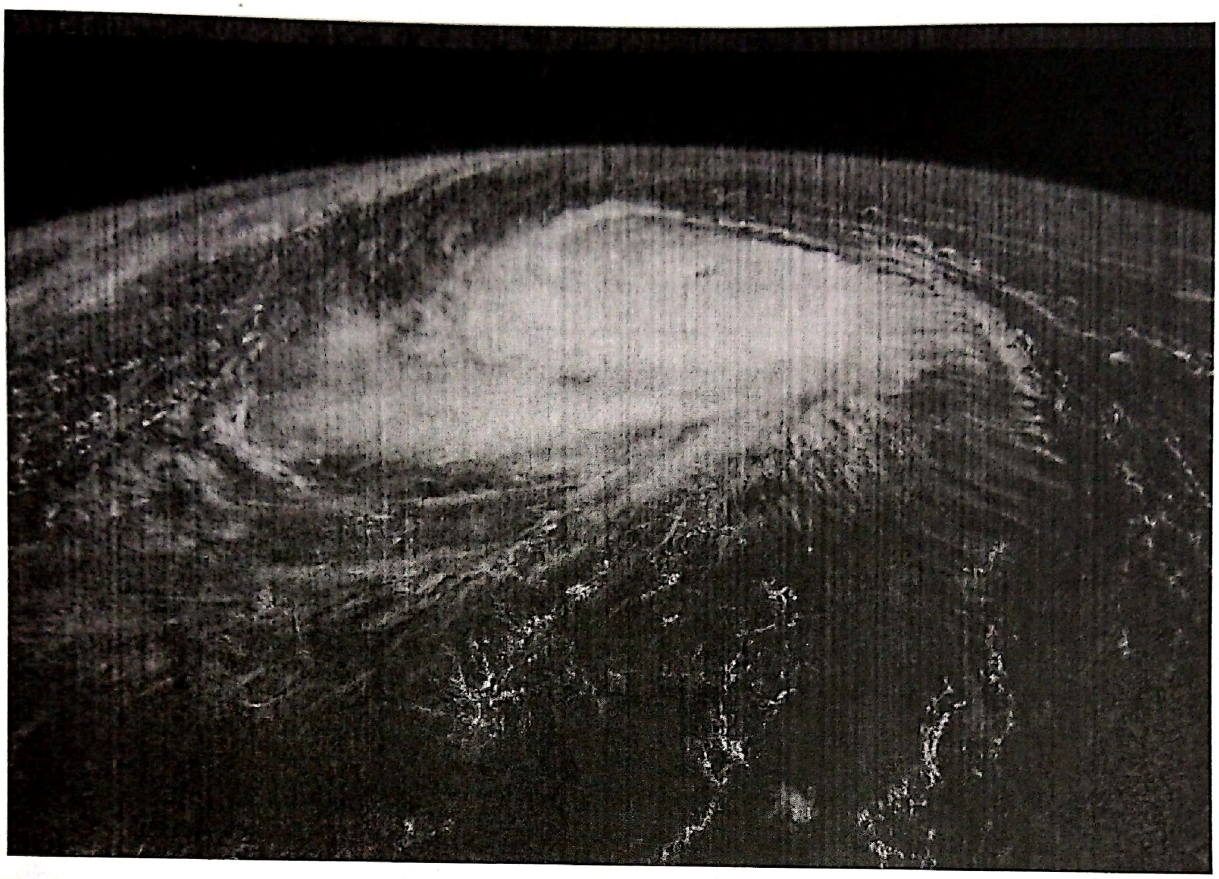
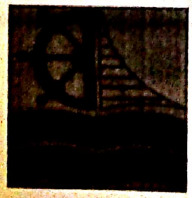
محسن صالحی



# Meteorology 1

# هواشناسی ۱



I.R.I.S.L maritime Training Institute, Bushehr Center

## THE ATMOSPHERE

The air around the earth is called the atmosphere. Different layers of the atmosphere are called by different names.

