ATMOSPHERE FOR DUMMIES;

Some notes on the atmosphere we fly in, inspired by a lecture given by Don Cameron at an Instructors Seminar, (with thanks to him and apologies for dummying it down and Ann Rich for correcting my English and my many misconceptions).

The Standard Atmosphere (which we balloonists use in calculating loading weights) is defined as a sea level pressure of 1013.25 mb or hPa, when the sea level temperature is 15°C and temperature aloft decreases at -1.98°C (-2°C to us) per 1,000 ft. as you climb away from the ground. This bottom bit of the atmosphere we fly in is called the *troposphere* and goes up to approximately 36,000 ft where the constant decrease in temperature stops and a uniform temperature of about -56.5°C is maintained for some distance from the earth in what is called the *stratosphere,* (it does eventually get colder when you do get further into space), The boundary between the troposphere and the stratosphere is called the *Tropopause*, (great name for an imaginary boundary). This is of course the scientists idea of the average, in practice, every day is different and it all depends where on the surface of the earth you are.

THE BEHAVIOR OF GAS IN THE ATMOSPHERE

A volume of gas expands and contracts in a simple relationship to pressure and temperature, so its *density* varies, (technically:- pressure x volume = constant x temperature), so squeeze a gas hard enough and all the molecules are pressed together until it becomes liquid. Liquids cannot be compressed any further, they can expand and contract slightly with changes in temperature, like sea water at the bottom of the ocean, it is under immense pressure but it still essentially has the same *density* as at the surface.

To understand what causes the pressure of air at the earths surface, you have to imagine a column of air resting on a square metre of the earth at sea level and rising all the way up into the *stratosphere*. The theoretical weight of all this gas in the column gives a pressure of over 10 tons per square metre, or about 1 kilogram per square cm. This atmospheric air pressure is usually expressed in units of millibars, (mb) or Hectopascal (hPa) although in practice the units are the same value.

As our bodies have the same pressure inside and out, we do not notice this pressure until we breathe, by lowering our diaphragms and increasing volume inside our chest, we create a small reduction in the internal pressure which causes the outside pressure to force air into our lungs.

WHAT DOES AIR WEIGH:-

1 cubic metre of air at 25°C weighs 1.184 kg, so 1 cubic foot of air at 25°C weighs 33.5gms.This scales up to 33.5 kilos per 1000 cu ft, which is an enormous 3.52 metric tons for a 105,000 cubic foot balloon envelope !!!

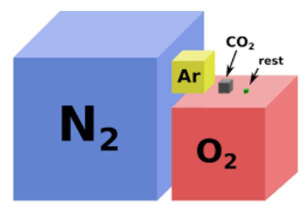
WHY DOES THE AIR GET THINNER AND COLDER WITH ALTITUDE AND WHATS ALL THIS ADIABATIC STUFF?

We have to go back to our metre square column of air pressing down on the earth's surface to answer that.

Take a walk up Kilimanjaro, (my granddaughter and son in law are doing that for Alder Hey Hospital), with a peak at almost 20,000 ft, by the time you get to the top you are half way to the Tropopause. Not only has it cooled down by 40 degrees but the remaining column of air pressing down on the mountain has only about half the weight of that at sea level, (atmospheric pressure reduces exponentially with height), reducing the air pressure to 5 tonne's per square metre or about 500 mb / hPa. The density of air reduces in the same way, so there are less air molecules per unit volume than at sea level. So when you breathe in at 20,000ft there is only half the air pressure around you to force air into your lungs and in the same volume of air taken into your lungs there are only about half the molecules of oxygen there was at sea level ! No wonder you get short of breath.

WHY DOES APPARENTLY COLD AIR RISE, WHAT CAUSES THUNDER STORMS AND WHAT'S ALL THIS LAPSE RATE NONSENSE.

The Standard Lapse (cooling) rate as you ascend up to the Tropopause is -2°C per 1,000ft, but this is an overall average for the standard atmosphere.

