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METEOROLOGY FOR AUSTRALIA

CHAPTER 12 – CLOUDS

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CONTENTS .... PAGE

CLOUD CLASSIFICATION

OVERVIEW

"Cloud is a visible aggregate of water droplets or ice crystals, white in appearance due to the reflection of white light. Fog is simply a cloud at ground level"

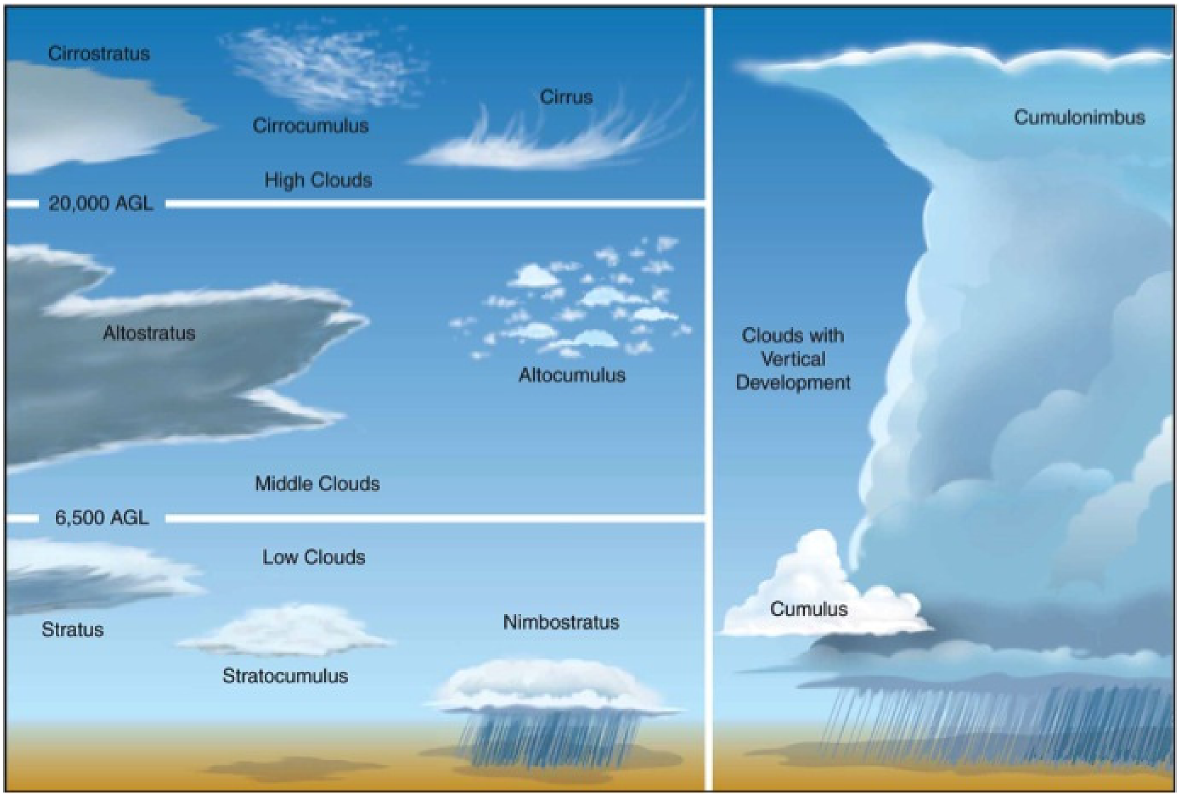
CLASSIFICATION OF CLOUD TYPES

Clouds are classified initially by their height above the ground and then their appearance. There are 3 main classes (the heights given below are for temperate regions only, diagram 12.a gives details of other regions).

i. **High Cloud:** bases higher than 16,500 ft. above the ground and known as CIRRO clouds.

ii. **Medium Cloud:** bases between 6,500 ft. and 23,000 ft. above the ground and known as ALTO clouds.

iii. **Low Cloud bases:** below 6,500 ft. above the ground. This group also includes Vertical Development Cloud which are clouds of great vertical extent.



