume of gas at a specific temperature and pressure there is always the same number of molecules.
- Air is made up of Nitrogen and Oxygen in the rough ratio of 4:1. Any air therefore has a mass relatively of $4N_2/1O_2$.
- Atomic Mass of N=7 and Oxygen 16.
- **Dry Air** = (4 x 7 x 2) 56 + (16 x 2) 32 = **88**

- A water molecule is H_2O (1 x 2+16)= 18
- Where this replaces an Oxygen molecule. 56 + 18 = **74**
- **Humid air is significantly lighter**.

- Smoke from a power station boiler contains the very heavy gas CO_2
- That is (1 x 12) + (16 x 2) 32 = 44
- Where this replaces an Oxygen molecule. 56 + 44 = **100** (heavy)

Thermal Mass

- The mass difference of dry air verses humid air is the same regardless of units used so 8800 tons of dry air 'coming down' verses 7400 tons of humid air 'going up' has considerable buoyancy before there is a temperature difference! This gives 1,400 tons of buoyancy compared to the 28 tons per degree temperature. This is an extreme and unrealistic example but amplifies the importance of varying humidity in the working layer and its variation with height is often more important than the environmental temperature reduction.
- Therefore an air mass lifting a gaggle of 20 gliders in total weighing perhaps 10 tons descending at one knot is unhindered in rising by the weight of the gliders, because the actual mass of the air is thousands of tons plus its velocity (several knots) thus having considerable energy and momentum.
- This along with the evaporation of water droplets (clouds dispersing) making cold air, is one of the most important aspects to get your head around.
- Air circulating in the form of a smoke ring (or doughnut shape) is easily induced and can be seen in many examples from the smoke of a cigarette to an atomic explosion. Can it happen in a natural environment?

Dry / Humid Air – Sink
Not hard but helps if you understand

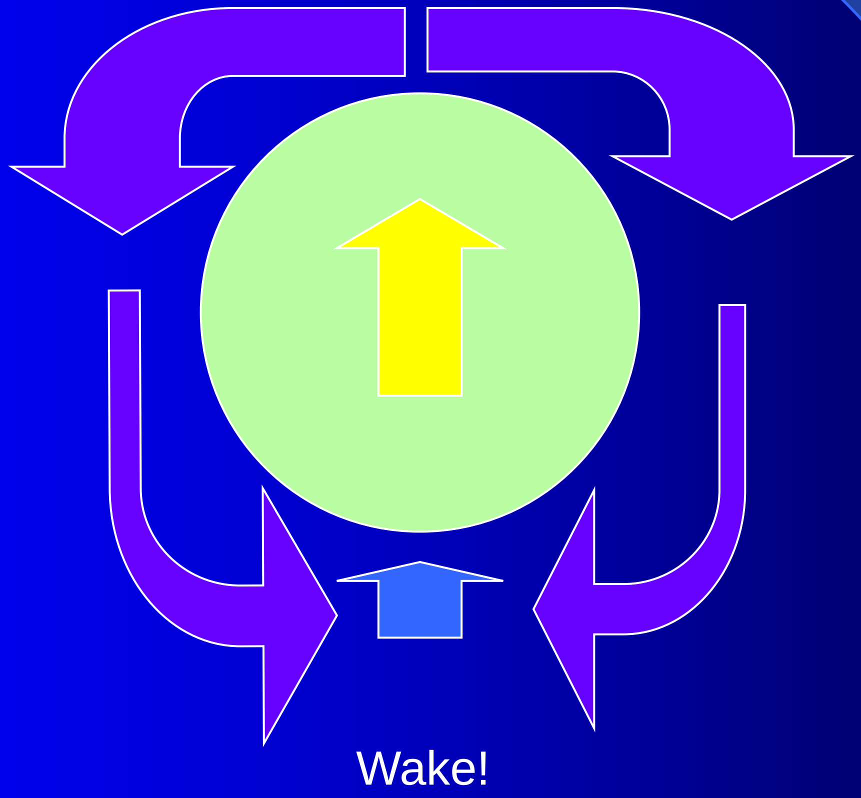
- Thermal mass. The development of sink is more complicated!
- The evaporation of water is the equivalent of reducing the air temperature by 80 degrees but then its density will reduce.
- So the density will have increase by 80 x 0.35%
- Therefore the density has increased by 28%
- Back to our thermal mass at 8000 metric tons then.
- The sink generated will be 2240 tons.
- However the buoyancy will have increased due to the increase in humidity by a maximum of 1400 tons.
- Therefore the net sink rate would be equivalent to 2240 – 1400 = 840 tons
- This is again an extreme and unrealistic example but further amplifies the importance of varying humidity in the working layer and its variation with height.

Thermal Structure

- Three Forces in a thermal.
- 1. Reduced Density - Buoyancy due to temperature relative to surrounding air.
- 2. Reduced Density - Buoyancy due to higher humidity relative to surrounding air.
- 3. Higher Pressure relative to surrounding air causing expansion.
- Two Motions within a thermal.
- 1. Vortex motion.
- 2. Rotational motion.

Thermal Structure, Vortex

- First to the vortex ring. Imagine a solid ball or balloon going through the air, an eddy will be set up which must cause a vortex motion. However, the faster the thermal rises, the stronger the vortex, therefore the stronger the sink around the bubble.



Forces in a simple thermal

- Before considering any movement of the air in and around a thermal you must simply remember two facts.
- Rising air primarily only has a vertical force acting on it, that of buoyancy, in other words straight up. (Occasionally it might exhibit an 'explosive' high pressure force of expansion)
- Sinking air has a vertical force acting on it, weight, so straight down!

Stop thinking thermals and think sink!

Whilst we often talk about climbing in strong or weak thermals, little is discussed about the structure of sink except that we had a bad bit somewhere, the distribution of which actually varies considerably over the sky at any one time.

It is in fact the sinking air which determines the structure of the soaring sky!

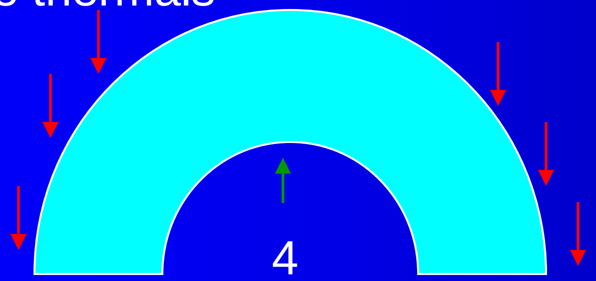
SINK!

- Consider the cloud at the top of a thermal. As it pushes up into the drier air the cloud droplets will start to evaporate.
- It takes as much energy (heat) to change a water droplet into a gas as heating the same water from zero to 80 degrees C. In other words a lot. This energy is taken from the dry air (which rapidly reduces in temperature) so the air next to a cloud increases in humidity, but becomes cold, dense and heavier than the air around it so descends, hence sink!
- The drier the air at height, the more rapid the cooling and the stronger the sink.
- Just like thermals, sink slugs can vary and even accelerate downwards.

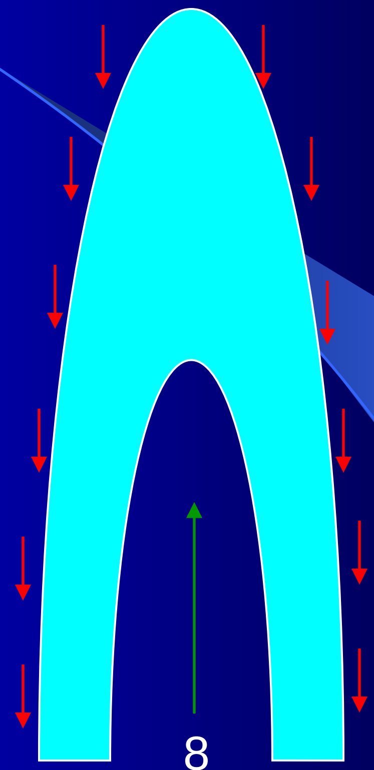
SINK!

The air where the cloud is, can not hold any more moisture so it condenses out as water droplets. The air surrounding the cloud is drier so the water evaporates, cooling the air.

