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CHAPTER 7 – ATMOSPHERIC STABILITY

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ATMOSPHERIC STABILITY

INTRODUCTION

The type of weather we experience is related to whether or not the air rises or falls in relation to the surrounding air. The term used to measure the resistance of a parcel of air to vertical movement is called **stability**.

A stable parcel of air resists vertical motion:

Air is said to be stable when a parcel of that air, displaced upwards, resists the displacement and returns to the level from which it started.

An unstable parcel of air rises and therefore has the potential to create hazardous weather and cloud development:

Air is said to be unstable if when a parcel of that air is lifted, it is warmer than its surroundings. It will continue to rise of its own accord until it encounters a stable layer. *("The state in the atmosphere in which air which is displaced vertically tends to become more displaced even though its original displacing force is removed")*

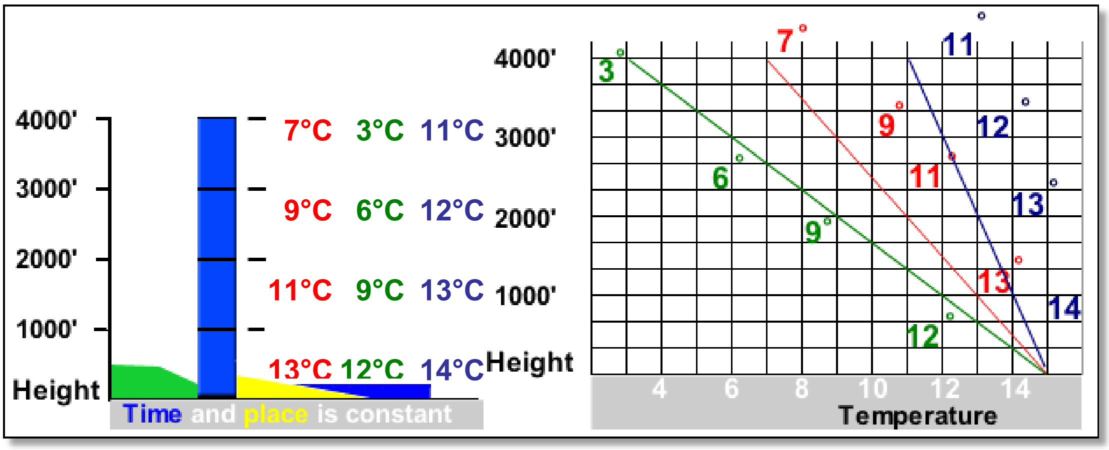
LAPSE RATE

ENVIRONMENTAL LAPSE RATE (ELR)

The ELR is the **actual** rate in change of temperature with height. It can vary depending upon a large number of factors. It may be + or - (ISA is approximately 2°C/1,000 ft.)

The ELR may vary widely from place to place, from day to day, and from one layer to another. The ELR may show a fall of temperature of several degrees / 1,000 ft. (a steep lapse rate), or a fall of only a small part of one degree / 1,000 ft. (a very shallow lapse rate). It may show no change of temperature with height (an isothermal layer) or even an increase of temperature with height (an inversion).

Normally the ELR is about 2°C/1,000 ft. Although wide departures from that value are common, the lapse rate is seldom more than 3°/1,000 ft., except perhaps in a very shallow layer close to the ground.



The average ELR is a decrease of 2°C/ 1000'.

When the temperature decrease with an increase in altitude is large, the ELR is said to be

When the temperature decrease with an increase in altitude is small, the ELR is said to be shallow.

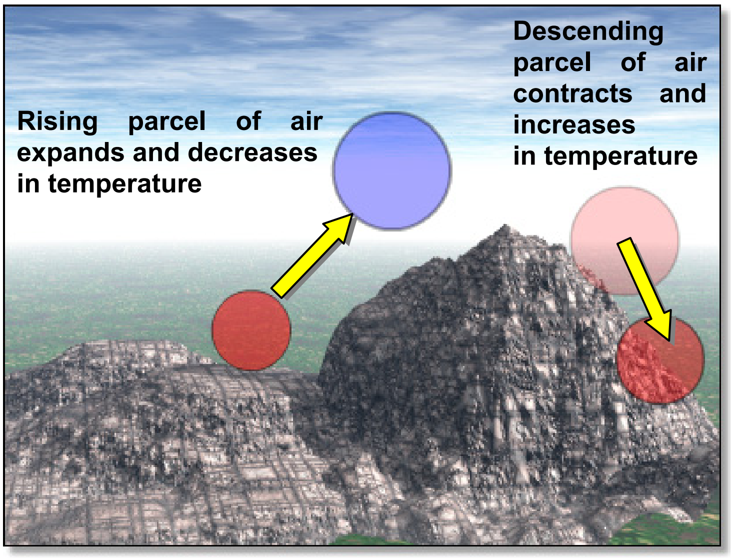
ADIABATIC PROCESS

An adiabatic process is one in which the temperature of a parcel of air decreases or increases as a result of a change in the volume or pressure, without adding or subtracting heat to or from that parcel:

EXPANSION → COOLING

COMPRESSION → HEATING

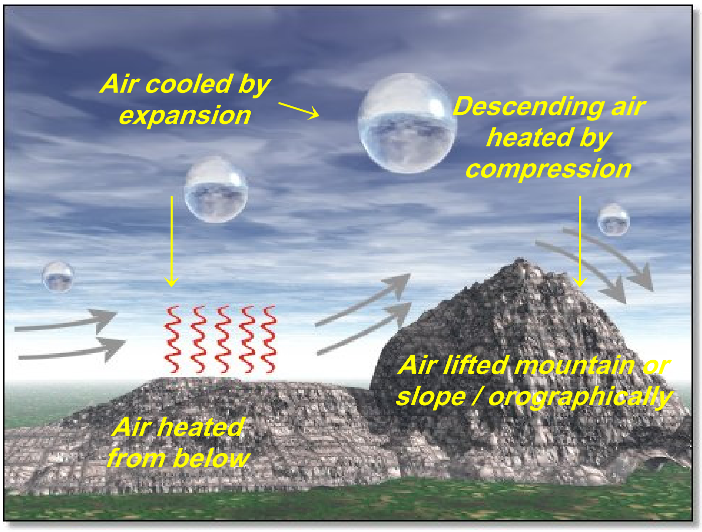
When air rises, it expands and therefore cools and when it descends, it compresses and therefore heats up.



DRY ADIABATIC LAPSE RATE (DALR)

If a parcel of air is unsaturated (RH < 100%), it will rise and cool adiabatically (condensation has not occurred).

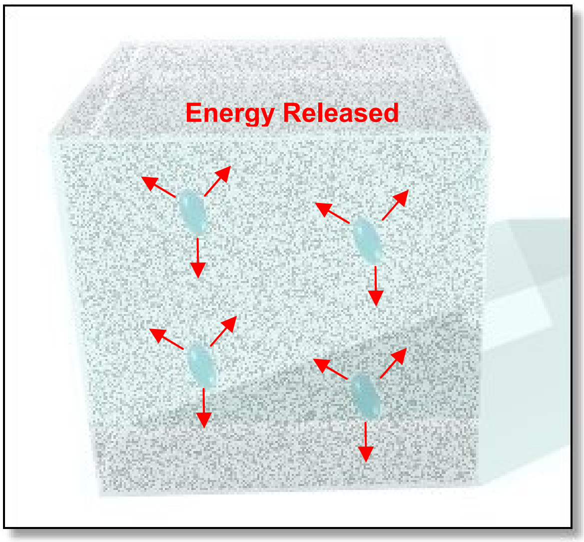
The adiabatic lapse rate for unsaturated air is 3°C/1,000 ft. As air rises it expands and cools. Similarly, descending air contracts, because of the greater pressure on it, and so raises its temperature. An adiabatic process must take place and must be on a fairly large scale so that the inevitable mixing at the boundary is only a small proportion of the whole process. **DALR is 3°C/1,000 ft.**



SATURATED ADIABATIC LAPSE RATE (SALR)

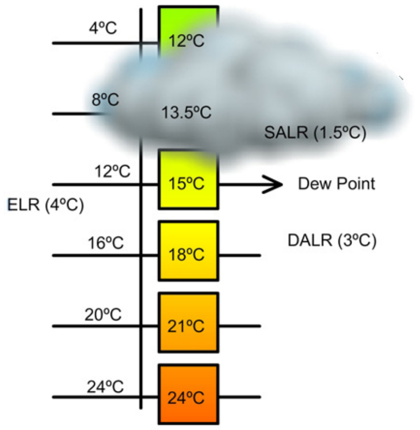
Once condensation starts taking place, latent heat will be released. This has a warming effect and therefore the SALR will be less than the DALR. At the base of a cloud the air is warm, holds a lot of water and therefore releases great amounts of latent heat. At this level, SALR may be as low as 1^{o}/000 ft.

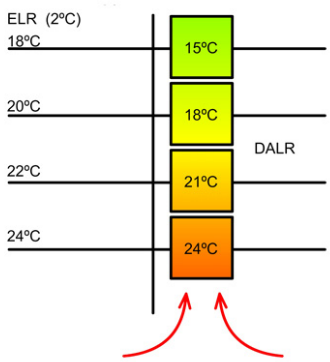
At the top of a cloud the air is cold, holds a small amount of water and only a small amount of latent heat is released. Here, SALR will be close to 3^{o}/1000ft. To overcome this variation through the vertical extent of the cloud, **an average SALR of 1.5°C/1,000 ft. is used**. While the SALR can be near 3°C/1,000 ft. but even the smallest amount of latent heat released will always reduce the SALR to less than the DALR



DETERMINING STABILITY

The stability or instability of the air depends upon how the temperature of a displaced parcel of air compares with the environment, level for level. The outcome will often depend upon the moisture content of the air, which determines whether the rising parcel of air changes temperature according to the DALR or SALR, and upon the ELR.