TYPE	ABBRE-VIATION	LEVEL	ALTITUDE OF BASE			APPEARANCE	APPROX. DEPTH	FLYING CONDITIONS		PRECIPITATION	ICING
			TROPICS	MID LAT.	POLAR			TURB.	VISIB'Y IN (M)		
Stratus	St	Low		ALL BELOW	6,500	Grey layer, uniform base, sun discernible some-times, (no halo).	1000'	Usually nil, occas. light.	40 to 200 M	Occasional drizzle.	Usually nil.
Cumulus	Cu	Low		ALL BELOW	6,500	Detached, rising mounds, dense, sharp outlines, domes, towers, dark base, brilliant when sun-lit.	Up to 15,000'. Large up to 30,000'.	Light in small, severe in large.	0 - 200	Occasional showers.	Small cloud - nil. Large cloud - rime and clear.
Strato-Cumulus	Sc	Low		ALL BELOW	6,500	Grey, whitish, patch, layer, rounded masses, rolls, may be merged.	1000' to 2500'	Light to moderate.	30 - 200	Light rain or drizzle.	Occasional light rime.
Cumulo-Numbus	Cb	Low		ALL BELOW	6,500	Heavy & dense, huge towering shape, very dark base, often flattened top, anvil.	Up to 60000'	Severe to extreme.	Usually nil.	Showers of rain, snow hail, heavy showers.	Definite risk of rime & clear.
Alto-Stratus	As	Medium (Middle)	6,500 to 25,000	6,500 to 23,000	6,500 to 13,000	Greyish/bluish sheet, or layer, fibrous or uniform, sun vaguely shows.	1000' to 4000'	Nil except in a front.	300 to 1000	Intermittent rain and virga.	Some risk of light to moderate rime.
Alto-Cumulus	Ac	Medium (Middle)	6,500 to 25,000	6,500 to 23,000	6,500 to 13,000	White/grey patches or sheets, rounded masses, rolls, diffuse.	Up to 1000'	Light to moderate.	Approx. 500	Usually nil, occasional light rain, snow, virga.	Some risk of light to moderate rime.
Nimbo-Stratus Can be low cloud.	Ns	Medium (Middle)	6,500 to 25,000	6,500 to 23,000	6,500 to 13,000	Grey/dark, immense-covers sky, diffuse, blots out sun. Can merge with lower stratus cloud.	5000' to 30,000'	Nil to light except in a front.	20 - 100	Moderate to heavy continuous rain, snow or virga.	Definite risk of clear & rime.
Cirrus	Ci	High	20,000 to 60,000	16,500 to 45,000	10,000 to 25,000	Detached white filaments with fibrous look.	100' to 1000'	Usually nil.	1000	Nil	Nil
Cirro-Stratus	Cs	High	20,000 to 60,000	16,500 to 45,000	10,000 to 25,000	Transparent, whitish cloud veil , smooth, produces halo.	Up to 1000'	Usually nil.	1000	Nil	Nil
Cirro-Cumulus	Cc	High	20,000 to 60,000	16,500 to 45,000	10,000 to 25,000	Thin white patches , - small clumps, - merged or separate.	Up to 1000'	Light.	1000	Nil	Nil

SUBDIVISIONS OF CLOUDS

Clouds may be further subdivided into individual types according to their appearance:

i. Cirrus (Ci): detached clouds of delicate and fibrous appearance, without shading, generally white in colour and often of a silky appearance. (Sometimes referred to as "mare's tails"). They appear in varied forms, such as isolated tufts, lines drawn across the sky, feather like plumes, or curved lines ending in tufts.

ii. Cirrocumulus (Cc): a cirriform layer or patch of cloud composed of small white flakes or globular masses without shadows. They are arranged in groups or lines, or more often in ripples resembling "fish scales"

iii. Cirrostratus (Cs): a thin whitish veil which does not blur the sun or moon, but gives rise to haloes. Sometimes a more or less fibrous structure distinctly shows, with disordered filaments, giving the sky a milky appearance.

Composition of the above clouds is in the form of ice crystals

iv. Altocumulus (Ac): layer or patch cloud, composed of laminae or regularly flattened globular masses, being fairly small and thin without shading. Sometimes they appear in parallel wave bands.

v. Altostratus (As): a fairly thick or grey veil similar in appearance to thick cirrostratus, obscuring the sun or moon, with lighter patches between the very thick parts. When not so thick, the sun or moon shows very vaguely.

Composition of the above clouds is water and/or ice crystals.

vi. Stratocumulus (Sc): a layer of patches or globular masses composed of laminae, being soft and grey with darker parts. These elements are arranged in lines or in waves which are often so close that their edges touch giving a wavy appearance.

vii. Stratus (St): a uniform layer of cloud resembling fog, but not on the ground. When appearing as a low, broken (or fractured) layer, it is referred to as Fractostratus (Fs).

viii. Nimbostratus (Ns): a low dark grey or black cloud, soft in appearance. They are sometimes given names like "rain cloud" when associated with rain. When no precipitation occurs, the base looks diffuse and "wet" because of the trailing precipitation called "virga", and the lower limits of the base are difficult to distinguish.

Composition of the above cloud types is water, with the exception of Ns which could contain both water and ice crystals.

ix. Cumulus (Cu): thick white clouds of vertical development taking on the appearance of a "cauliflower". Against the sun, these clouds exhibit dark shadows with bright edges.

x. Cumulonimbus (Cb): heavy masses of cloud with extreme vertical development. The cumuliform summits rise in the form of towers, upper parts having a fibrous appearance and often spreading out in an "anvil" shape. The base of a Cb often has a layer of fractostratus cloud beneath it.

Composition of the above cloud types is water or, in the case of Cb, water plus ice in the form of crystals and hail.

Special types of cloud

i. Fractos Cloud: the prefix "fracto" may be added to the name of a cloud to indicate that it occurs in broken patches.

ii. Castellanus: when cloud takes on the appearance of a turreted structure similar to that of towering cumulus clouds, but on a smaller scale and with bases in the alto level, it is known as altocumulus castellanus.

iii. Lenticular: clouds that take on the appearance of "almonds" or "lenses", with smooth clear-cut edges. When they take on such an appearance, the word "lenticularis" may be added to the name of the cloud.