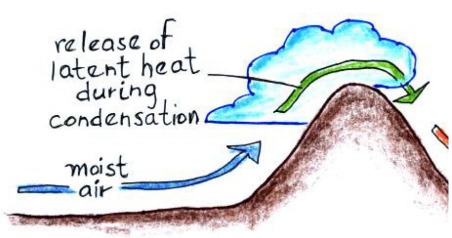


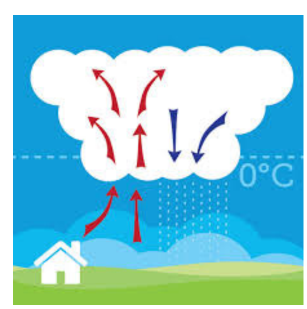
Our air, a mixture of Nitrogen, Oxygen, Carbon Dioxide and trace gasses (including water vapour), is a dynamic soup stirred by the heat of the sun and the rotation of the earth, (which at the equator is over 1000 mph), this drags the air mass with it, giving us the coriolis effect, twisting the different air masses into the familiar high and low pressure systems we see on weather forecasts, this is the result of nature constantly trying to equal out the temperature difference between the equator and the poles.

Air can be lifted up as a parcel, or on a larger scale as what is described as an "air mass". As the air rises (usually too quickly for it to exchange heat with its surroundings) the pressure decreases, the air expands and cools down. This cooling process is called "Adiabatic". Adiabatic means a change in temperature without an exchange of heat, and this cooling rate for ascending air is called the dry adiabatic lapse rate and is -3°C per 1000 ft (or -10°C per km). The exact opposite effect is true for sinking air.

Adiabatic heating and cooling is a strange phenomenon, when you squeeze air, like pumping up a cycle tyre, the pump gets warm, adiabatic heating, if you take the valve out of a car tyre, the escaping air is cold, as it rushes out of the valve the expansion of the previously compressed air causes adiabatic cooling.

Our atmosphere is never quite "dry" as it contains water vapour in varying quantities, so a rising mass of air containing water vapour is likely to reach a point where it cools to its "dew point" the point at which it can no longer absorb the water vapour it contains, which then begins to condense out as tiny droplets of water, (forming fog or cloud), This air mass now has a slower rate of cooling called the "wet or saturated lapse rate" of -1.5°C per 1000ft. This means it cools down more slowly as it rises, thus becoming slightly warmer than the air around it.



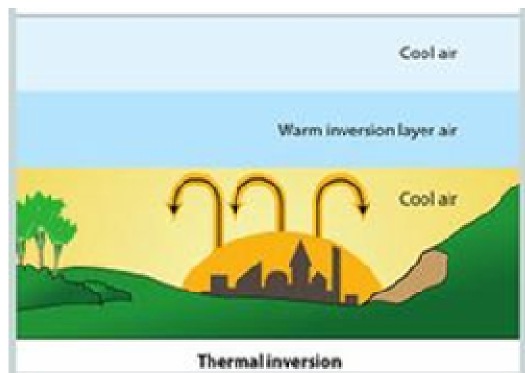


WHY?

It's to do with something called Latent Heat. It requires energy in the form of heat (the latent heat of evaporation), to assimilate water into the air in the form of water vapour and then, when the atmosphere cools and the water vapour condenses out, this heat is released back into the air mass, giving it buoyancy in comparison with the environment, it is this warmer air that rises faster.

Although latent heat may be difficult to understand we have examples of its use all around us, our domestic fridge or freezer uses the latent heat of evaporation to take heat from the inside the fridge and transfer it to a radiator at the back. Steam issuing from the mouth of a kettle will give you a more painful scald than boiling water because as it condenses on your skin it gives up the latent heat it acquired when it turned from boiling water to steam, OUCH !
It is similar with the burn you get from leaking propane, as the propane is normally a gas at atmospheric pressure, if you get a little liquid on your finger it immediately turns back to gas taking the latent heat it needs to evaporate from your skin, PAINFUL !

ATMOSPHERIC STABILITY AND INVERSIONS:-



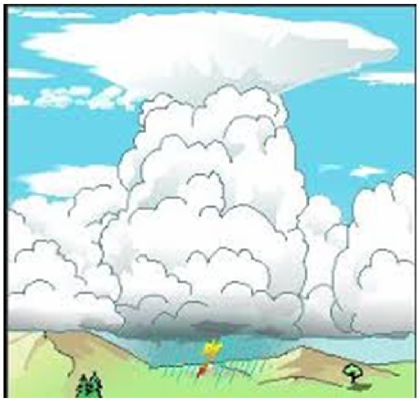
The relationship between the lapse rate of the environment and the lapse rate of a rising parcel of air (dry or saturated) determines the stability of the atmosphere. A dry parcel of air rising will cool at -3°C per 1000ft while the air around it cools at -2°C per 1000ft. This rising parcel is soon colder than the air around it and will tend to sink back to its starting point. This is a stable atmosphere.