Broad Cloud therefore broad area of 'moderate sink' and average thermals

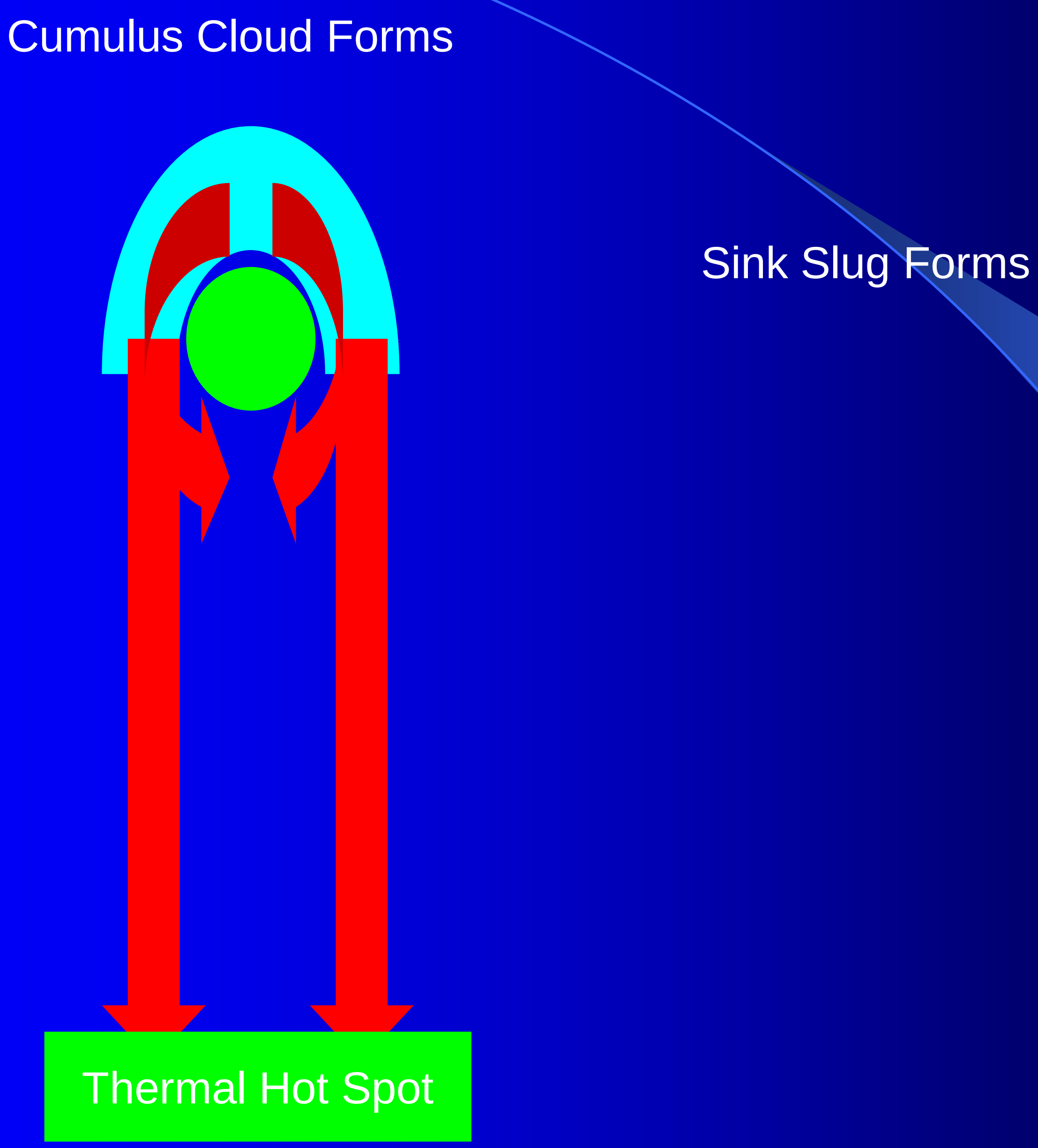


Tall Cloud therefore 'strong' band of sink but indicates stronger lift



The higher the cloud/s, the stronger the developing sink

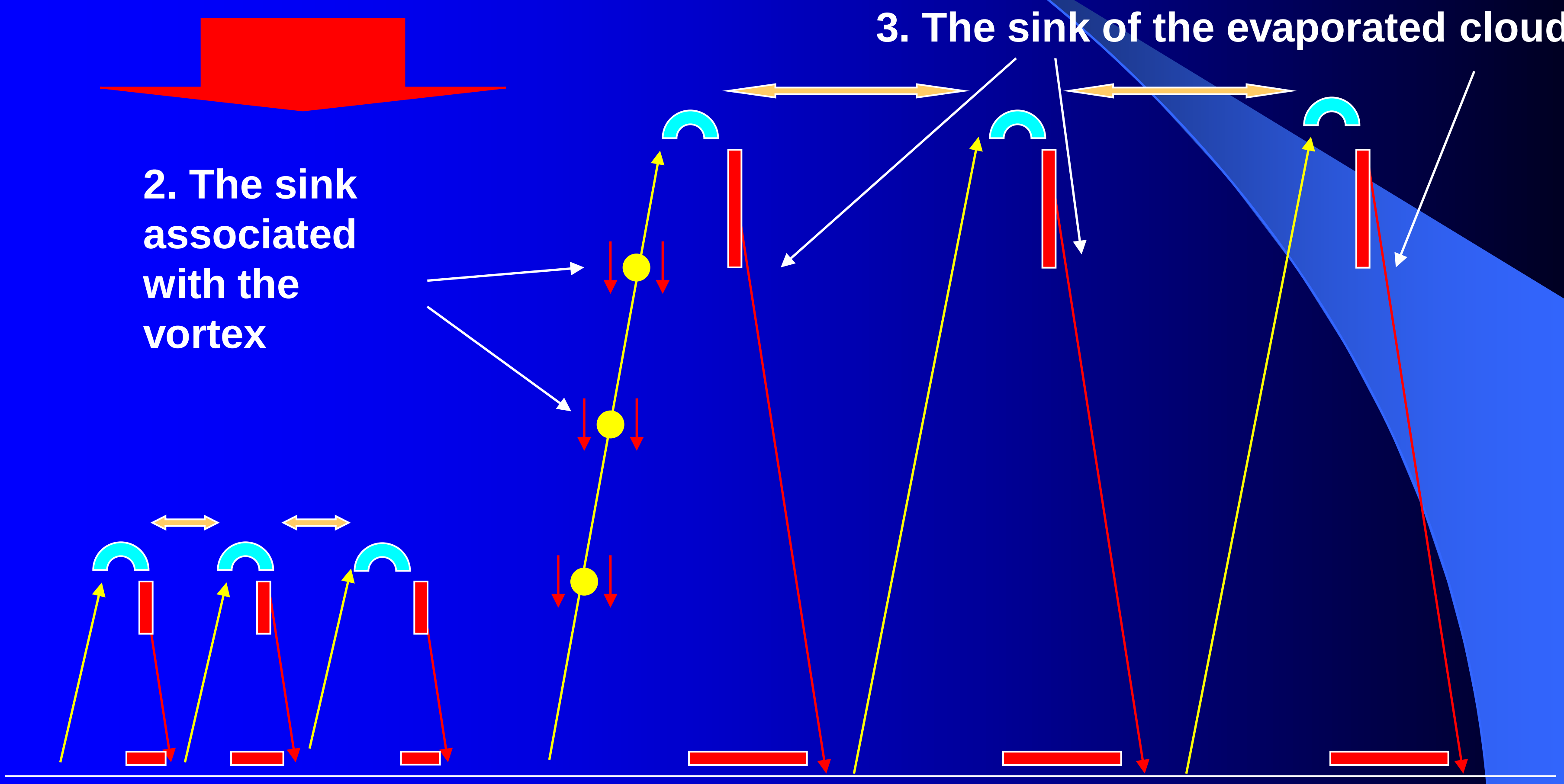
Lift and Sink Cycle



Why the higher the cloud base, the further between thermals?

- The controlling force is the sink.
- Ignoring wave, there are three types of sink.

1. Mass sink, subsidence



Types of Thermals

- Just for now, consider that there are three BASIC types of thermals.
- 1. Weak ones, just rising air over evening forests with no associated sink. Simple and used primarily on evening final glides – no significant vortex.
- 2. Columns.
- 3. Bubbles.
- References to hot / warm / cold are simply air temperatures relative to the adjacent air at that height providing either buoyancy (lift) or sink.

Ground Sources

- There can be good areas for thermal generation but then more specific points where the thermal/s are triggered.
- Take a look at a pan of boiling water, the bubbles are generated in the same spot every time, even if you stir the water. Bubbles in coke/lemonade just the same. No surprise then that our thermal sources are largely the same place time after time, but only on a blue day!
- Thermals depend on buoyancy and float upwards in a similar way. Physics limits this buoyancy and even with huge heat sources the rate of ascent soon slows and is limited by the surrounding airs' physical properties. (Both Friction and Profile Drag).
- In simple terms the buoyancy of the thermal is balanced by the drag it creates. BUT this is far from the whole story, see later.

Ground Features

A blue day with no/little wind.

The basics of which bits get hotter than other bits should be fairly obvious therefore the thermal sources should be simple to see obvious.

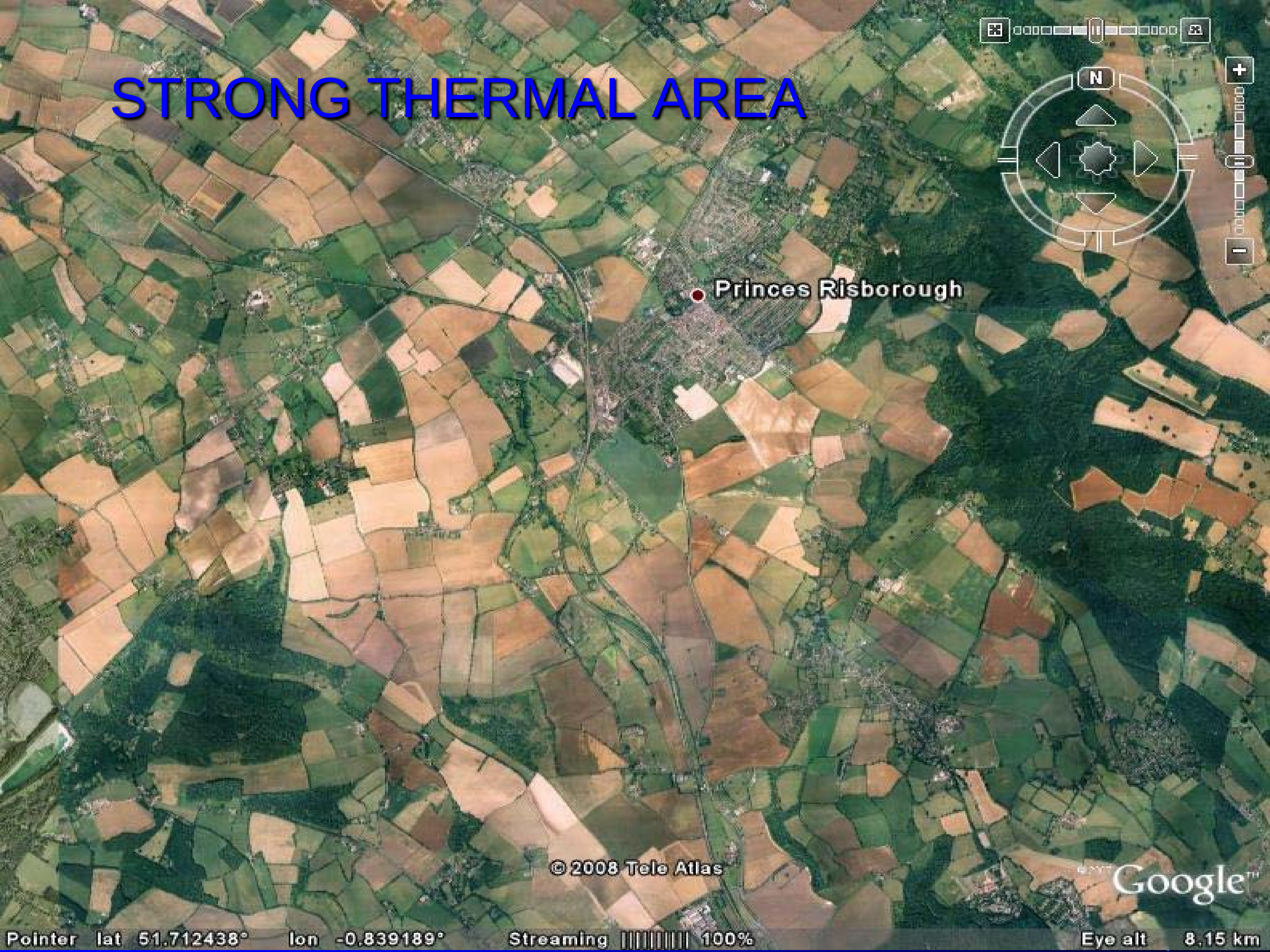
BUT: You need to have a thermal contrast or trigger point between two adjoining areas of ground (or land and water) to generate a thermal trigger.

Triggers to help the generation are important. The easiest comparison is to consider drops of water forming as condensation on a caravan bathroom ceiling. It is only after the drops have achieved an adequate size or join together that they actually drop off. A breeze or shake will encourage some but not all, to fall earlier.

Colour, material (crop), dryness/dampness, angle to the sun, slope and orientation to the wind are all important. A thermal in a large field can be triggered by a specific point, like a high point or where there is a small line of bushes/trees at one end.