CLOUD FORMATION

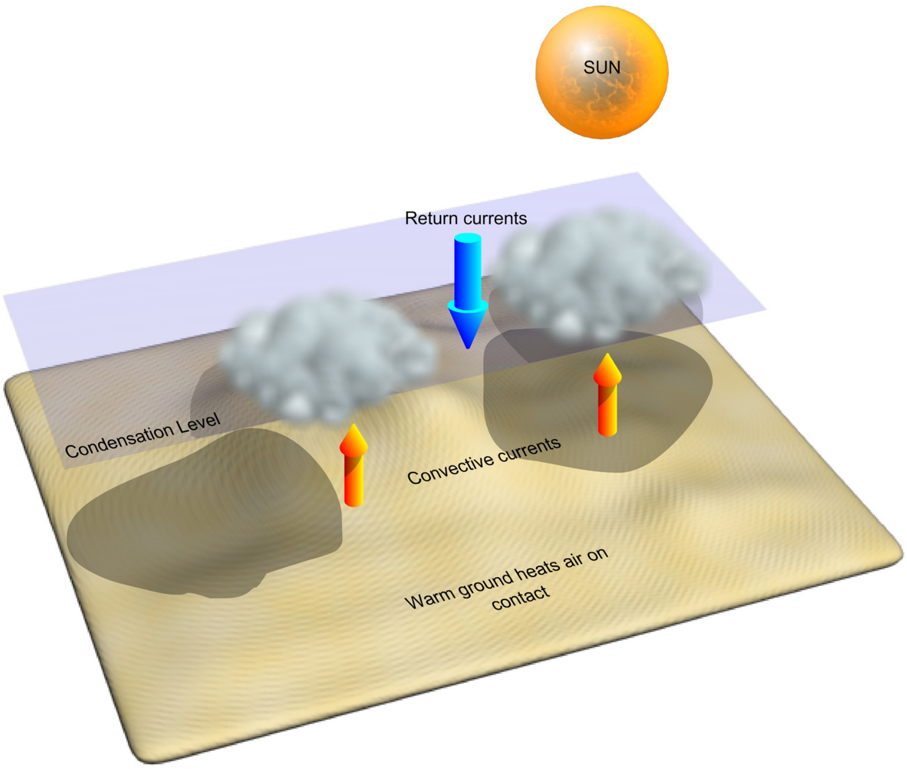
Introduction

Cloud is formed when moist air is forced to rise and cools adiabatically to a temperature below the dew point. Condensation occurs around hygroscopic nuclei with the formation of vast numbers of tiny water droplets which are held aloft in suspension in the air. The height in the atmosphere at which condensation begins is called the Condensation Level.

THE PRINCIPAL LIFTING PROCESSES

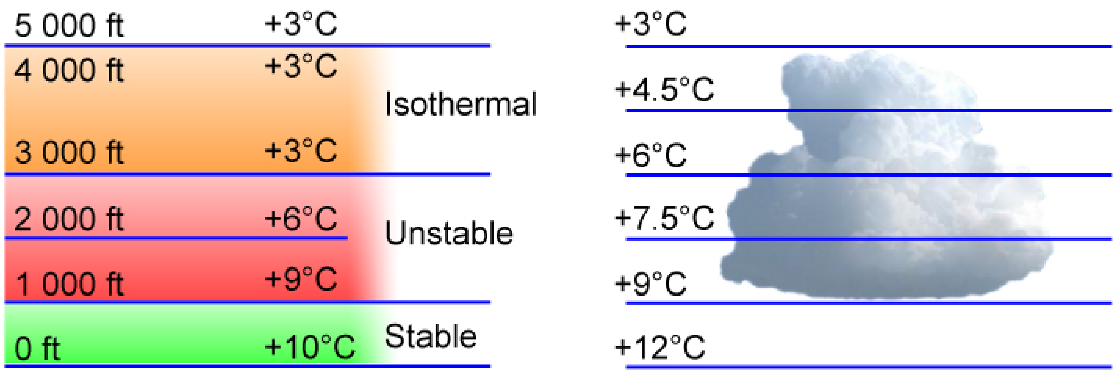
a) Convective Clouds

After strong surface heating, air in contact with the warm surface heats and air is warmer than the environment it will continue to rise. Convection produces cumulus type clouds.



i) Cumulus Cloud

During the day, the land surfaces heat up by solar radiation, some absorbing more heat than others, such being tarmac, runways, roads, sand, ploughed fields, rocky outcrops and mine dumps. Air in contact with such surfaces is heated up, expands, becomes less dense and rises. These convective currents of warm rising air are known as **thermals.** Should this rising air be moist enough, and dew point reached, clouds of the cumulus type will form. These smallish, vertically limited, cumulus clouds are known as fair weather cumulus, the bases of which are at the condensation level, with tops rarely exceeding 5,000 ft agl.