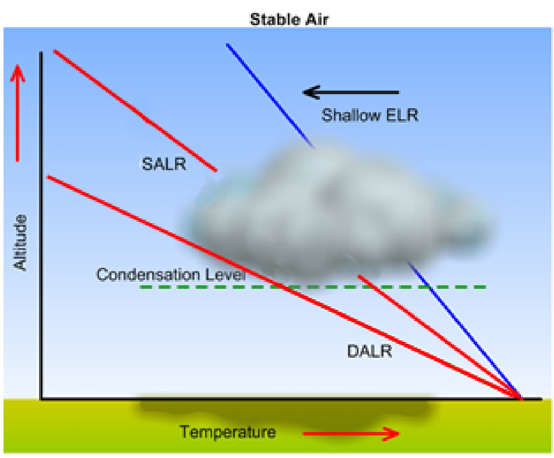


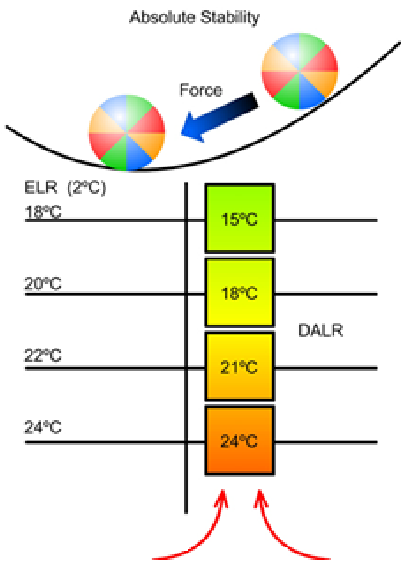
Unstable **Stable**

A parcel of air will initially rise and cool at the DALR but once condensation has occurred the parcel of air will now cool at the SALR (remember; a parcel of air will cool at the DALR or SALR regardless of the ELR). If the rising parcel of air is warmer than the surrounding air, then the parcel of air is unstable, if colder than the surrounding air the parcel of air is stable.

STABLE ATMOSPHERE

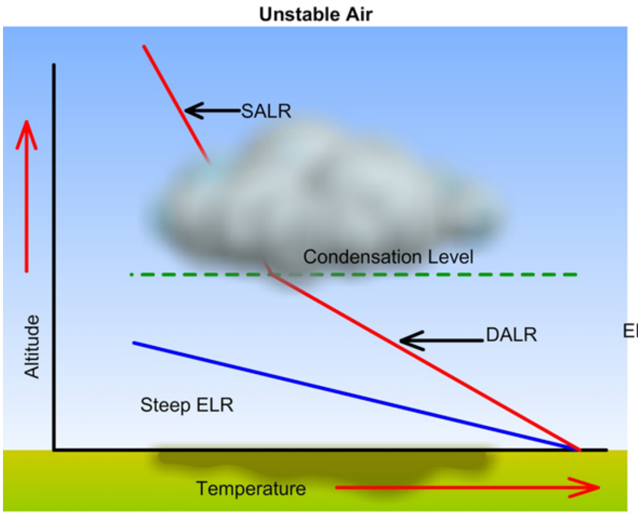
A parcel of air is considered stable, if when forced to rise, it tends to return to its initial position. It is colder than the surrounding air, therefore it is heavier and it sinks.

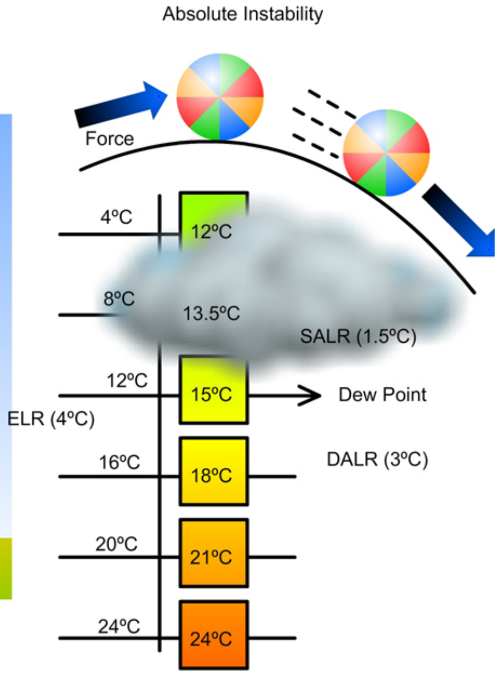




UNSTABLE ATMOSPHERE

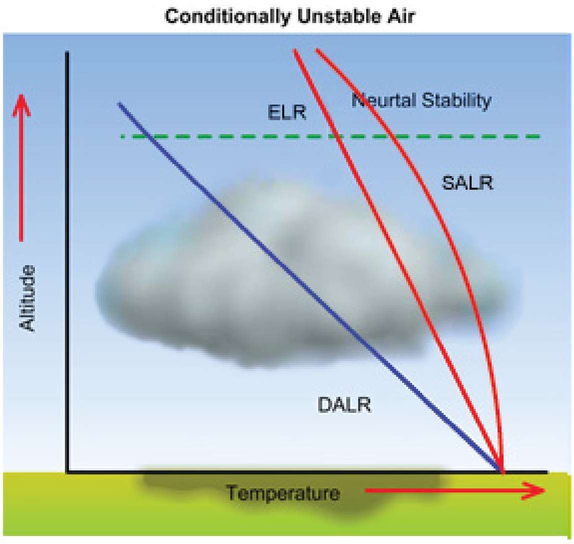
A parcel of air is considered unstable, if when forced to rise, it continues to rise of its own accord. It is warmer than the surrounding air; therefore it is lighter and rises.