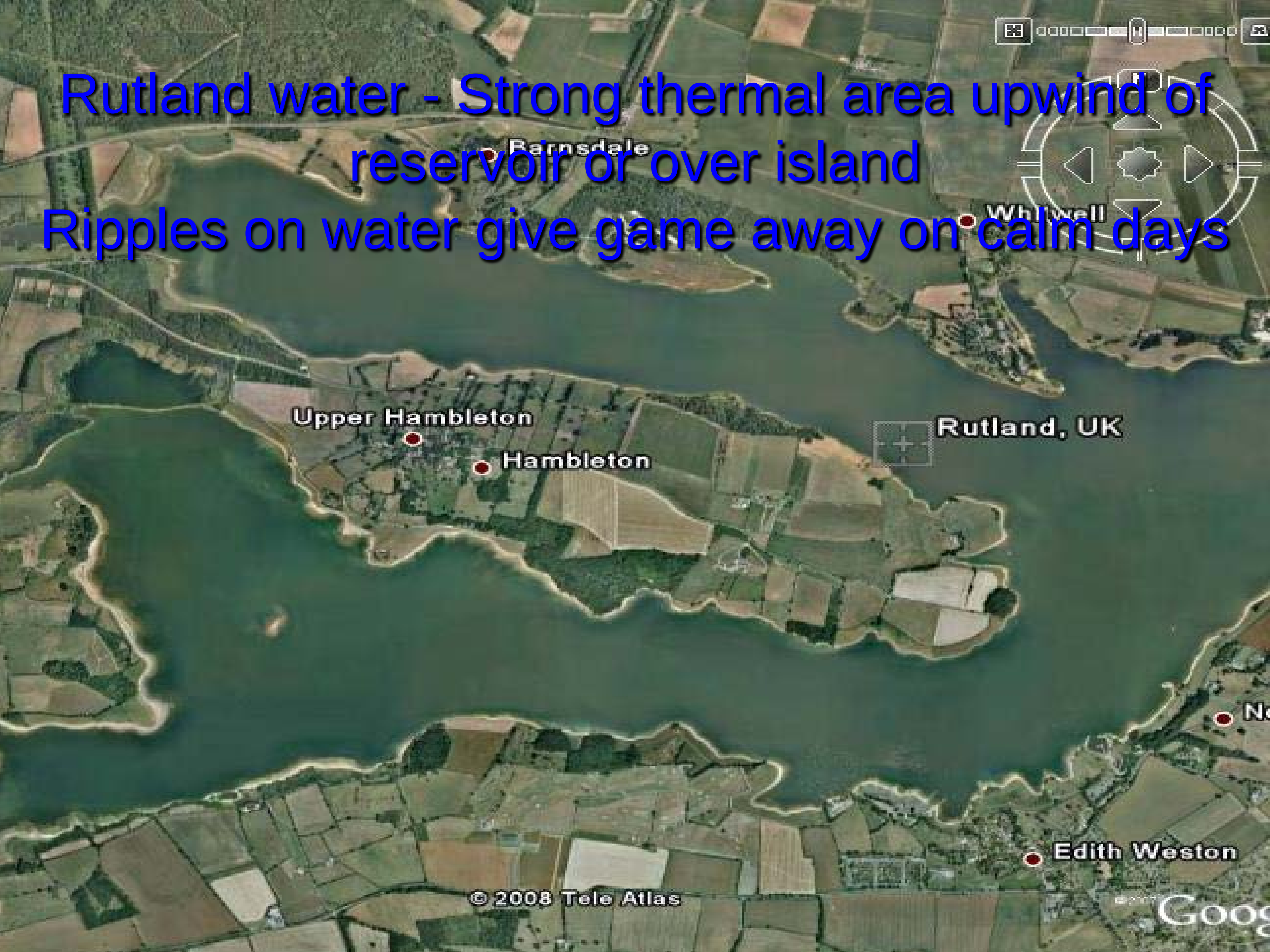
If the ploughings of a field are aligned to both the wind and the sun the thermal will be stronger than if the wind and/or sun are across it.

STRONG THERMAL AREA

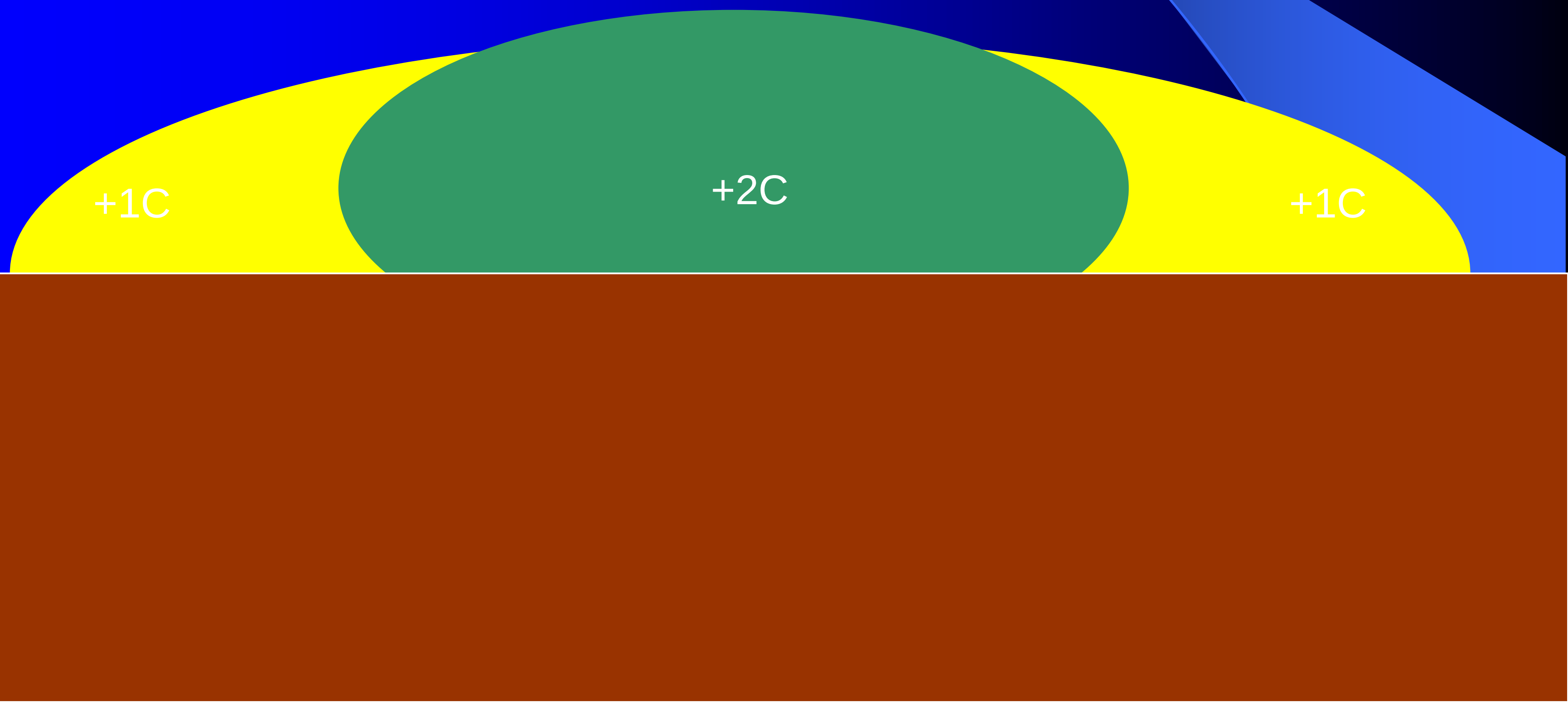


STRONG THERMAL AREA
Hughley
Presthope
Bourton
Easthope Wood
Easthope
© 2008 Europa Technologies
© 2008 Tele Atlas
Google
Pointer lat 52.565715° lon -2.613476° Streaming |||||||||| 100% Eye alt 5.17 km

Rutland water - Strong thermal area upwind of reservoir or over island
Ripples on water give game away on calm days