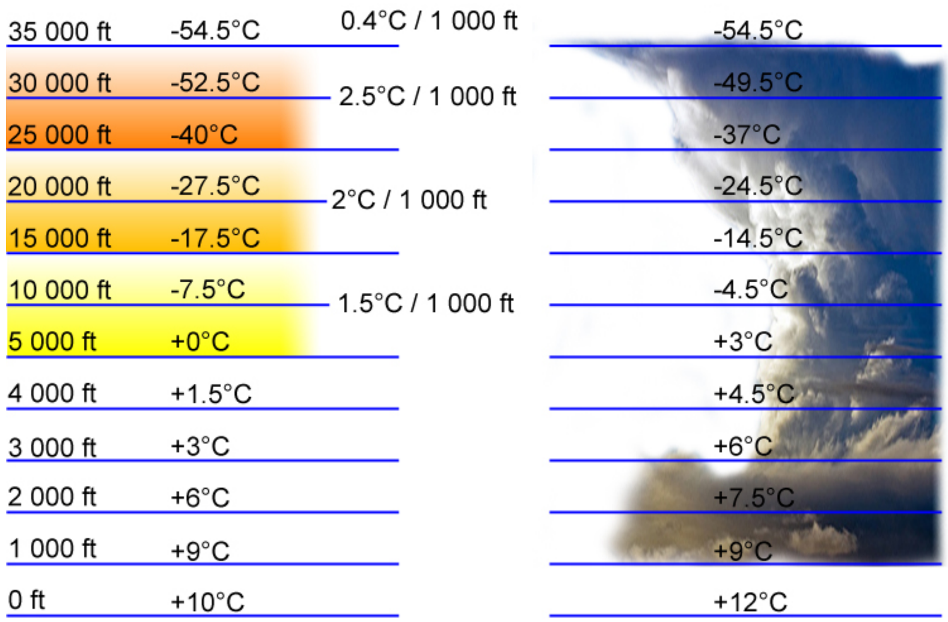
Formation of Cumulus

In the previous diagram, the lowest layer at 1,000 ft has an ELR of 1°C/1,000 ft. and is therefore stable. From the 1,000 ft. layer to the 3,000 ft. layer, the ELR is 3°C/1,000 ft; it is steep and produces and unstable layer. From 3,000 ft. to 5,000 ft. the temperature remains constant (an isothermal layer) and is therefore stable.

Now, as the surface temperature increases to say +12°C, a thermal is set up and the air cools at the DALR until at 1,000 ft both ELR and the cooling air are at the same temperature. Assuming 1,000 ft to be Condensation Level, lifted air cools at the SALR of 1.5°C/1,000 ft until a height of 5,000 ft, where once again both temperatures are the same. The vertical extent of the cloud is now regulated by the unstable layer sandwiched between two stable layers. Obviously, sufficient moisture must be present and available to maintain the cloud once it starts to form.

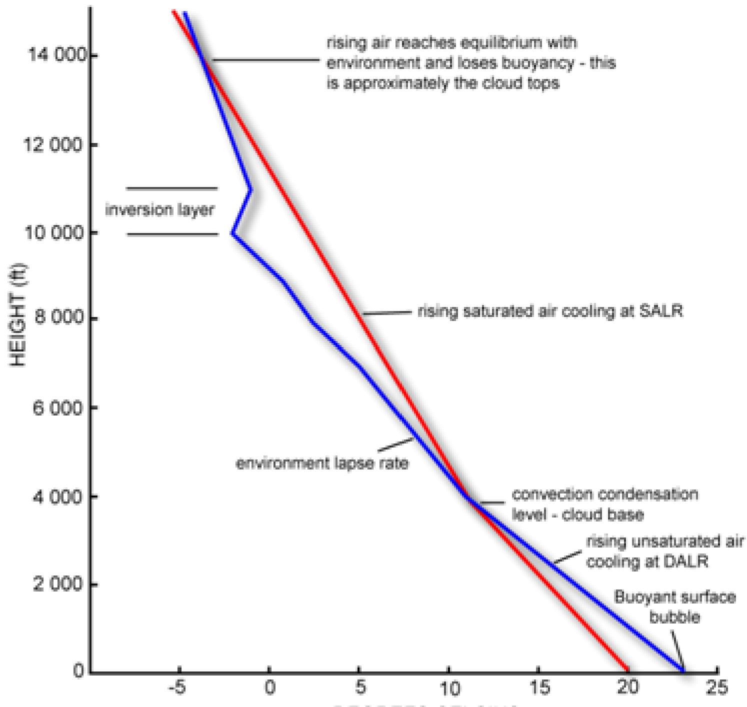
ii) Cumulonimbus Cloud

The formation of cumulonimbus starts in the same way as the formation of cumulus, with the same conditions up to 3,000 ft agl. Above the 3,000 ft layer, the rising air is cooled at the SALR of 1.5°C/1,000 ft and is continually warmer than the surrounding air and therefore unstable. In this case, the condensation level was well within the bounds of the convective impetus and a condition of instability persisted to the tropopause, where within the last 5,000 ft the ELR showed a very small lapse rate (almost isothermal).



Formation of Cumulonimbus

In the diagram above, the cloud top is at a temperature of -54.5°C and most cloud particles will be in the form of ice crystals. Going down through the cloud, the proportion of supercooled water increases until at about 7,000 ft, cloud particles will be in the form of water droplets.