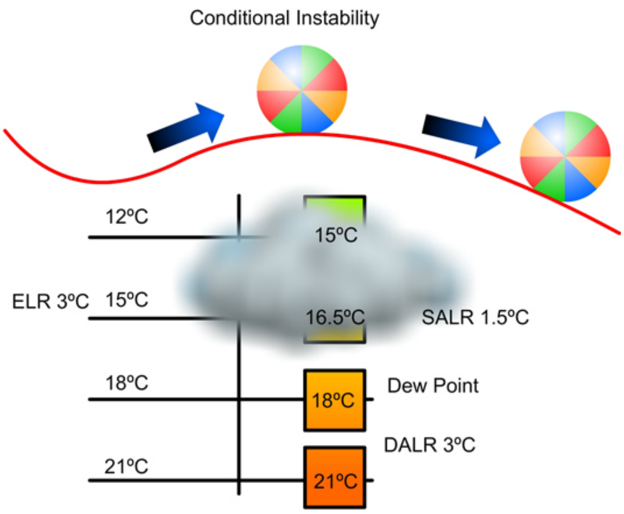




CONDITIONAL STABILITY

The atmosphere is conditionally stable (sometimes called conditionally unstable) if it is stable when dry, but unstable when saturated.



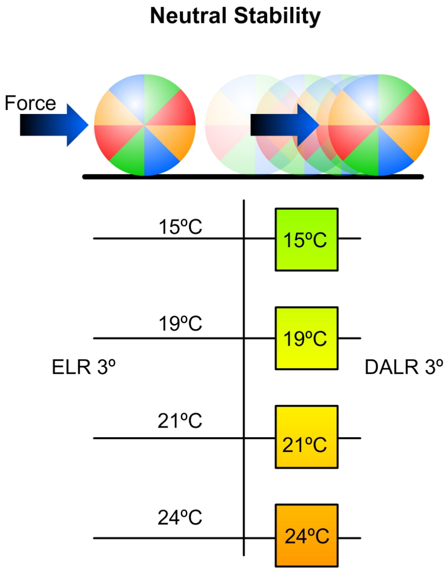


Most ELRs are neither less steep than the SALR nor steeper than the DALR. ELRs between these two absolute extremes are more common and are known as 'conditionally unstable'.

Consider an ELR of 2°C/1,000 ft. If the air is dry, any rising parcel would cool at 3°C/1,000 ft and would soon become colder at each level than the environment, and would sink back. If the parcel is saturated, however, it would cool at a rate of 1.5°C/1,000 ft and become warmer, level for level, than the ELR.

The ELR would therefore be stable if the air is dry (ie. not saturated), and unstable if the air is saturated. ELRs lying between the DALR and the SALR are therefore described as being conditionally unstable while the moisture content is unknown. If dry they are stable; if saturated they are unstable.

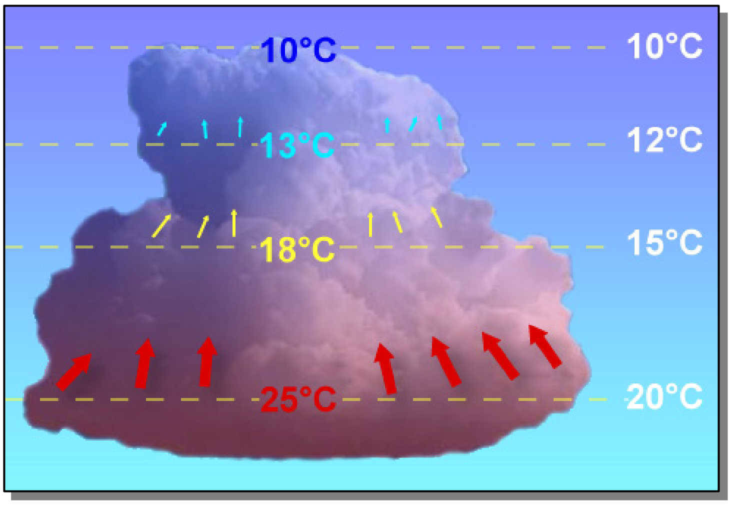
NEUTRAL STABILITY



- ELR is 3°C in dry air.
- ELR is 1.5°C in saturated air.

The parcel of air has the same temperature as the surrounding air and therefore will not continue to rise or fall. This condition is not very likely to be found to any large extent in practice.

CLOUD TOPS



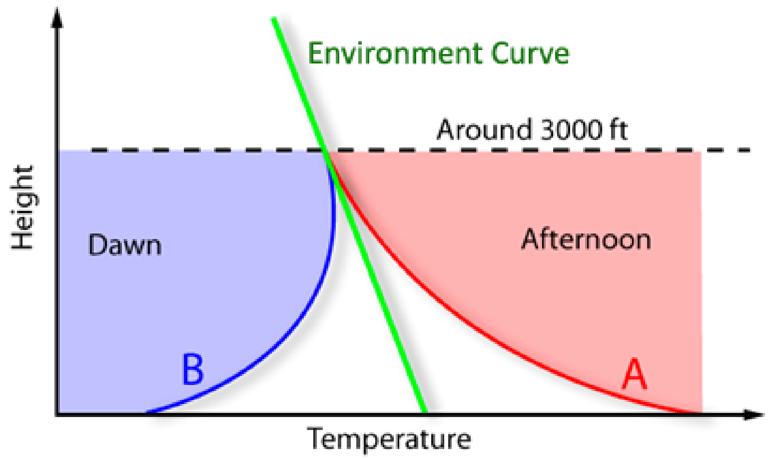
A parcel of air rises because it is warmer than the surrounding air. As long as the parcel is warmer than the surrounding air it will continue to rise. The air will stop rising when the parcel of air has reached the same temperature (or is cooler than), the surrounding air.