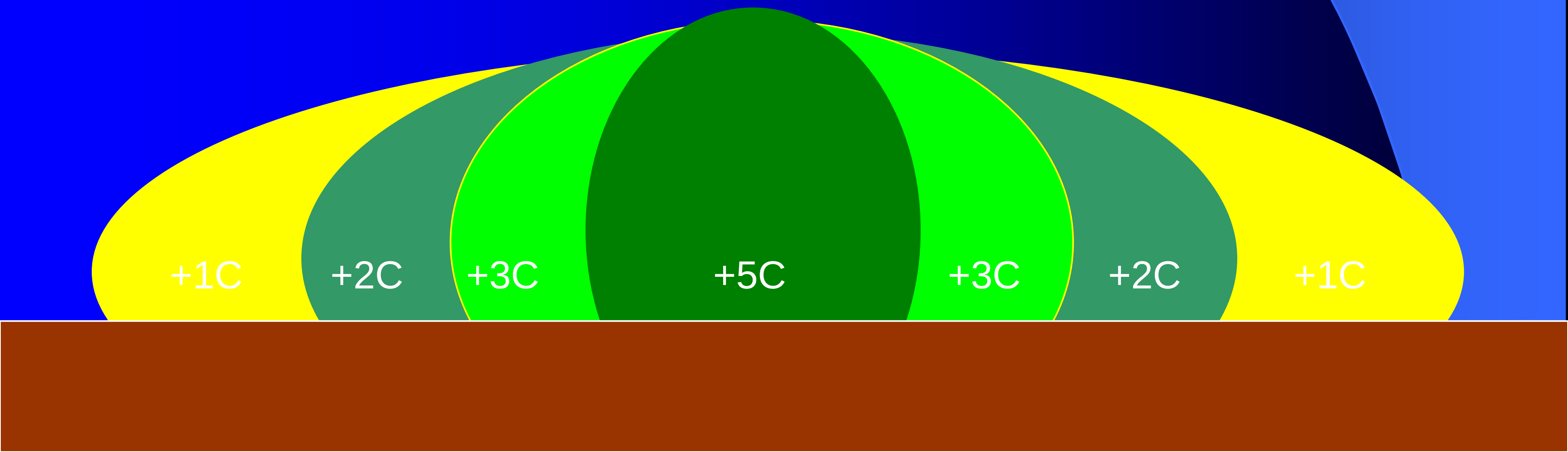


Weak Thermals!
(Small Field)
Less than 200 metres Wide

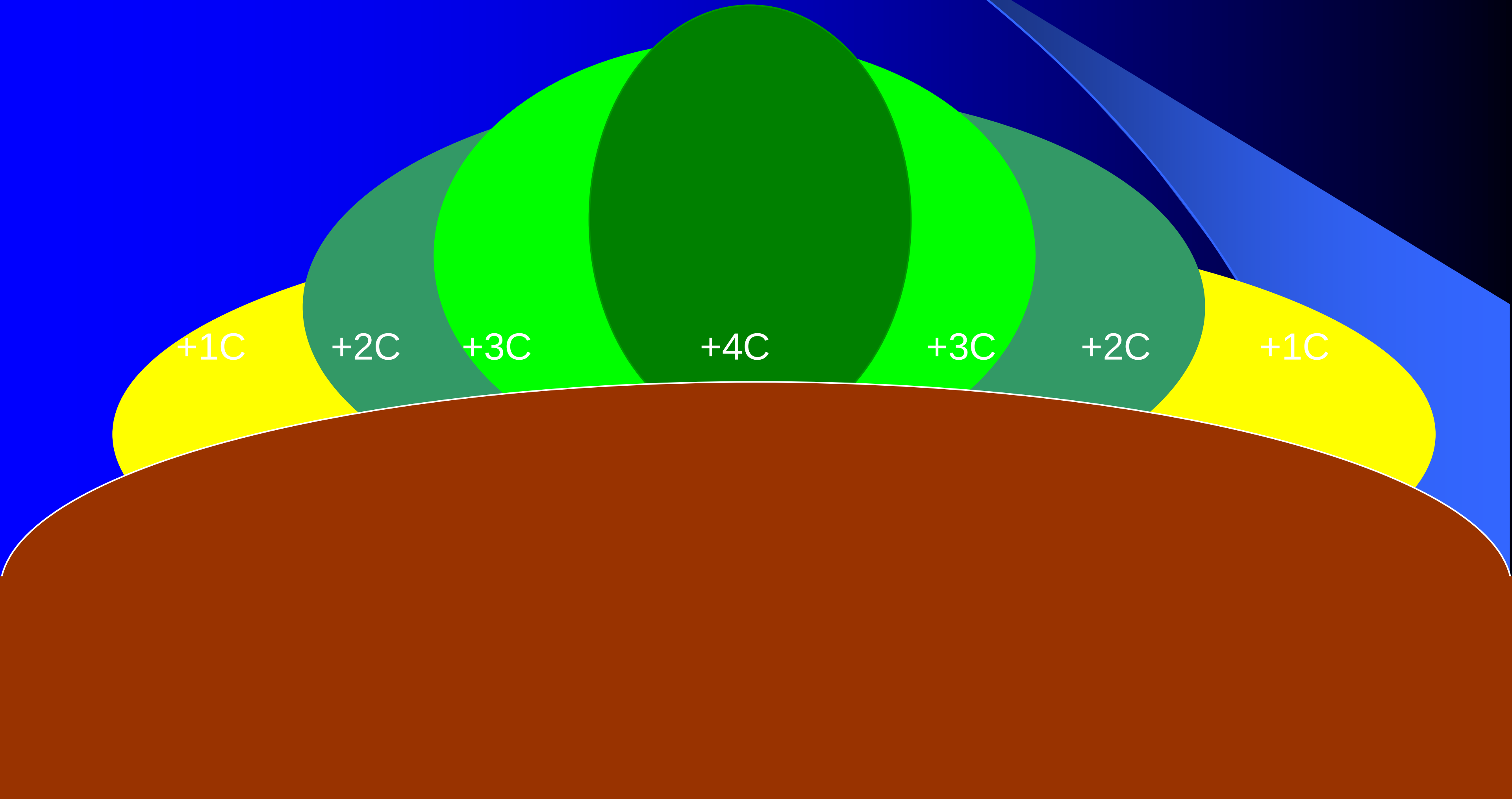


Strong Thermals!
(Big Field/Town)
Greater than 200 metres wide

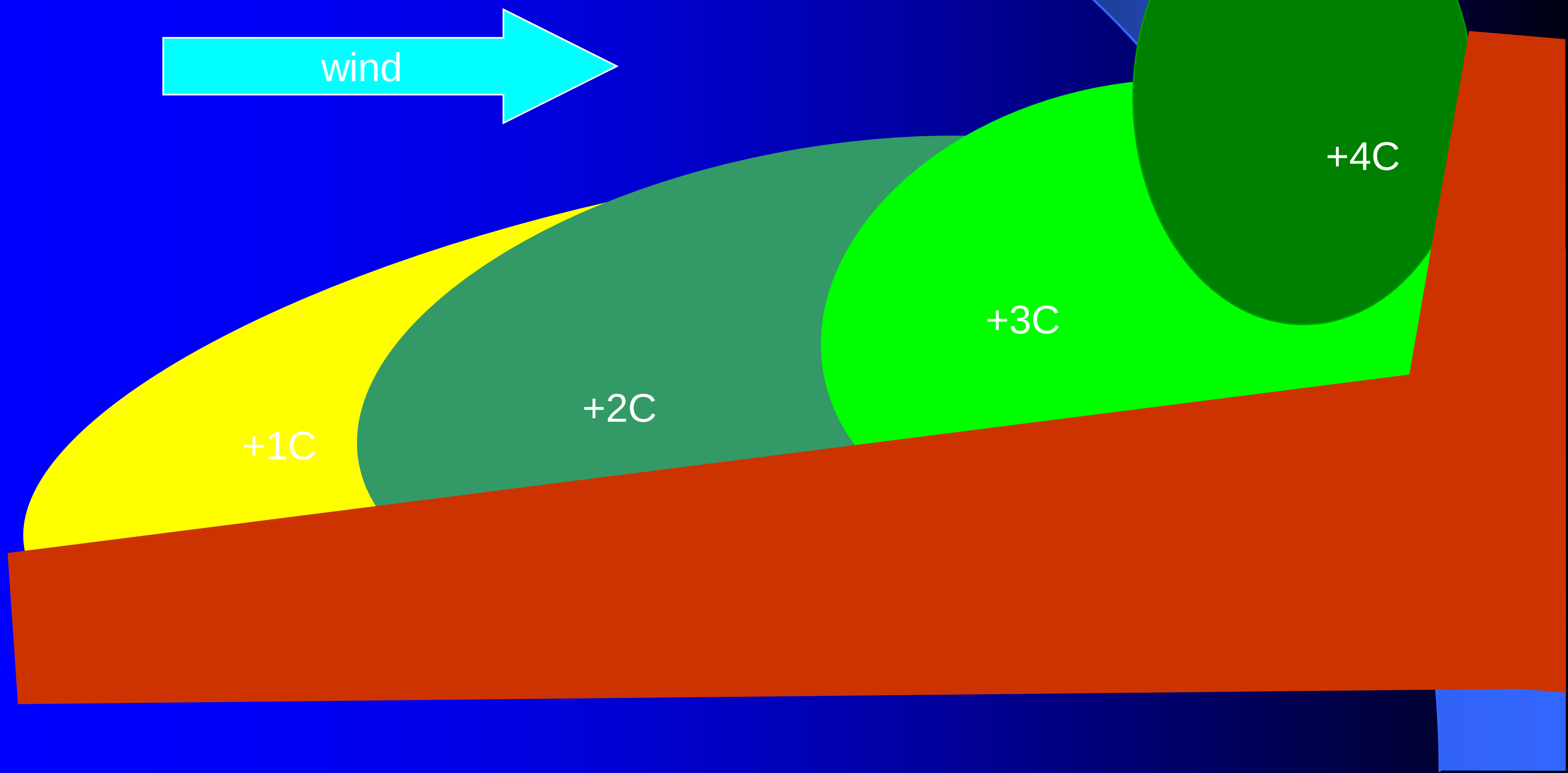
Imagine drops of water forming on the ceiling of the bathroom. It is only when they get big enough and join up that you actually get a drop to fall. Reverse this process for rising bubbles of air. If say it has to get 2 degrees hotter than the adjacent air before it lifts off and then it encourages or sucks all the other hot air up with it to form a strong thermal. Big towns, industrial complexes become good strong thermal sources but also explains the pulsing of such thermals rather than continuous thermal hot spots.



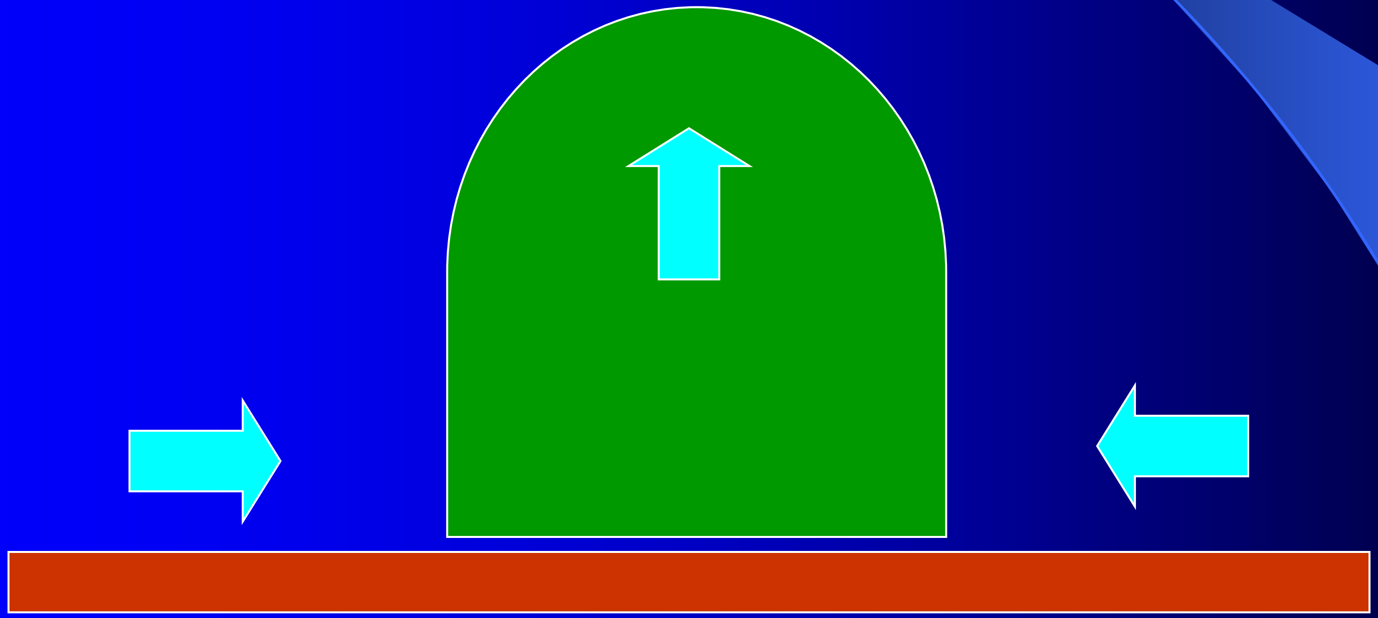
Stronger Thermals!
(Big + High point)
Greater than 200 metres wide



Strong Thermals!
(Big - Down wind Barrier)
Greater than 200 metres wide



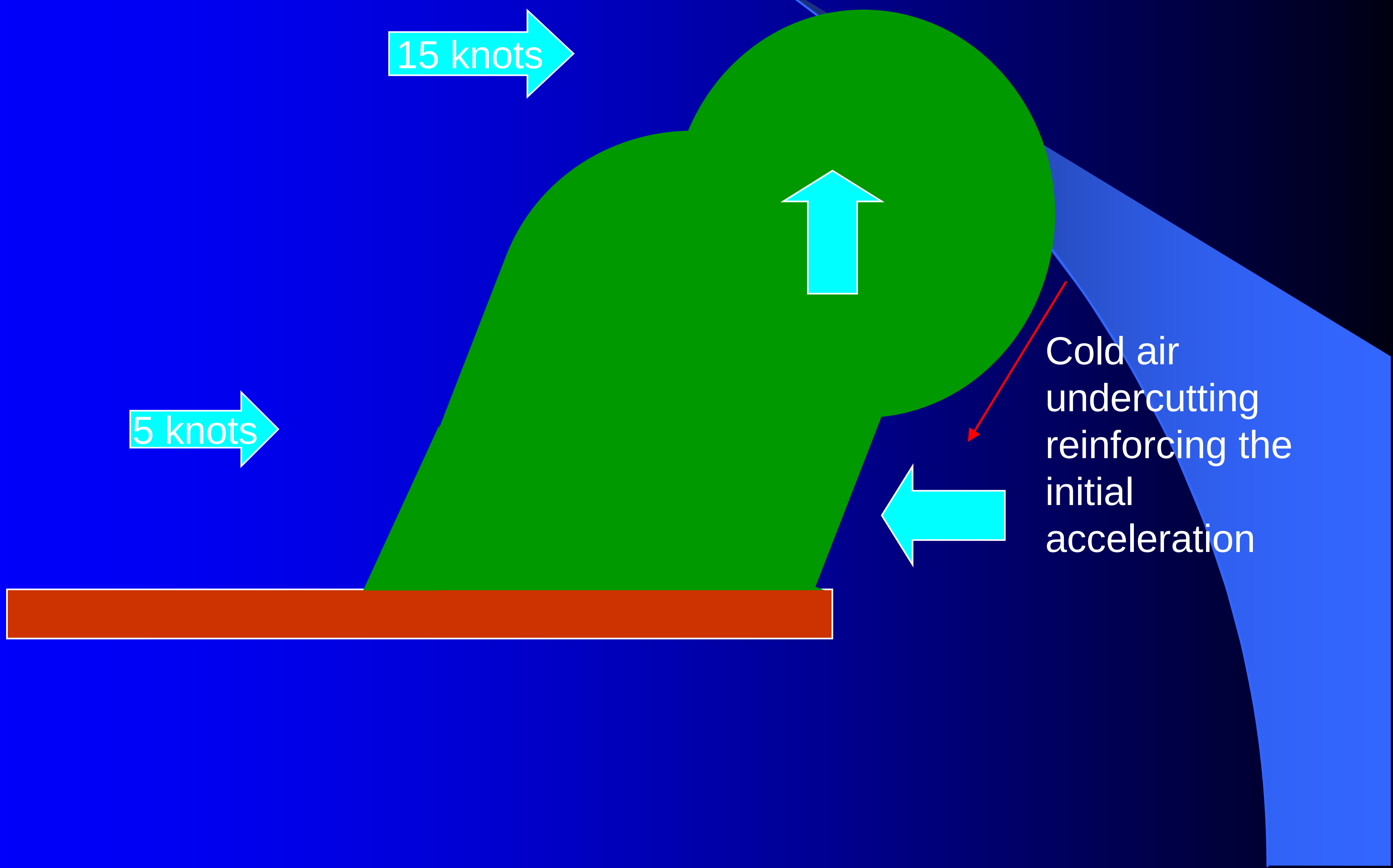
Surface Vortex
The first 500 feet! Nil Wind



Surface Vortex
The first 500 feet!