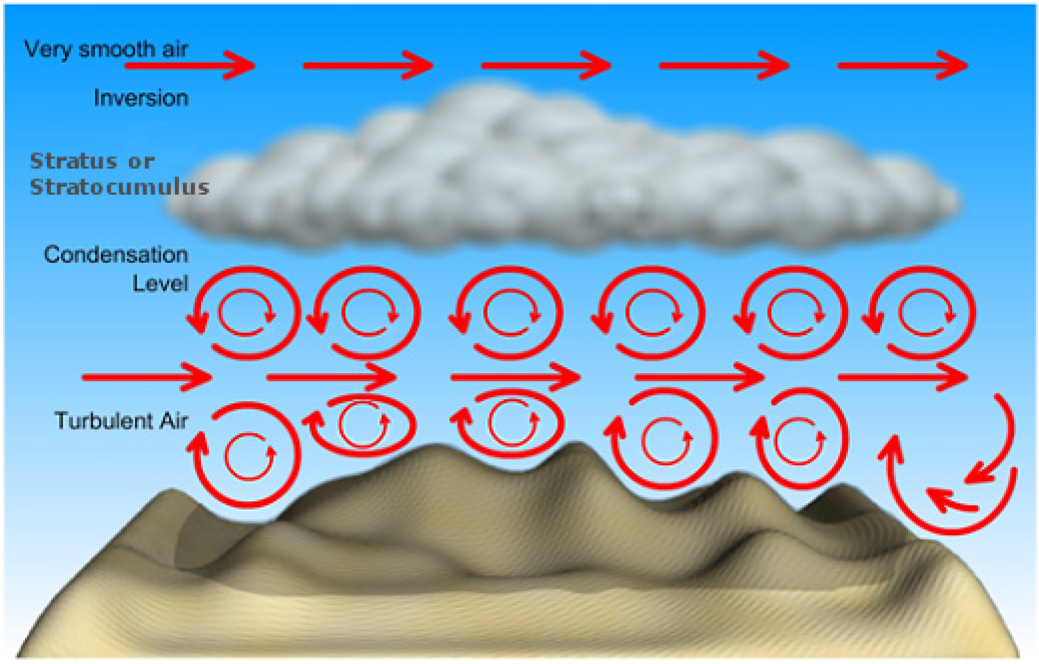


Convective cloud of the cumulus or cumulonimbus type may form when cool, moist, unstable air, moves over a warm land or sea surface giving, rise to convective thermals.

b) Turbulence Cloud

Air that is lifted by turbulence may become saturated and created stratiform cloud. Depending upon wind strength, stability and the degree of turbulence, the cloud will either be stratus or stratocumulus.

When a strong wind blows near the ground, a large amount of turbulence generated, affecting levels up to 3,000/4,000 ft. This air, given a suitable amount of moisture content; cools adiabatically with resultant cloud formation, even through the relatively small increase in height. The height of an obstacle about 600 ft high is sufficient to create the required turbulence to heights of 4,000 ft.

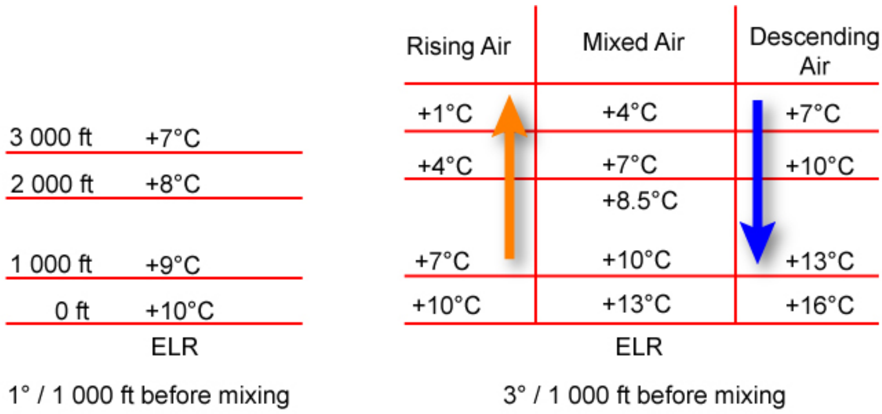


The formation of such cloud requires four factors to be fulfilled:

- Humidity must be high enough for the condensation level to be within the turbulent layer.
- Turbulence must be active enough for this level to be reached.
- A stable lapse rate must exist so that the cloud is restricted to the height of the turbulent layer.
- Turbulence must be effective enough (8 knots of wind or more) for the air to be lifted and cooled adiabatically while mixing, thus changing the lapse rate.

A high relative humidity and a wind of less than 10kts results in Stratus.

A lower relative humidity and a wind greater than 15kts results in Stratocumulus.



Turbulence Mixing

Consider a typical layer of stable air 3,000 ft in depth, the ELR of the layer being 1°C/1,000 ft. The air is forced to rise due to turbulence, cools at the DALR from +10°C at the surface to +1°C at 3,000 ft, while the air that sinks, warms adiabatically at the DALR (if dry) from +7°C at 3,000 ft to +16°C at the surface. Thus, the effect of turbulent mixing is always to **lower** the temperature at the **top** of the layer, and **raise** the temperature at the **surface**. In a thoroughly mixed layer the lapse rate increases.