An Inversion is a negative lapse rate, (warmer air above), creating a "ceiling", putting a lid on rising air and preventing condensation occurring, usually caused by an area of high pressure in which descending air is warming up as it descends, (due to adiabatic warming), and becoming more dense with the increased air pressure.

An inversion can also be caused by local ground conditions, especially after a cloudless night when the air near the surface is cooled by the heat of the day radiating out into the stratosphere unhindered by cloud cover and then we get a band of cold air near the ground with a warmer layer above, often causing a ground mist, especially in summer, (radiation fog).

Occasionally this layer can be several hundred feet above the ground but these low level inversions are usually temporary, unlike high pressure inversions which can last for days and are usually higher in the atmosphere and can be easily seen when flying as a murky grey line with clear blue sky above.

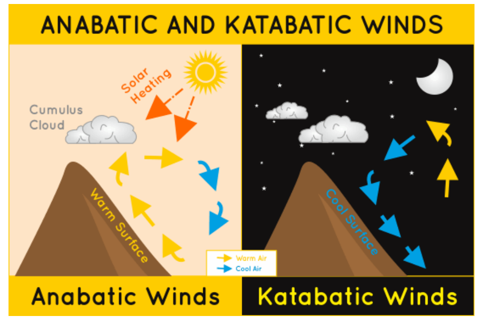
ATMOSPHERIC INSTABILITY:-



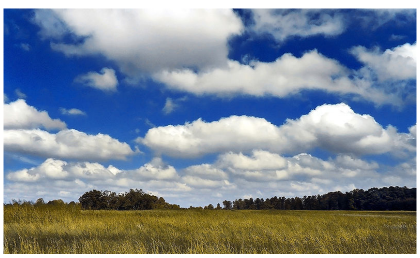
If the parcel of rising air cools down more slowly than the environment then it will go on rising. An air parcel that is saturated (water vapour condensing) is cooling at the “wet” adiabatic lapse rate of -1.5°C per 1000ft, so it will always be warmer than the air around it and go on rising. This is an unstable situation.

In the real atmosphere the vertical temperature profile (local lapse rate) can have a whole range of values including inversions, instability and thermals (rising/falling parcels of air) often resulting in rising air condensing into clouds, giving up its latent heat and continuing to rise until reaching warmer air, (the inversion “lid”), sometimes in the tropics this is can be as high as the tropopause. In extreme cases the energy released by condensing rising air can be extreme, resulting in cumulo-nimbus clouds and thunderstorms, giving gusting conditions on the ground due to the effects of these extreme up (and down) draughts.

SOME OTHER ATMOSPHERIC TERMS YOU MAY HEAR:-

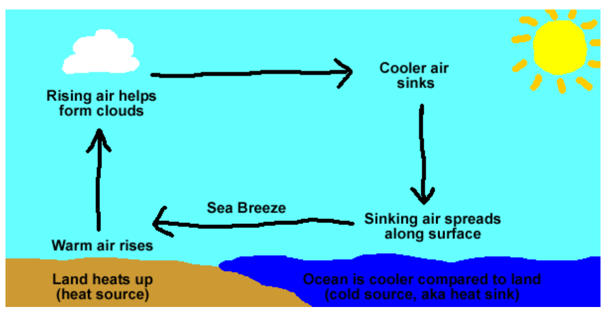


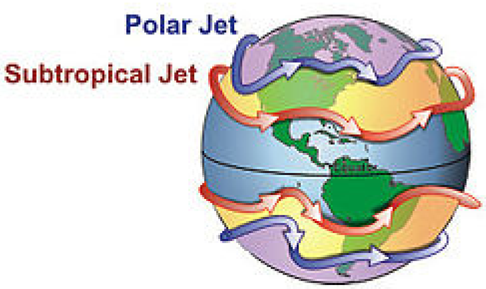
Katabatic and Anabatic Winds:-
Anabatic wind is air rising up a slope due to heating of the upper slope which causes heating of adjacent air which with thermal expansion becomes lighter. This air warmed air rises and pulls up air to replace it from lower down the slope. Katabatic wind is cold air descending due to radiative cooling, becoming heavier and descending down the mountain slope.