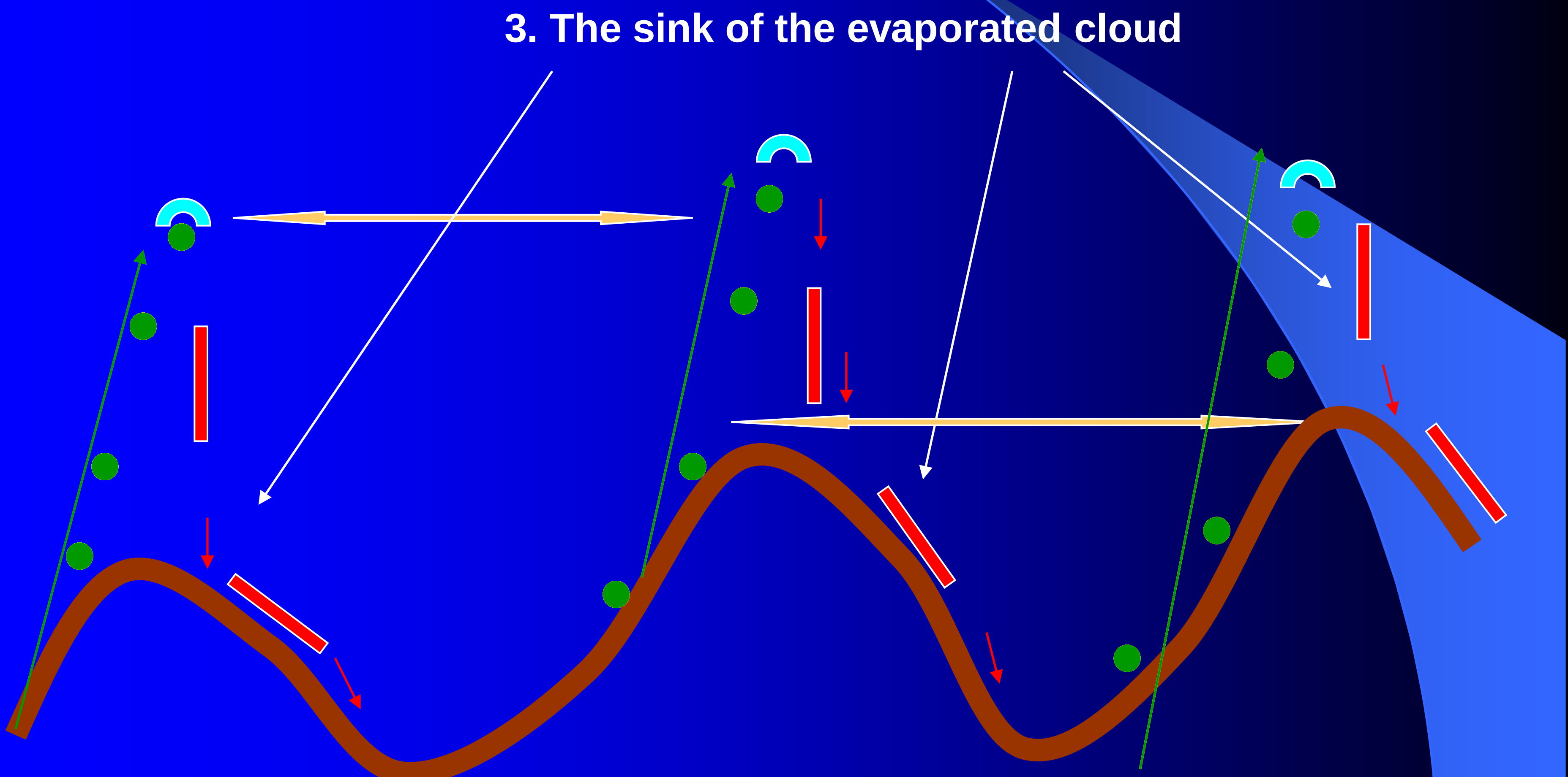
- Assuming a thermal of 200 metres diameter the initial birth and structure can make thermalling below 500’ difficult if there is any degree of wind!
- The literal surface wind (where we stand) will be lighter than the wind at 50’ so as the warm air rises the top of the thermal drifts (gets blown over).

Surface Vortex
The first 500 feet! Some Wind



Hills make their own weather!

- The controlling force is the sink.
- Ignoring wave,



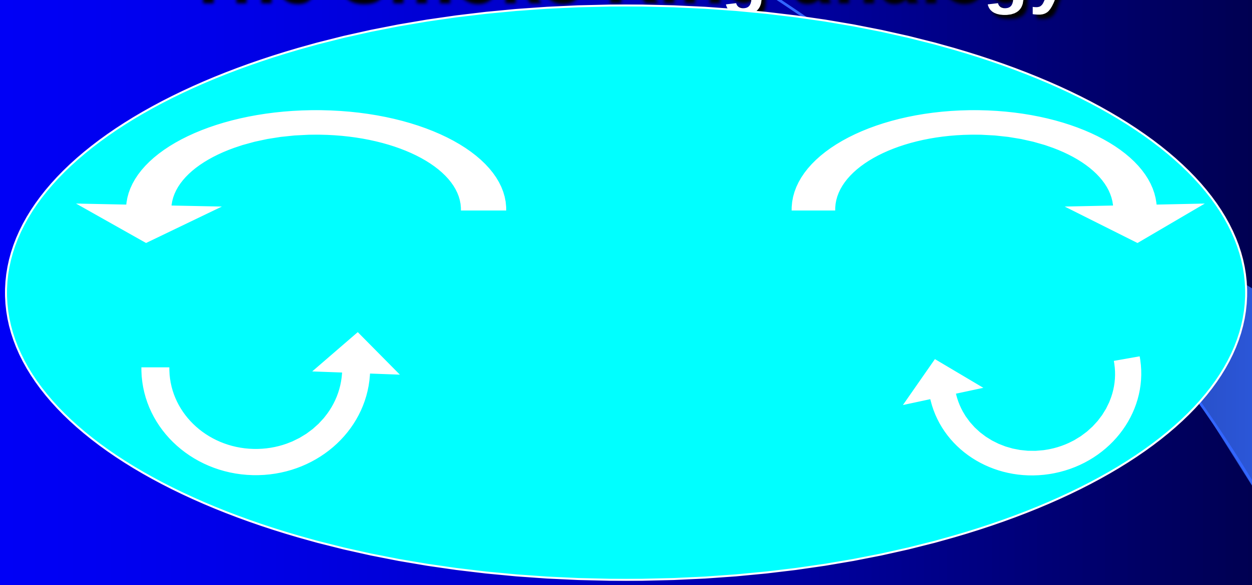
Surface Vortex

- Imagine hitting a balloon through the air. It rapidly slows (drag) and then descends slowly, regardless of the size of the balloon. The same if you try to ascend a helium balloon quickly – it won't! (Or try to make a supersonic airship!)
- For a natural weak thermal it is common for the vortex to form shortly after leaving the ground, but perhaps not go up much but instead, just drift downwind largely rotating within itself.

Thermal Vortex

- If a significantly stronger vortex is generated to the air it will travel considerable distances at great speed before being destroyed. If you induce a strong vortex motion to a thermal bubble then you get the thermals we want. The ascent of hot air into cooler air, however, continues to provide energy to the vortex bubble and maintains the vortex and a strong thermal to cloud base.
- The rising vortex can be further enhanced by strong sinking air – see later.
- Once a thermal leaves the ground its energy is fixed so thermal source size and relative temperature matter!
- Watching a large flock of sea gulls also show the bubble structure starting from a low altitude.

Vortex ring formation
The Smoke Ring analogy



This motion is fundamental to strong thermals, without which we wouldn’t get strong thermals.

And equally important to understand is that it’s limited - simply by physics.

Thermal Structures

- Before arriving at the climbing part of a thermal you must go through the sink, which effectively tells you, assuming lift and sink are directly related, how strong the thermal should be.

  You will also pass through a horizontal gust which you will see on the ASI, if you look for it. This gust is indicated with relatively no lag and is accurate!

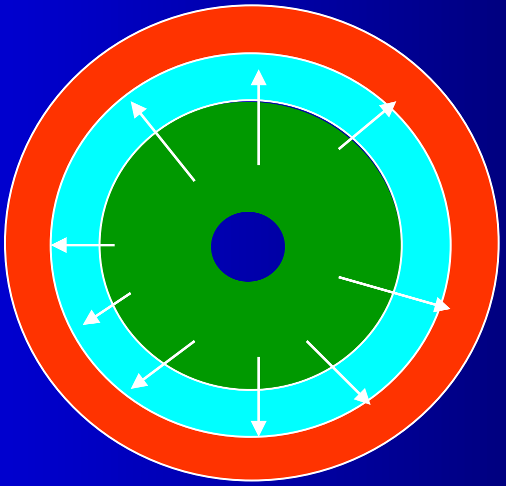
  Usually the gust is at least as much as the thermal strength. It is also indicated on the total energy vario (but with lag) as a climb!

Variometer Information

- The variometer is a good indicator of SINK but can be used to confirm your suspicion that you might be in a thermal.
- The total energy (TE) system indicates a change of energy by combining changes of climb or descent with changes of speed. Ideally if you do a loop in smooth flat air the variometer should not indicate a climb, but slight change in ROD as performance is gained or lost. This reduces ‘stick lift’ which can be demonstrated with the TE switched off. As a rule though, always fly TE on.
- Horizontal gusts, however, can mislead the pilot as it indicates a climb or descent on the vario (because it recognizes an increase or decrease of energy). This is why the vario fluctuates whilst stationary on the ground on a blustery day.