At the surface, thoroughly mixed air attains a **mean** temperature of:

$$(+10°C) + (+16°C) = \frac{+26}{2} = +13°C$$

While at 3,000 ft it attains a mean temperature of:

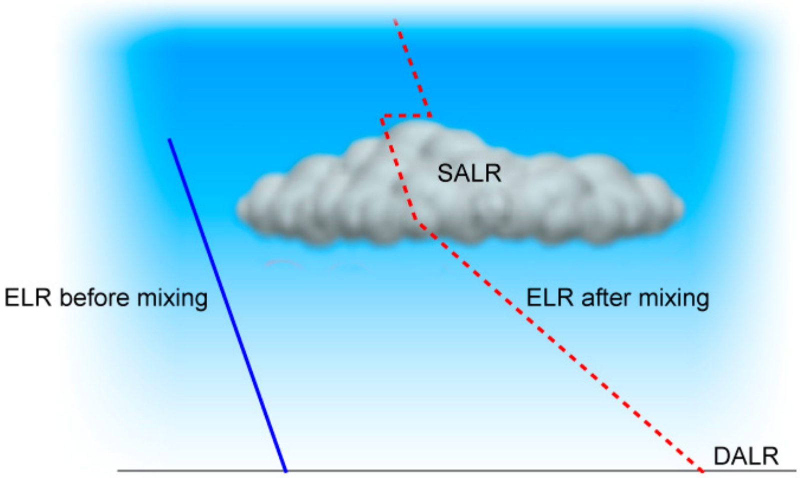
$$(+1°C) + (+7°C) = \frac{+8}{2} = +4°C$$

giving a new steeper lapse rate of:

$$+13°C - 4°C = 9°C/3,000\ ft$$

$$= 3°C/1,000\ ft$$

This same process occurs if saturation is reached, only this time, producing a lapse rate of 1.5°C/1,000 ft. Thus the effect of turbulent mixing always tends towards the DALR below the cloud and the SALR within the cloud. If condensation is reached then the cloud will be restricted to the top of the turbulent layer due to the stable lapse rate above the turbulent layer. The cloud will be of stratiform type, e.g. stratocumulus.



Turbulence Cloud ELR

Referring to the figure above, it is important to note that after mixing, the increased lapse rate will tend to **increase** the stability of the layer of air above the turbulent layer. This is a pre-requisite for layer type cloud formation. Also note that the temperature above the turbulent layer will have reduced at the original ELR and so will be warmer than the temperature at the top of the layer, thus there is an inversion.

This stratiform cloud rarely exceeds 3,000/4,000 ft in depth. If thermal currents are present they will tend to lift the base of the cloud.

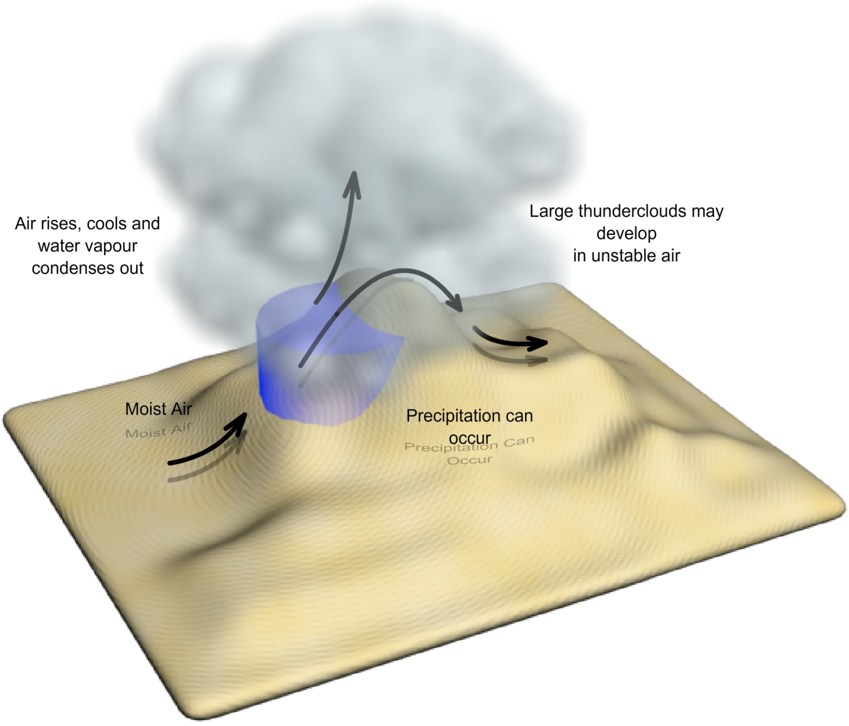
Often after a very clear night (when terrestrial radiation is maximum) an increase in turbulence just after dawn may give rise to a very sudden formation of low cloud, which may clear during the day. Very rapid changes of turbulence and relative humidity usually occur towards evening and again in the early morning therefore the formation of turbulence cloud is more probable.

Another type of turbulence cloud which forms on occasion is the ragged fracto-stratus cloud below rain-bearing cloud, such as nimbostratus, altostratus or cumulonimbus. Falling rain below these clouds increases the relative humidity and turbulence easily causes low cloud formation.