The height of the cloud tops is a function of stability, unstable air producing higher cloud tops and vice versa.

DIURNAL VARIATION IN STABILITY

Conditions are most stable in the early morning, but as the temperature increases, the ELR increases and the atmosphere becomes increasingly unstable.

At 2pm local time (A)	Maximum surface temperature
	Maximum ELR value near the surface
	Maximum instability in the lowest layers
and around dawn (B)	Minimum surface temperature
	Minimum ELR value near the surface
	Minimum instability (ie. Maximum stability) in the lowest layers.



REVISION

- ELR varies considerably (ISA 2°C/1,000 ft.).
- **ELR is most important when determining the stability of the atmosphere**.
- DALR = 3°c/1,000 ft.
- SALR = 1.5°C/1,000 ft.
- ELR < SALR = stable
- ELR > DALR = unstable
- SALR < ELR < DALR = conditional instability

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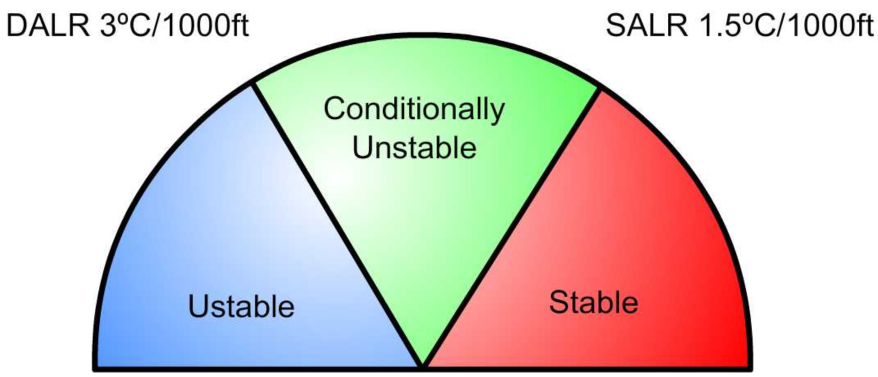


CONDITIONS THAT INDICATE A STABLE ATMOSPHERE

- Smooth flying (generally calm conditions)
- Stratiform cloud
- Inversions (fog)
- smog
- dew
- frost
- Low cloud and drizzle
- Possibly poor visibility
- Mist

CONDITIONS THAT INDICATE AN UNSTABLE ATMOSPHERE

- Cumulus clouds
- Precipitation
    - Showers
    - Hail
- Turbulence
- Thunderstorms
- Tropical rainfall
- Dust storms
- Good visibility when clear of clouds, showers and dust storms.

RADIOSONDE

All the factors involved with stability require the ELR and humidity to be known. Meteorological observers determine these factors by sending up a radiosonde balloon. A transmitter sends temperature, pressure and humidity data. Wind direction and speed are calculated either from positional data plotted by a radar station tracking the radar reflector attached to the base of the balloon, or by positional data from an on-board GPS receiver in the radiosonde. The meteorologist can then base their forecast on actual conditions.

AEROLOGICAL DIAGRAMS

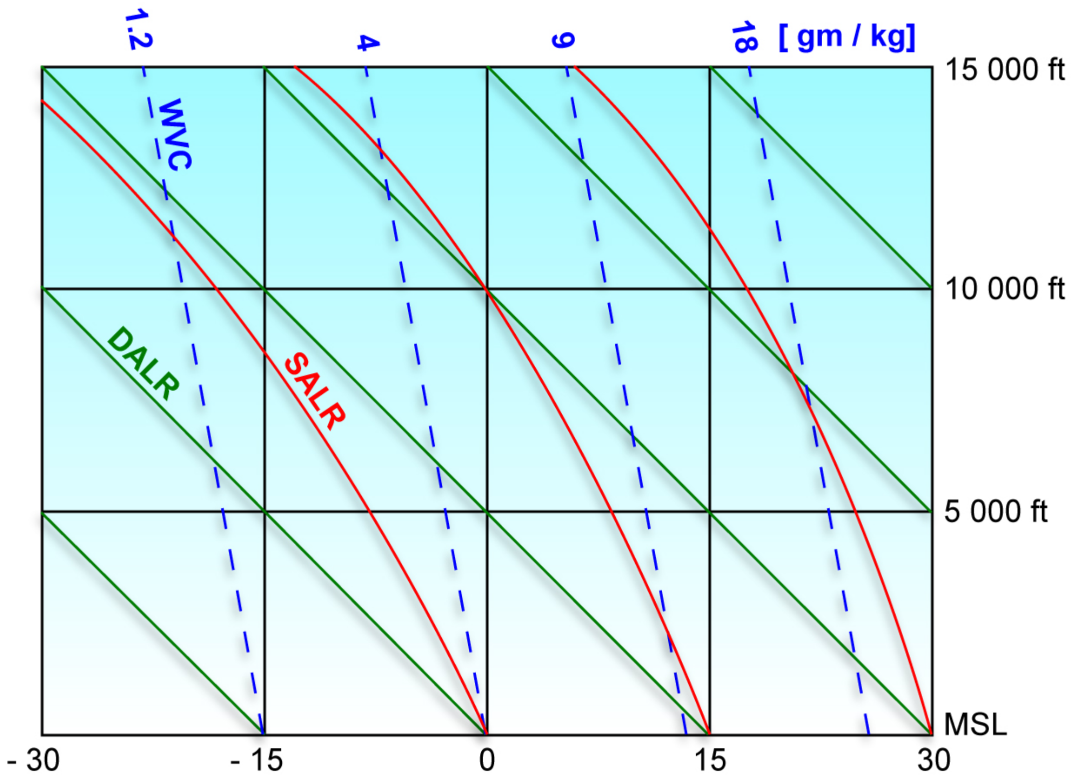
An aerological diagram is a graph on which observations of pressure, temperature and humidity aloft are plotted.