The chemical composition of dry air is remarkably constant everywhere over the earth's surface and up to a height of at least 19 kilometers. Chemical analysis shows that the amount of each gas is as follows:

| Gas | volume % |
|---|---|
| Nitrogen | 78 |
| Oxygen | 20.9 |
| Argon | 0.9 |
| Carbon Dioxide | 0.03 |

There are also very small amount of other gases.

**Vertical structure of the atmosphere**

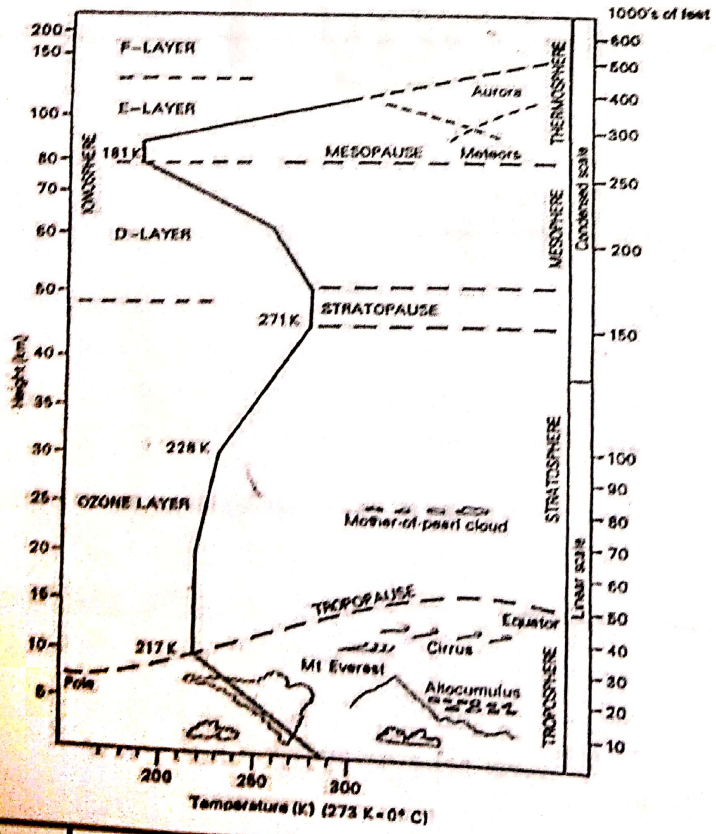
The figure illustrated the vertical structure of the atmosphere. The lowest region is called TROPOSPHERE. The properties of this layer are as follow:

-this layer contains the greater mass of air

-almost all water vapor and clouds contained

-the most important feature of this layer is that the temperature decreases with the height.

-the thickness can vary between 9 and 16 kilometers. The height is about 9 kilometers above the poles and is about 16 kilometers above the equator.



Higher in the stratosphere, a small quantity of ozone is found. Mainly in layer about 20 and 40 kilometers above the earth's surface. The ozone layer is important because ozone is strongly absorbs radiation of certain wave-lengths emitted by the sun. if this ozone layer was not present an excessive amount of ultra-violet radiation would reach the earth with harmful effects upon many forms of life.

Other layers of atmosphere after troposphere are stratosphere, mesosphere and thermosphere. The region between atmosphere layers is called as Pause.

The boundary between troposphere and stratosphere is called as tropopause.

The boundary between stratosphere and mesosphere is named stratopause.

The boundary between mesosphere and thermosphere is mesophause.

**Adiabatic change of temperature**

Change of air temperature due to increase or decrease of its volume (height) without exchange of heat with surrounding.

This is the name for change in temperature, pressure and volume which produced in a substance when no heat is allowed to reach or leave it while it is being compressed or expanded. When the air is compressed (volume decreased), its temperature rises, and when it is allowed to expand (volume increased), its temperature falls.

In one method of refrigeration, a compressed gas is allowed to escape from the cylinder and in rapid expansion, it cools enough to cause freezing.

**Wet and dry air**

Any parcel or sample of air that is fully saturated is called wet air or saturated air.

Any sample of air that is not fully saturated is called dry air.