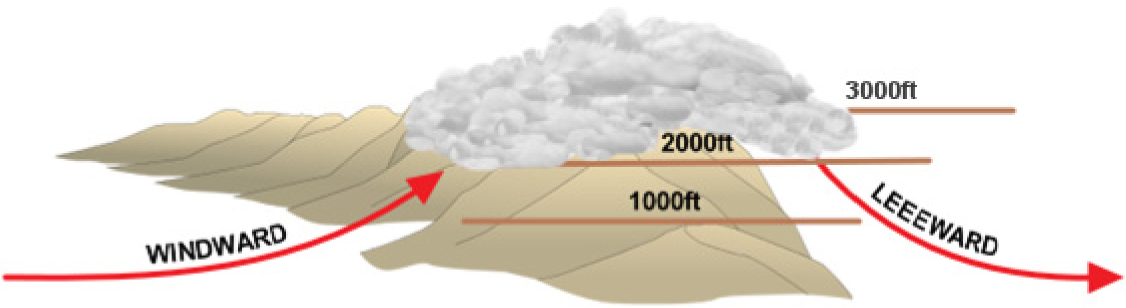
Where wind changes rapidly with height (windshear) through a humid layer, higher layer cloud may be formed, such as altocumulus or stratocumulus.

c) Orographic Clouds

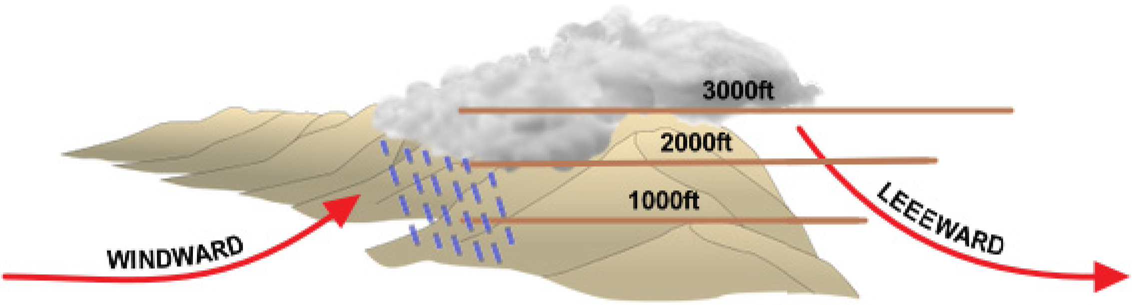
If air is forced to rise by a barrier, e.g. a mountain range, the air cools adiabatically and if saturation is reached, cloud forms. Moist stable air forms stratus cloud; unstable air produces cumulus and cumulonimbus. The cloud base height is called the lifting condensation level because the air is forced to rise.



When there is no precipitation, the base of the cloud on the windward side of the mountain is at the same height as the base of the cloud on the leeward side but if precipitation occurs, the cloudbase on the leeward side will be higher.