Thermal Structure

- Top View
- The thermal is always expanding (or trying to) as it climbs



SINK

ZERO LIFT GUST on ASI

LIFT

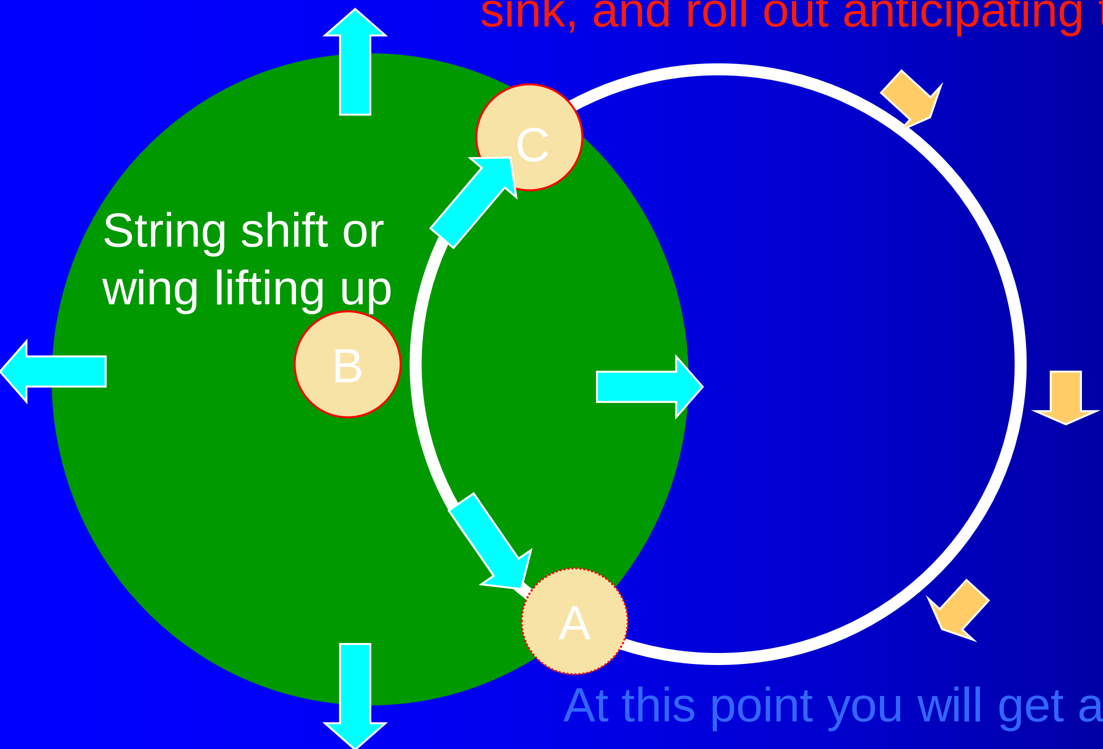
Thermal Structure

- With all this in mind then;
- Approaching a thermal you will first experience the downdraft, turbulence, then the speed increase, then the lift. The speed increase will also be detected on the variometer in the total energy system as a climb, do not be fooled! (You are not climbing).
- If you don’t hit the thermal head on then you will feel the wing lift and/or better, see the string indicating a brief side slip i.e. string blown away from the thermal centre due to the horizontal gust. Time to roll with full aileron and rudder! The bigger the gust the stronger and tighter will be the thermal.

Basic Thermalling

Just avoid the sink!

C At this point you will get a **gust speed DECREASE.**
You now know the thermal is exactly behind you.
Turn hard nearly 180 to keep out of the increasing sink, and roll out anticipating the gust increase



The ASI gusts are proportional to the strength of the thermal

At this point you will get a **gust speed INCREASE**

A You now know the thermal is in front of you

Either roll out or progressively increase bank to a steep tu

Avoid the sink!

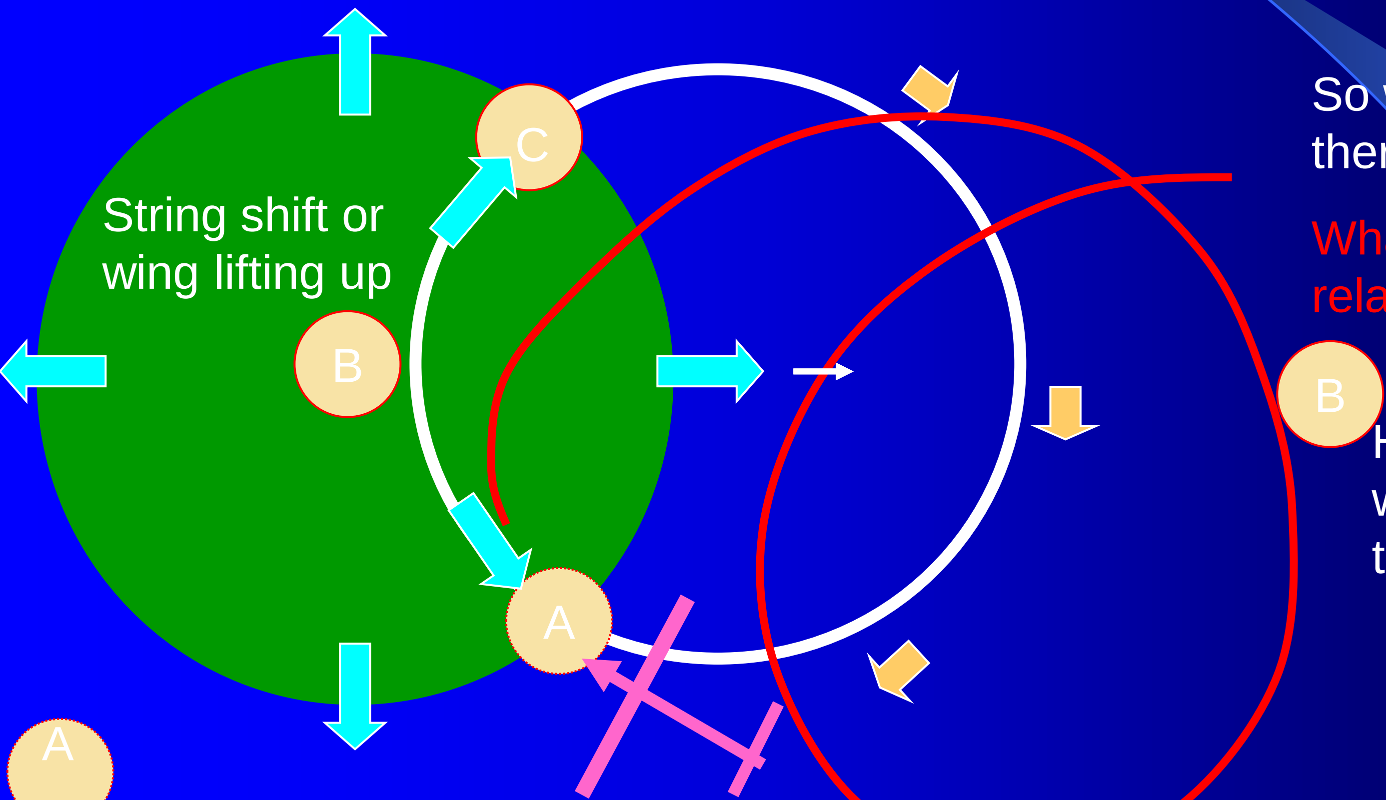
Basic Thermalling

C

At this point you will get a **gust speed DECREASE. (on the ASI) (+TE Vario down)**

You will be **pushed out** away from the thermal

What you think you are flying in a steady turn



So where did the thermal go?

What you actually fly relative to the thermal

Here there is a cross wind relative to the thermal

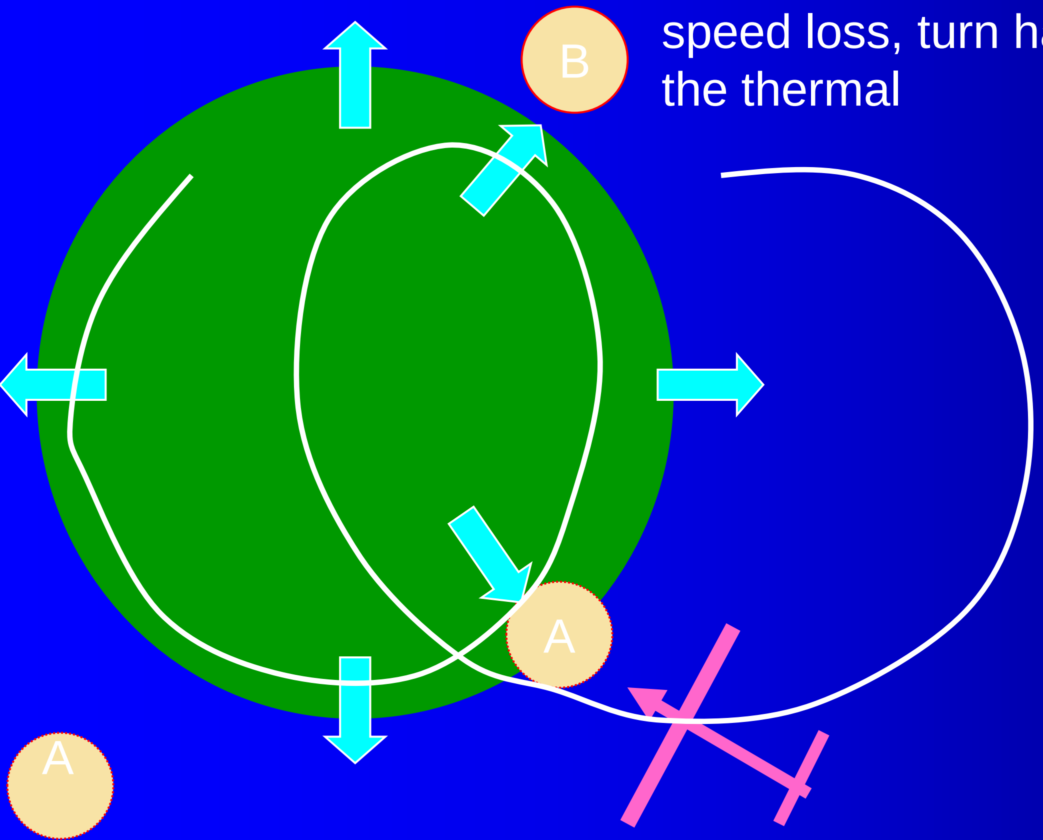
A

At this point you will get a **gust speed INCREASE (on the ASI) (+TE Vario up)**

Here you will get a head wind, **slowing** your progress towards the lift

Basic Thermalling

Centring without rolling out but anchoring on the strongest part by slowing down and increasing the bank



speed loss, turn hard to get back to the thermal

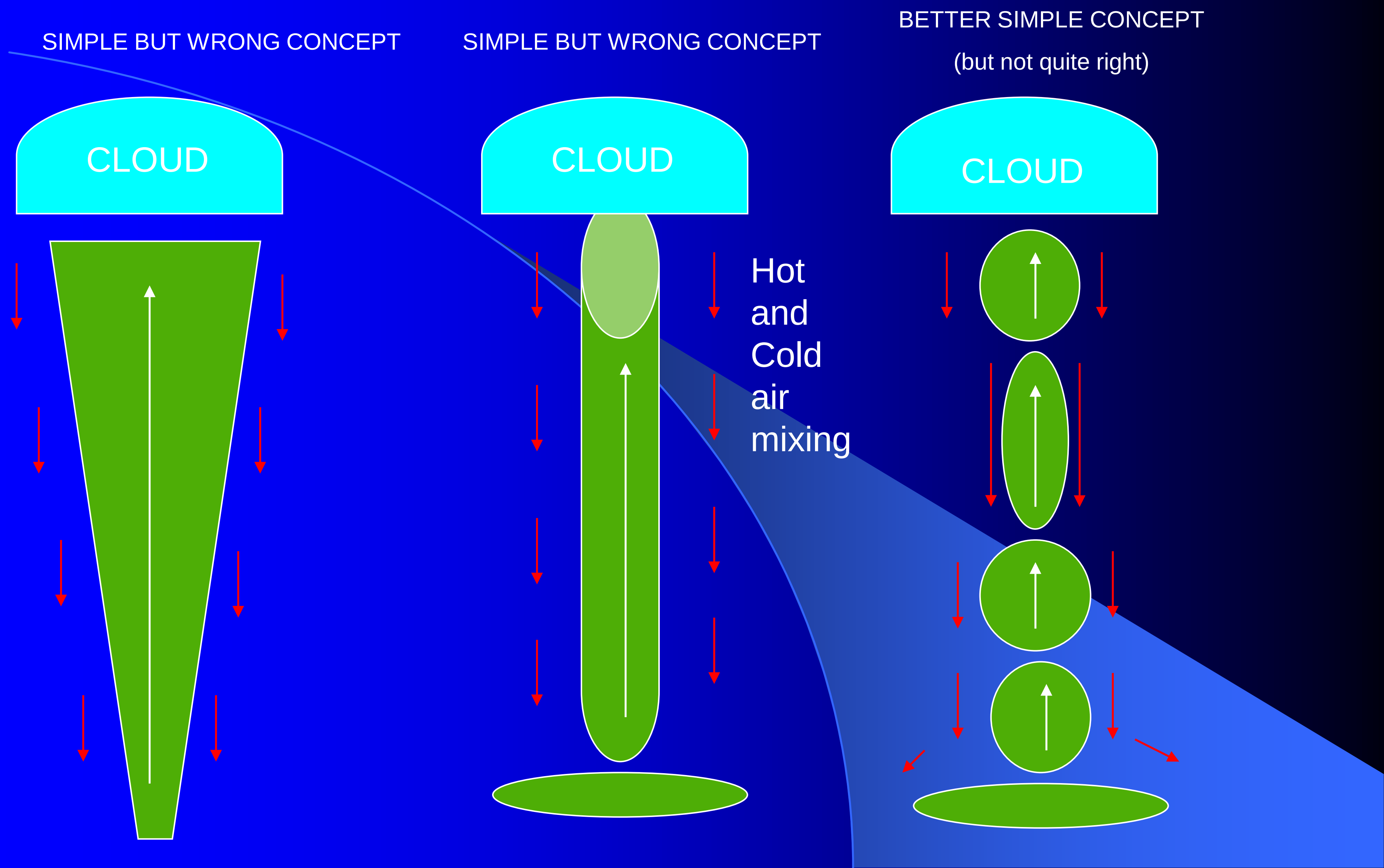
At this point you will get a **gust speed INCREASE (on the ASI) (+TE Vario up)**