**DALR** (Dry adiabatic Lapse Rate)

The temperature of a dry parcel of air, which is made to rise, falls at a steady rate of 10 °C for every km of ascent i.e., the adiabatic lapse rate of a dry parcel of air, or Dry Adiabatic Lapse Rate (DALR) is 10 °C per km.

**SALR** (Saturated Adiabatic Lapse Rate)

The temperature of a saturated parcel of air, which is made to rise, falls at a rate of approximately 5 °C per km of ascent i.e., the adiabatic lapse rate of a saturated parcel of air, or Saturated Adiabatic Lapse Rate (SALR), is about 5 °C per km.

SALR is less than DALR because, as the saturated air is cooled, its capacity to hold water vapour decreases and the excess moisture condenses into water droplets. This condensation releases latent heat that warms up the parcel of air. The temperature of the rising parcel of saturated air, therefore, falls only by about 5 °C per km instead of 10°C.

SALR is slightly variable - less at the equator and more at the poles.

**Stablle of Air**

Atmosphere is said to be stable when distribution of temperature and humidity with height are such that any small displacement of parcel of air by force, tend to restore the parcel to its former level.

In other words, a parcel of air which is forced upward or downward, tending to return to its original position called as stable air. It occurs when lapse rate is less than DALR and SALR

**Unstable air**

The atmosphere is said to be unstable when distribution of temperature and humidity with height are such that any small displacement of parcel of air by force, tending to move it further away from its former level.

In other words, a parcel of air which is forced upward or downward, tending to continue up or down. It occurs when lapse rate is more than DALR and SALR

**Neutral equilibrium of air**

When a parcel of air is forced upward or downward, it remains in the same position without any intension to move further away or return to its original place

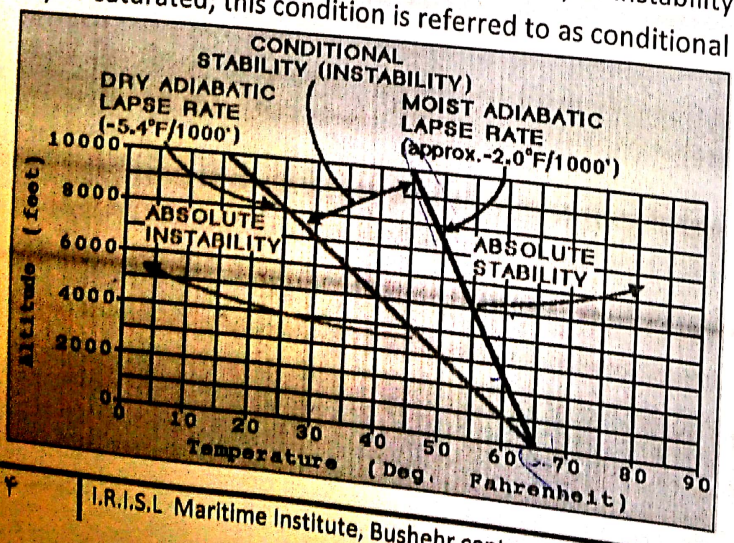
If ELR (Environmental Lapse Rate) coincide DALR when parcel is dry or with SALR when parcel is wet, then parcel of air which is displaced upward, is the same temperature of surrounding air at that level and have no tendency to return original place.

**Conditional Stability**

If the environment is such that the actual lapse rate existent is less than DALR but more than SALR, conditional stability is said to exist

This means that if the parcel of air is dry, it is colder (and hence denser) than the surrounding air at the same level, and would try to return below to its original position i.e., stable equilibrium.