The reference lines which facilitate the plotting of a sounding and its assessment after plotting are isobars, isotherms, dry adiabats, saturated adiabats and lines of constant saturation ie. mixing ratio.

Most aerological diagrams show dry and saturated adiabats as well as lines for pressure and temperature. This enables the calculation of the stability of the air by comparing the actual values of temperature and pressure with the nearest adiabat. Many variations of the aerological diagram exist with the axis for differing data set at differing at angles but all are used to provide an identical outcome.

The “tephigram“or the”skew T log P” are the most common type of aerological diagrams used by many of the world’s meteorological offices and a simplified version has been used here. The major axis represent height and temperature. A dry parcel of air will rise and follow the dry adiabat. A saturated parcel of air will rise and follow the saturated adiabat. Another line represents the water vapour content.

It also shows how the dew point varies with height when a parcel of air is lifted. (Sometimes this may be shown as a “mixing ratio” instead of water vapour content). From the radiosonde transmitter the ELR is obtained and plotted on the graph.

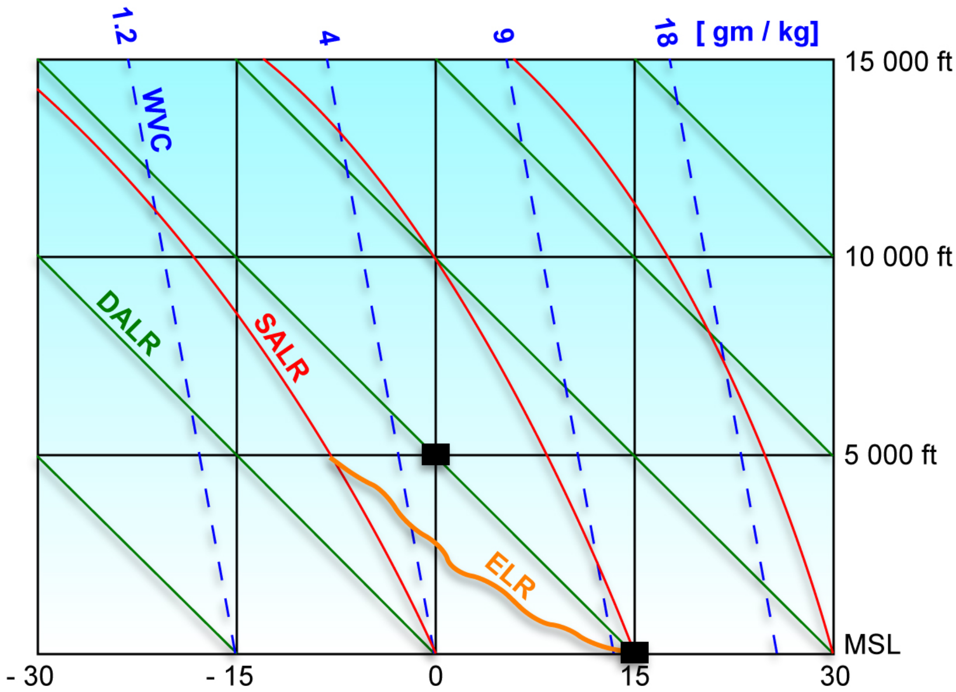


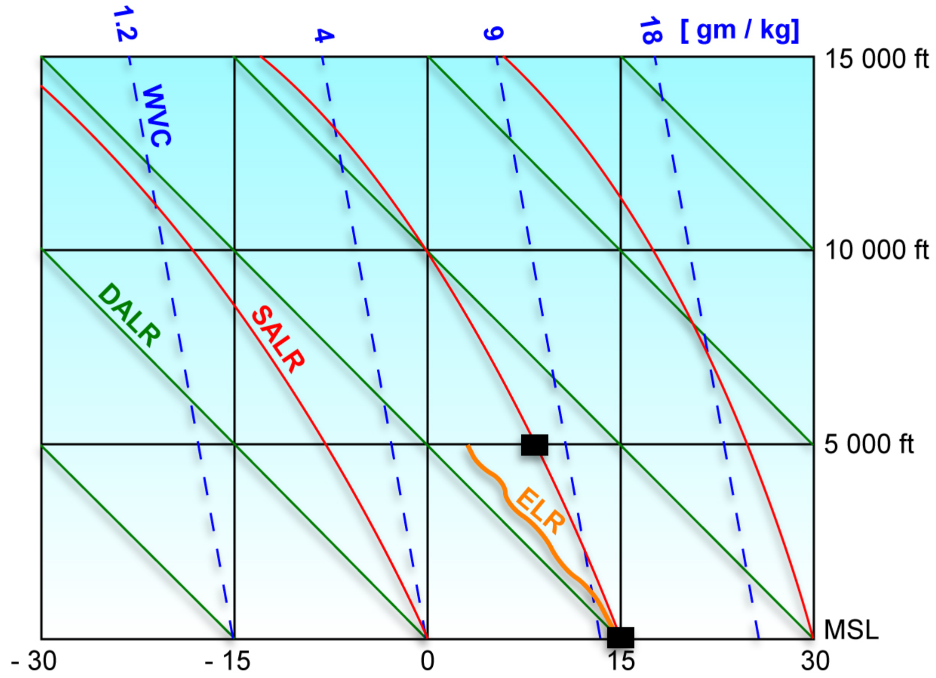
STABLE AIR

Stable air (as previously mentioned) occurs when a parcel of air that is displaced vertically will tend to return to its original position. On the tephigram, the parcel of air will rise and cool and the dry adiabatic lapse rate if dry, and at the saturated adiabatic lapse rate if wet. If when comparing the temperature of the parcel of air to the ELR, the parcel is always cooler than the surrounding air, stability exists.

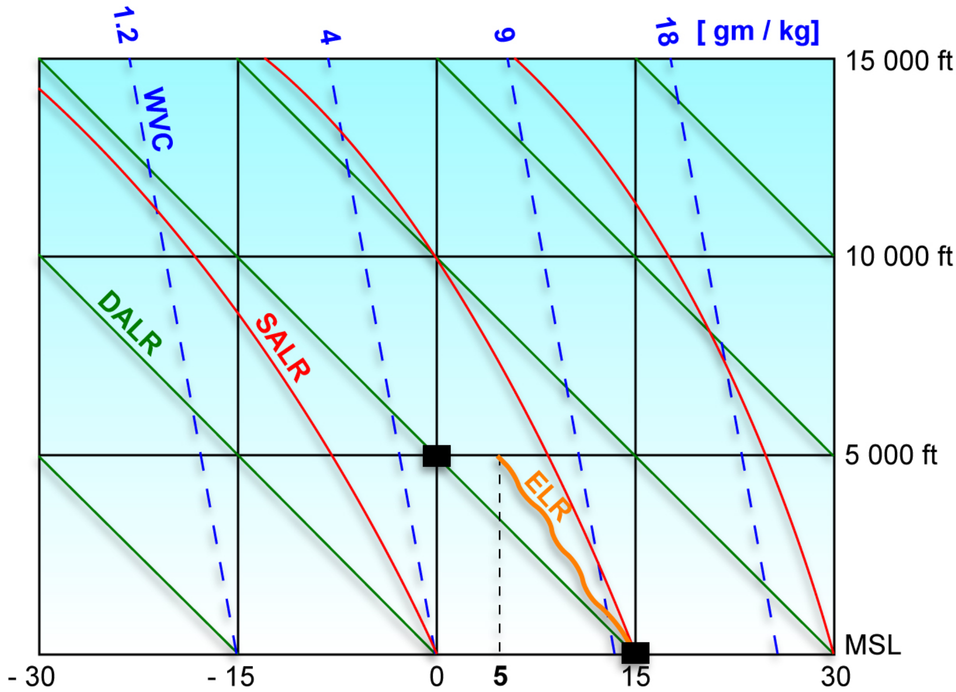
UNSTABLE AIR

Similarly, if when comparing the temperature of the parcel of air to the ELR, the parcel is always warmer than the surrounding air, instability exists. As long as the parcel of air is warmer the surroundings, it will continue to rise. For example, the base and tops of thermals used by glider pilots can be calculated this way.