Here you will get a head wind, **slowing** your progress towards the lift

Thermal structures

- Consider first a column of warmer bubbles of air rising. It starts with a heat source which heats the air and then it rises forming a vortex.
- The surrounding air will act as an insulator as the warm air expands but is restricted as the edges mix with the surrounding cool air.
- If the thermal is stronger it will be narrower, therefore, the stronger the thermal, the tighter you must turn. The turn radius is the important factor and is achieved either at high speeds with high angles of bank or slow speeds and less angle of bank.

Thermal Structure no wind

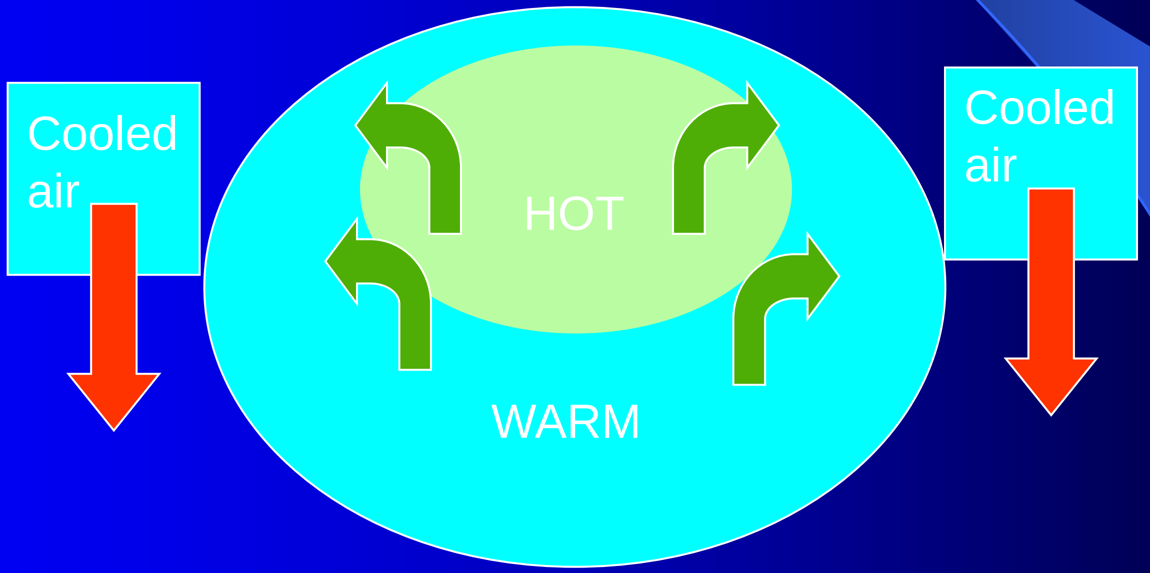


Thermal Structure

- When the bubble gets to cloud base the dry air immediately above is cooled and forced to start off outwards and downwards.
- Although the cold dry air was stable before, it is now next to humid air (possibly even at the same temperature) but being denser dry air and rapidly cooling from the evaporating cloud droplets, it descends into the moist air where it continues to sink as it remains relatively heavy.
- The air of the adjoining thermal is less dense and possibly warmer so the descent of the cold air will continue. The severity of the sink will also depend not on just the thermal temperature difference but also the relative humidity's and the height of the cloud cells.
- Which is why thermals can get stronger with height as they climb into drier air, and sink can become quite severe lower down.

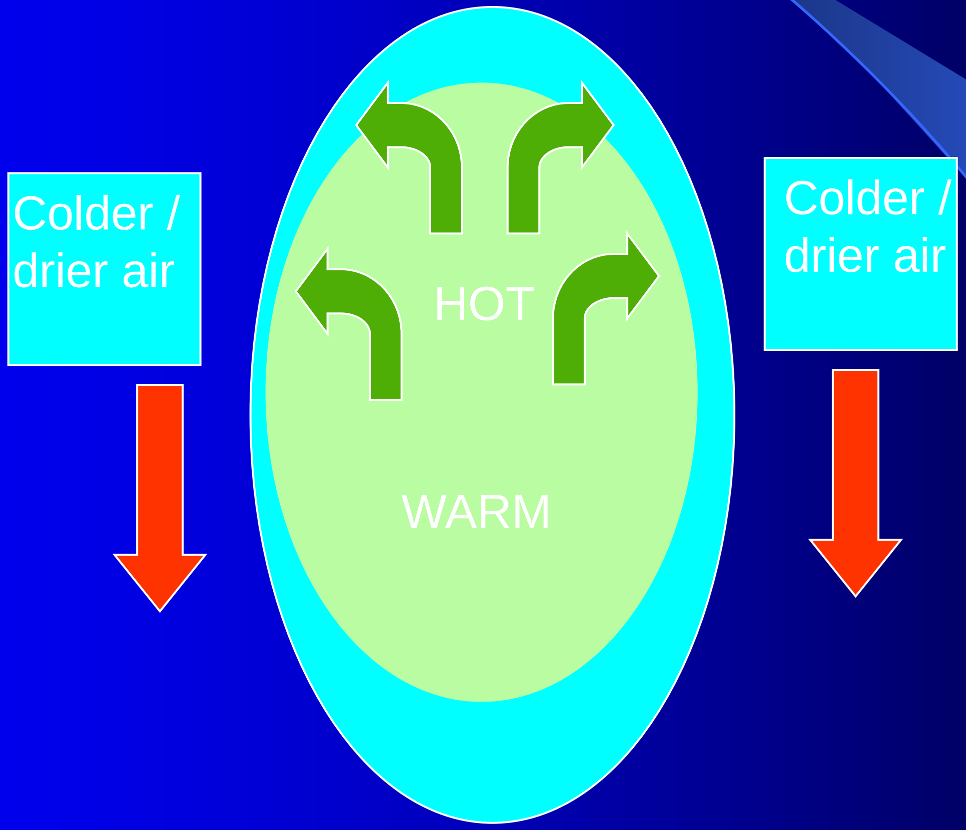
Thermal Structure

- Side View Simple concept



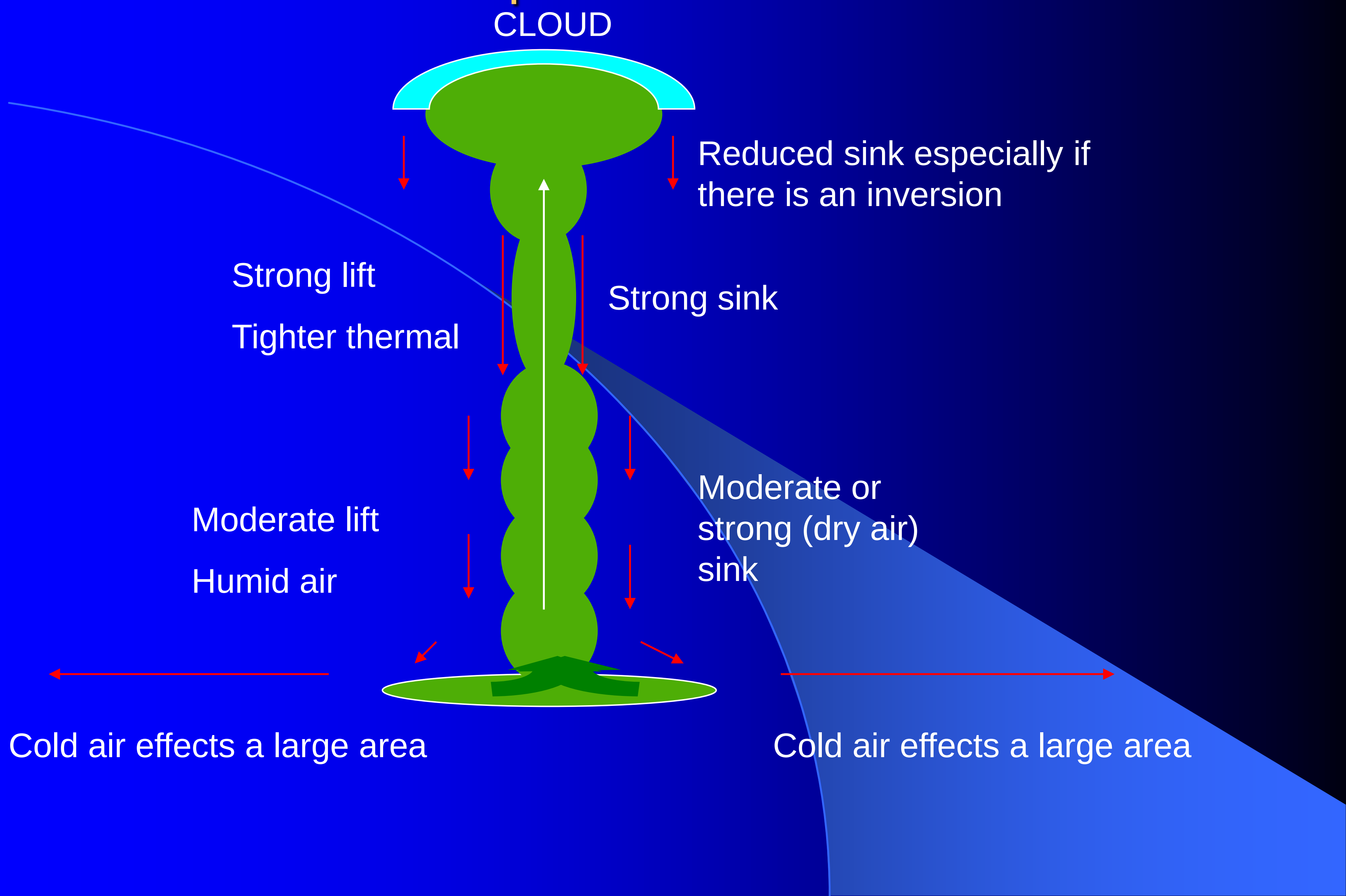
Thermal Structure

- Temperatures are simply relative
- If the thermal climbs into colder / dryer air it will become stronger, narrower, yet taller. It must reduce its form drag.