Thermals:- are parcels of warm air rising, usually caused by sun-shine warming the earth, and hence the air immediately above. (but not always), when they reach their dew point they form cumulous clouds, especially noticeable on a nice summers day

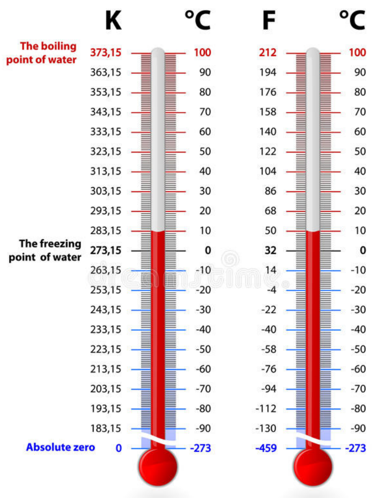
Sea Breeze:- More differential heating. The ground gets warmer than the sea and so does the air above it which rises and draws in replacement air from the cooler sea. Officially it is described as a wind strong enough to overcome the gradient offshore wind but on the west coast where I live, it also acts to strengthen the gradient onshore wind during the day until the heat of the sun diminishes enough to kill it, and we can fly !



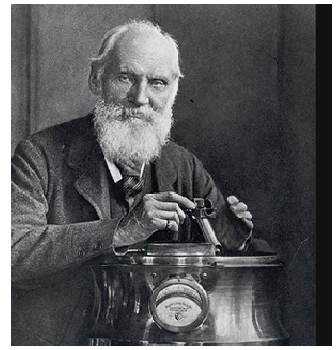


Jet streams:-
They are fast flowing, narrow, meandering air currents high in the atmosphere, the main jet streams are located near the tro-popause and are westerly winds (flowing west to east). Only actually discovered in the early 20th Century they are the cause of much of our weather and have helped us to circum-navigate the earth by Balloon.

SOME GAS RELATED FACTS:-



In the 19th Century scientists were struggling with the standard Celsius temperature scale as it contains negative values below the freezing point of water, so in 1846 Lord Kelvin, a famous Scottish scientist created a temperature scale that went from absolute zero, 0° Kelvin, (a hypothetical temperature when all molecular movement stops), going all the way up to much higher temperatures using the same units as the Celsius scale, (100° between freezing and boiling water) plus 237.15°. this gave a temperature scale without any negative values making life much easier for the scientists but very confusing for us mortals.



Lord Kelvin with his Experimental Apparatus

GASES TURN INTO LIQUID AT:-

Butane +272°K / 0°C, Propane +231°K / -42°C, Methane +109°K / -164°C, Nitrogen, +77° Kelvin /-196°C, Oxygen, +90°Kelvin /-183°C, Hydrogen, +20°Kelvin / -253°C, Helium, +4° Kelvin / -269°C.

WHICH IS HEAVIEST:-

Standard Temperature & Pressure (STP) is the standard measurement and equates to a gas at 0°C and 1013 mb/hPa atmospheric pressure.

Butane weighs in at 2.5 gms/ltr @ STP
Propane is 2.01 gms/ltr @ STP
Air is 1.30 gms/ltr @ STP,
so Propane and Butane are both heavier than air and will fill drains and hollows if allowed to escape from a cylinder.
Methane is 0.7 gms/ltr @ STP, (Methane is the main constituent of natural gas)
Helium is 0.18 gms/ltr @ STP, about 7 times lighter than air
Hydrogen is 0.09 gms/ltr @ STP about 14 times lighter than air

WHAT ARE QNH & QFE which we hear talked about the atmosphere:-

QNH The air pressure at sea level where you are, (probably).
QFE The ground level air pressure at a designate site, usually an aerodrome runway.
Transition Altitude:- The height above which airplanes set their altimeters to a standard 1013 mb / hPa to maintain separation when flying through different pressure zones, (not usually used when flying balloons below 3,000 ft) !

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