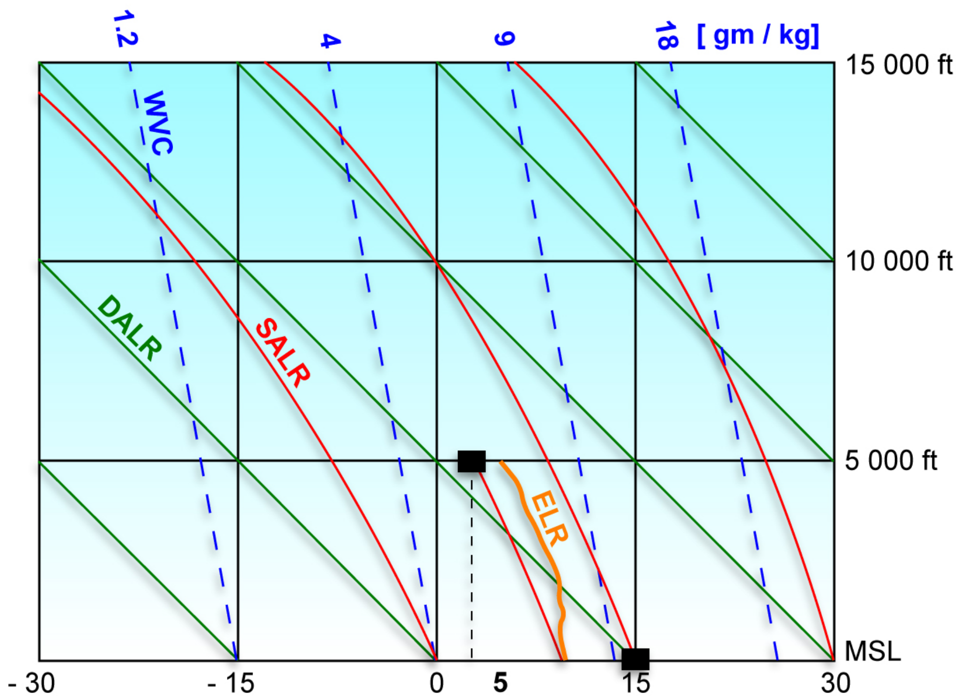

1.2
4
9
18
[gm / kg]
15 000 ft
10 000 ft
5 000 ft
MSL
WVC
DALR
SALR
ELR
- 30
- 15
0
15
30


1.2
4
9
18
[gm / kg]
15 000 ft
10 000 ft
5 000 ft
MSL
WVC
DALR
SALR
ELR
- 30
- 15
0
15
30

DRY STABLE AIR



SATURATED STABLE AIR

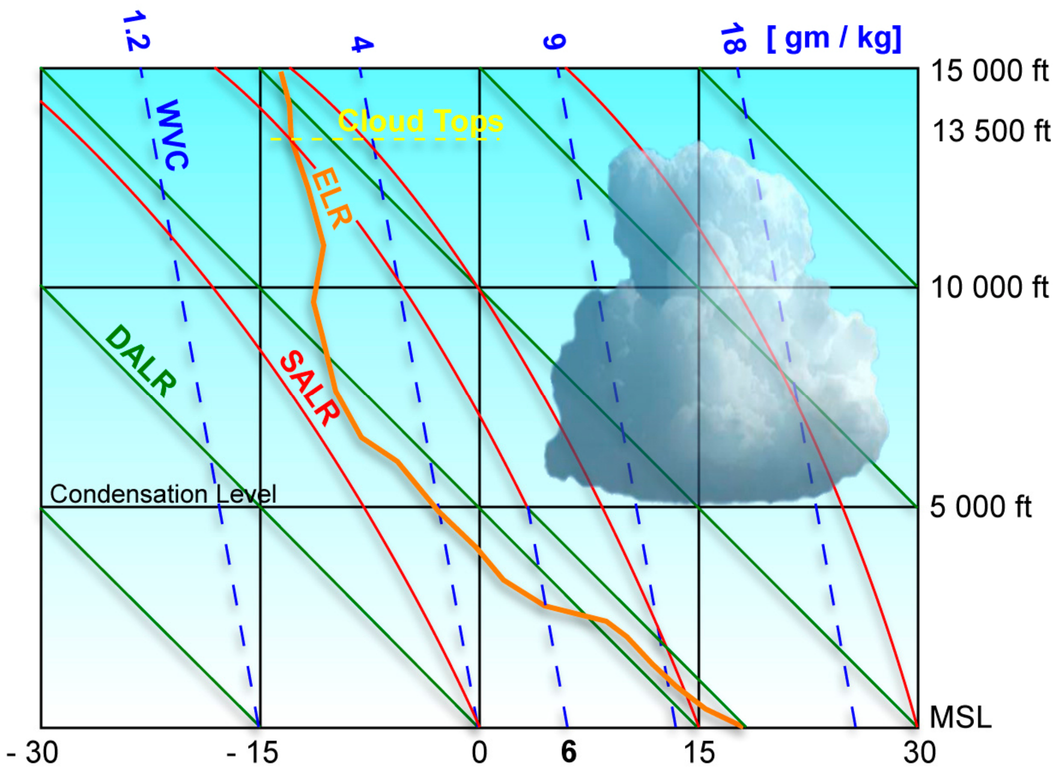


CONDITIONAL INSTABILITY

On the tephigram conditional instability is indicated by the rising parcel of air being colder than the surrounding air when rising at the DALR but being warmer than the surrounding air when rising at the SALR after condensation has occurred.

CLOUD BASE AND TOPS

On the tephigram, the dry adiabat through the dry-bulb temperature, the saturated adiabat through the wet-bulb temperature, and the water vapour content line through the dew point, all meet at the condensation point. (cloud base). The parcel of air now rises at the SALR. If the SALR line remains to the right of the ELR, the parcel of air being warmer than the surrounding air, will continue to rise until the 2 lines intersect. The temperatures are identical; the parcel of air stops rising and cloud tops can be calculated.



FREEZING LEVEL

The freezing level in the free air outside a cloud is the point at which the ELR line crosses the 0°C line. Inside a cloud the freezing level occurs at a point at which the SALR line crosses the 0°C line.

ELR temperature plots also can be used to indicate inversions, (both surface and upper air), tropopause heights, frontal zones, turbulent layers, adiabatic heating for descending air and more. Although it is unlikely for the pilot to use an aerological diagram, it is important to have an understanding on how the raw data can be used in the production of a final forecast.