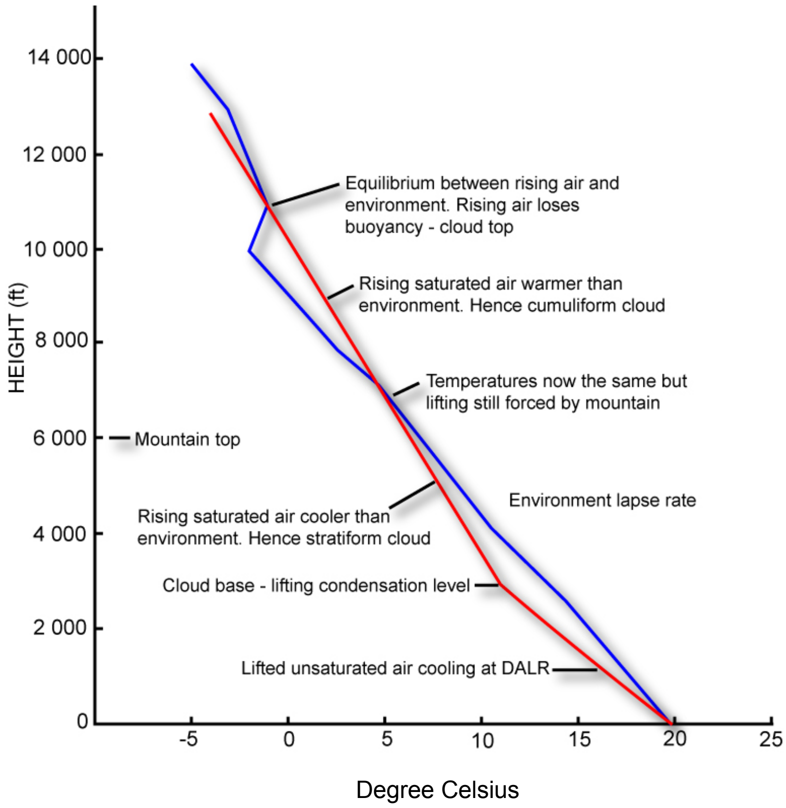


No Precipitation



Precipitation on the windward side

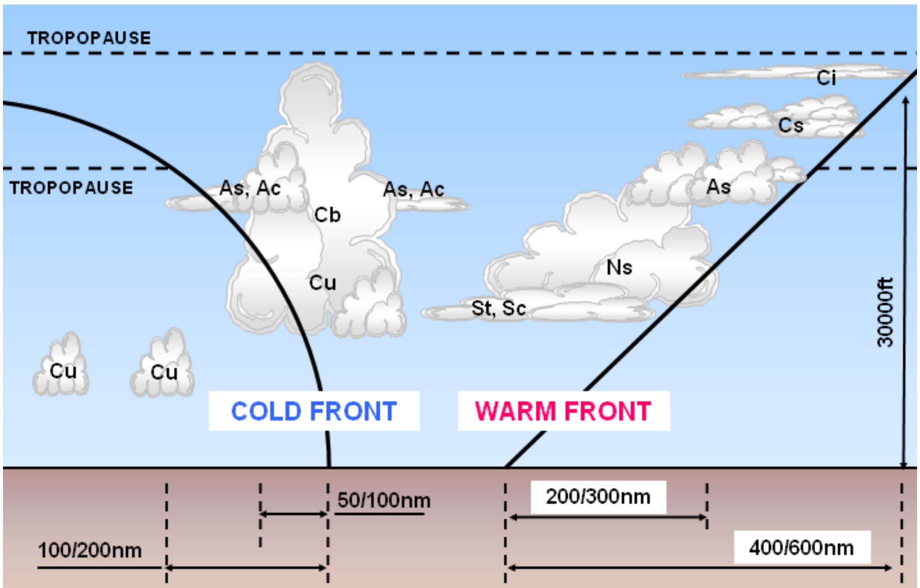
If the air is unstable, when forced to rise, it may produce cumulus or even cumulonimbus cloud.



Cloud due to Forced Ascent over a Mountain

d) Frontal Clouds

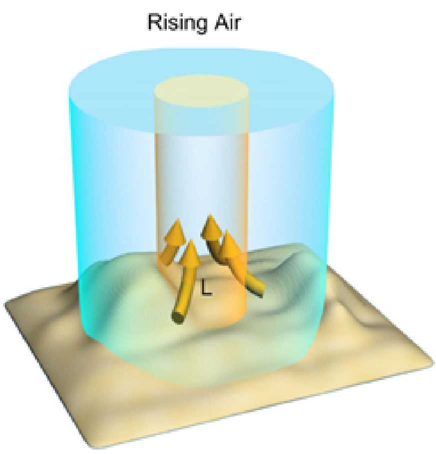
Frontal weather will be discussed in detail in Chapter 16, but this paragraph explains in sufficient depth, those aspects of frontal activity which lead to the formation of clouds.

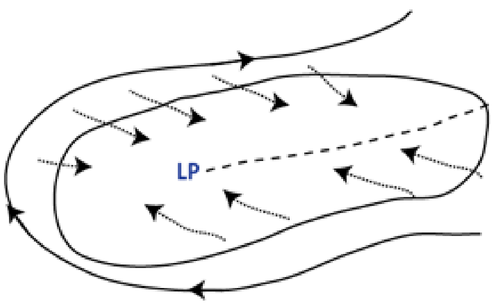


A front is the boundary between two air masses of differing temperatures. At this boundary air will be forced to rise. If warm air is "lifted" up by cold air pushing underneath it, then it is a cold front. If the warmer air "climbs" up over cooler air, then it is called a warm front. Regardless of this, at either sort of front, air will be caused to rise, and should that air contain sufficient moisture, then cloud will form. The nature of this cloud will depend, as always, on the stability of the air, but in this case, also on the degree of force which causes the air to lift. Typically, warm front cloud will be stratiform, layered all the way to the tropopause. Because of the degree of force starting to lift the air, cold front clouds are far more likely to be cumuliform, quite possibly even containing a cumulonimbus. See diagram above

e) Ascent in a Low or Trough

In the Southern Hemisphere air above 2,000 ft. flows clockwise around a LP or trough parallel to the isobars. However, surface winds veer and therefore converge and ascend. If there is sufficient moisture there will be widespread cloud.





CLOUD DISPERSAL

INTRODUCTION

Mixing with dry air, falling precipitation, turbulence and solar heating all cause cloud dispersal. However **the main process for dispersal is warming of the air**. When air descends (in a high pressure), the air warms adiabatically. As the temperature rises above dew point, cloud particles evaporate.

EFFECT OF SUBSIDENCE OF AIR

Fast Descent

Air descending rapidly, for example down the lee slope of a mountain, it will warm adiabatically. If saturated at the start of its descent, it will dry out quickly. The slightest warming will reduce the relative humidity to less than 100%, and **subsiding air can therefore be considered to warm at the DALR immediately.** During the descent the dew point temperature will gradually increase at about 1/2°C/1,000 ft owing to the increase in pressure. The relative humidity therefore falls quickly and air at the bottom of a long, fast descent is always warm, and very dry.

Slow Descent

In more gentle descents, which take days or weeks rather than minutes, loss of heat by radiation reduces the rate of warming to less than the DALR. A slow descent is typical of an anticyclone. Since subsidence has ensured that the air is dry, the reduced lapse rate causes considerable stability and so cloud of great vertical extent will not be found. Near the surface, if the air is cooled and moistened, low cloud can form below the subsidence inversion.