Thermal Structure - no wind

Yet a better picture of the structure



Nil wind therefore a rare simple column thermal

Lapse Rates

The adiabatic lapse rate is simply the rate of change of temperature with height.

1. For moist air the rate is 3 degrees per 1000 feet.

In simplistic terms this is the air from the ground up to cloud base.

2. For dry air the rate is 2 degrees per 1000 feet.

In simplistic terms this is the air above cloud base.

3. The actual lapse rate is called the environmental lapse rate which, amongst other things, varies between these two rates, depending on humidity. Tee-Phi Gram.

Lapse Rates

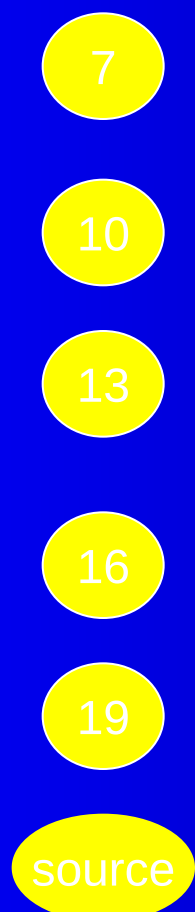
- On a normal good day we find that the air at ground level is moist with a ‘high’ level of humidity but pushing up into often drier air towards cloud base.
- This means that the moist rising thermal becomes relatively lighter than the air around it as it rises and the thermal becomes stronger and more developed.

Lapse Rates Rising/Sinking Air

Imagine then that the actual (environmental) rate is 2.5 degrees per 1000 feet (50% humidity).

Height	Temp
4000	5
3000	7.5
2000	10
1000	12.5
Ground Level	15

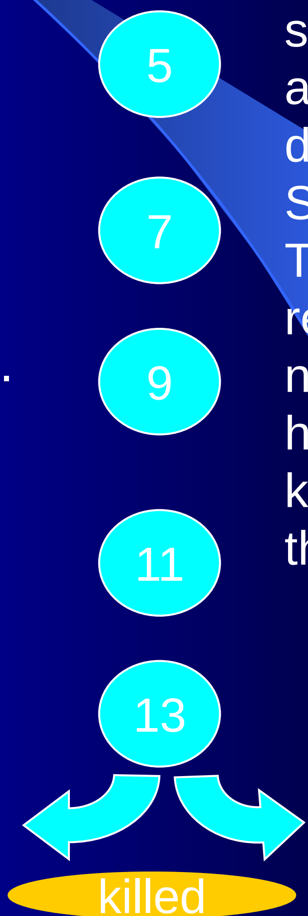
Moist thermal cooling at 3/1000



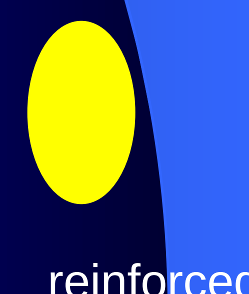
In this example it would appear that the thermal gets weaker as it climbs but this depends on relative humidity.

Normal to have a lower humidity (drier) at height.

Dry sinking air at 2/1000

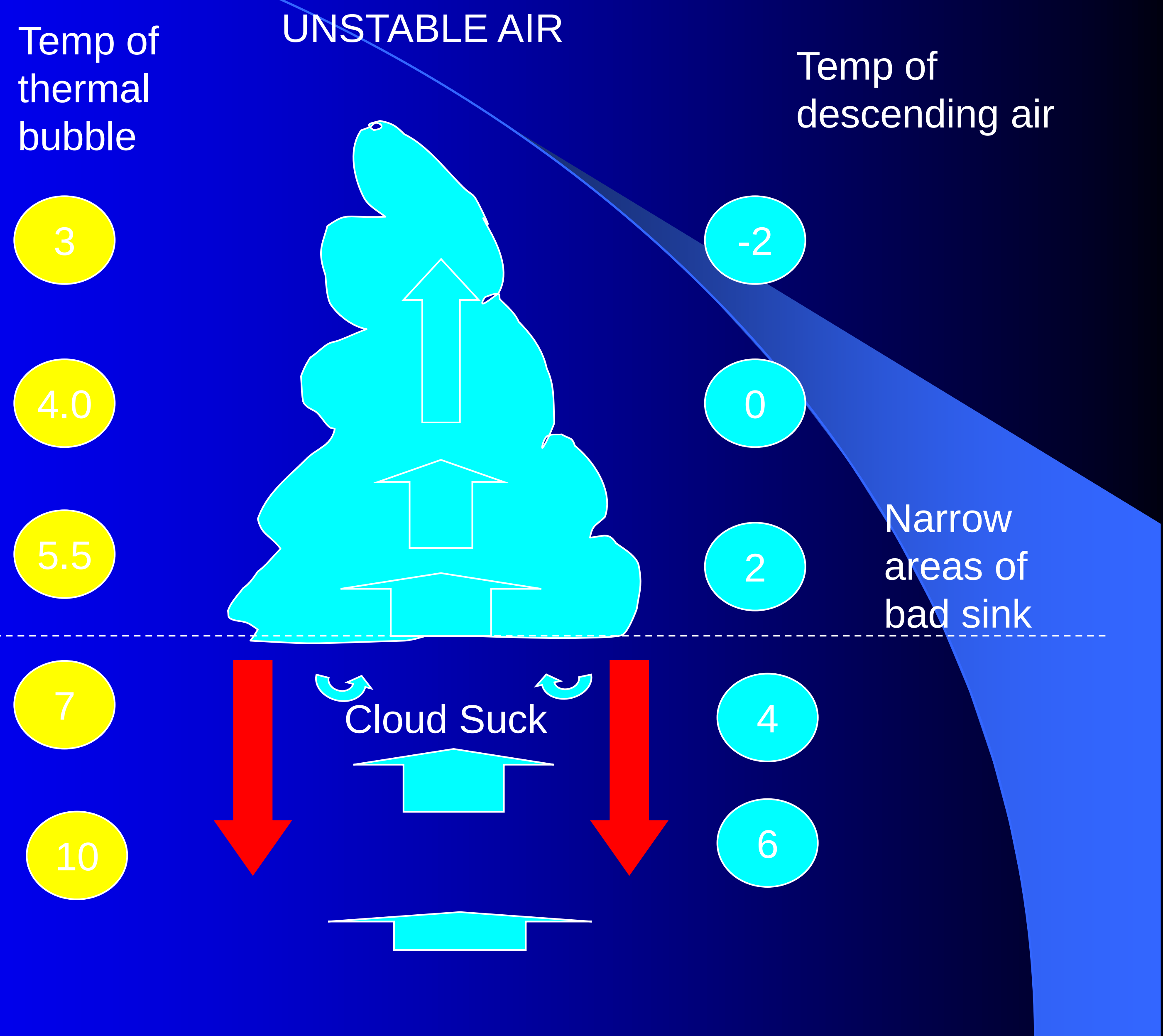


Note therefore, sinking air accelerates downwards! Sink Slugs. This can reinforce the next thermal hot spot or kill potential thermals.



Cloud Development (Shapes)

Height	Ambient Temp
7000	-1
6000	1
5000	3
4000	5
3000	7.5

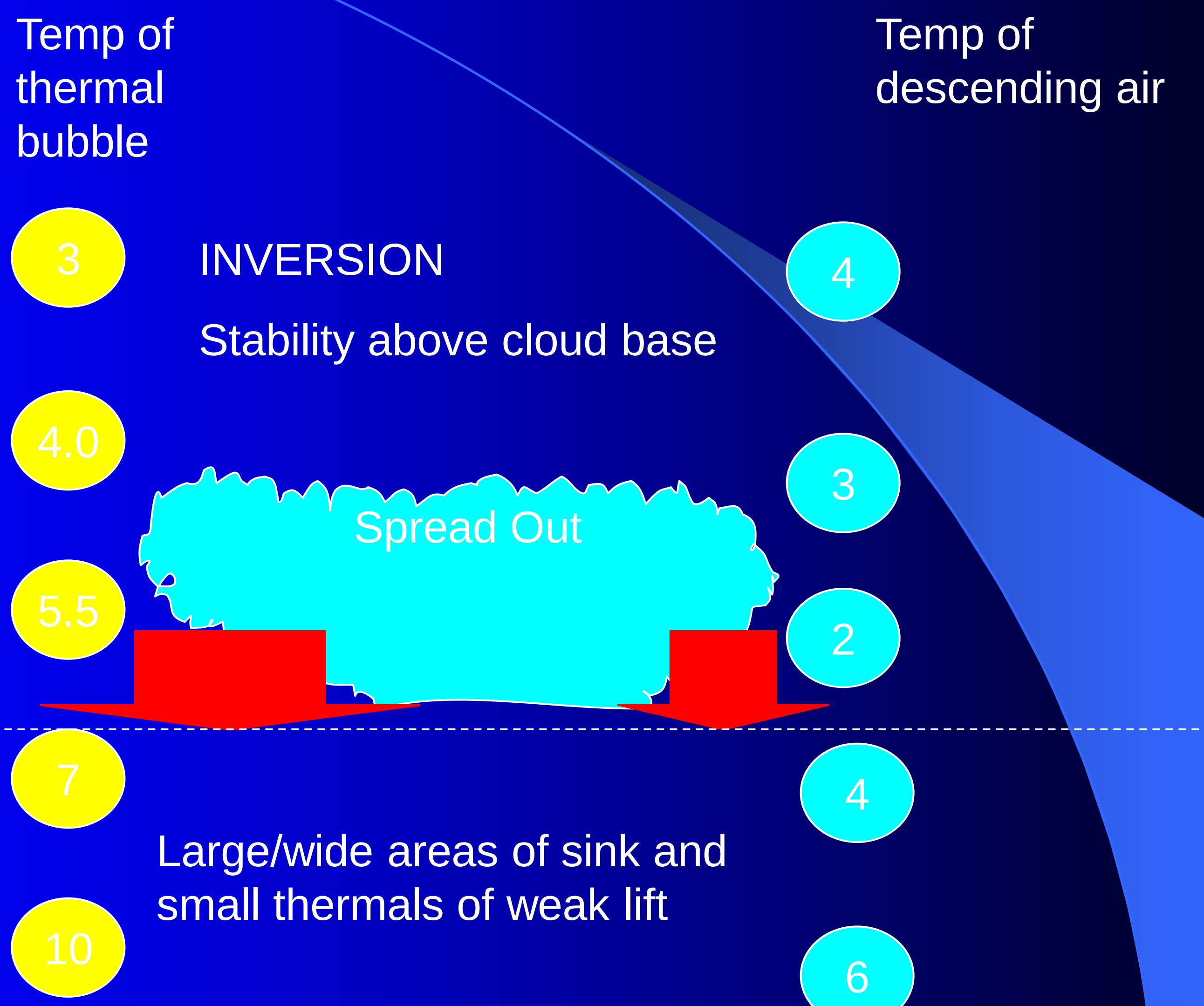


Cloud Suck!

- Finally, the thermal may accelerate upwards from cloud-base because the rate of cooling of the air is then only 1.5 C per thousand feet. (3 C below cloud base) reinforced by the surrounding cold descending air.
- This is because the humid air above cloud base within the cloud gives out heat as the water vapour condenses, causing the air above to accelerate upwards and ‘suck’ air drawn in from below upwards to the accelerating thermal above. The higher the cloud, the greater the suck!

Cloud Development (Shapes)

Height	Ambient Temp
7000	4
6000	3
5000	3
4000	5
3000	7.5



Ground Heating is modified by cloud shadow and sink slugs