If the parcel of air is saturated, it is warmer (and hence less dense) than the surrounding air at the same level, and would try to continue upwards, in the direction of the original disturbance i.e., unstable equilibrium. In this case, Stability or instability depends on whether the parcel is dry or saturated; this condition is referred to as conditional stability. SALR < ELR <DALR

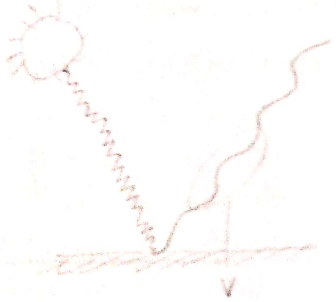


**Atmospheric temperature**

The temperature of air depends on a number of factors, the first of which is amount of heat entering and leaving the atmosphere. Nearly most of heat is reaching the earth from the sun in form of wave in very small wavelength which travels through the atmosphere in light speed. No energy is lost by radiation during passage through the space. On the earth (sea and land) these waves are partly absorbed by the surface (causing increase of temperature) and partly are reflected back to the space in the form of long wave radiation. The long wave radiation is partly lost to the space and partly absorbed by the atmosphere (causing increase of temperature)

Water present in atmosphere as vapour or as cloud absorbs only a small fraction of the incoming short waves radiation but strongly absorbs the outgoing long wave radiation.

On cloudy nights, part of the outgoing radiation is absorbed by clouds and partly is reflected back again towards the surface. That's why cloudy day is warmer than clear day. (Green house effect)



**The seasons**

Due to tilt of the earth aixs, the angle of sun ray direction will vary by change of seasons. On beginning of spring and autumn. The angle between sun and equator is nil therefore sun will almost be on equal distance from north and south hemisphere. During northern spring and summer, the sun will be above the north hemisphere and during northern autumn and winter; the sum will be above southern hemisphere.

**Diurnal variation of atmospheric temperature**

It has been observed that atmospheric temperature reaches its maximum at about 1400 Hour's local time and reaches it's minimum at about half-hour after sunrise. Since this happens once per day this is called diurnal variation of atmospheric temperature

## Diurnal range of atmospheric temperature

The difference between the maximum and minimum values in a day is called the diurnal range of atmospheric temperature for that day.
Diurnal range of air temperature over land is large (as much as 20°C) whereas over sea, it is very small (less than 1°C) for the following reasons:

-Land, being a solid, has a low value of specific heat so heats up or cools very quickly.
But Sea, being a liquid, higher value of specific heat so heats up or cools very slowly.
- Heat received from the sun is retained by the top layer of land (only a few centimeters deep) as land is a poor conductor of heat. But at sea heat is distributed over a large mass of water by convection currents
-Evaporation of water during day causes adiabatic cooling which balances some of the Heat received from the sun.

### Atmospheric pressure

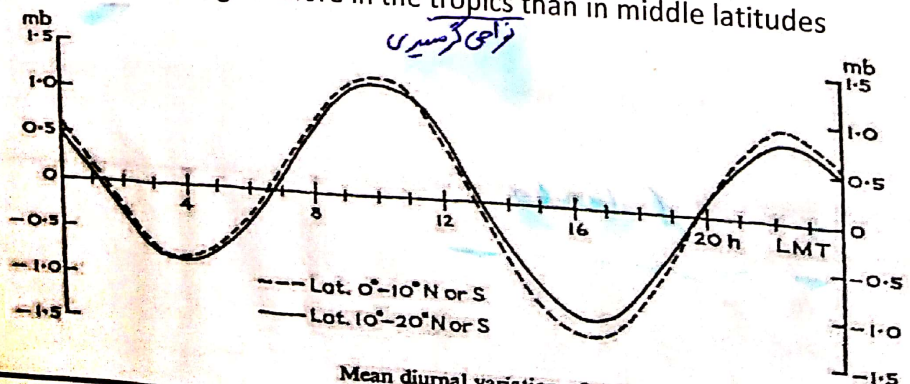
Atmospheric pressure is the force exerted, per unit area, by air. It is thus the weight of the column of air above a unit area.

### Units of atmospheric pressure

Pascal (Pa), equal to one Newton per square meter ($N/m^2$).
1 bar=100 000 pascal
1000 mb =1 bar =750.1 mm of mercury
1 bar = 1.02 kg per cm2 or 10.2 t per m2
The average atmospheric pressure at the earth's surface is about 1013 mb.

### Semi-diurnal variation of atmospheric pressure

Due to many causes, which are not fully understood, atmospheric pressure changes with the time of the day. It has been observed that it is maximum at about 10 & 22 hours and minimum at about 04 & 16 hours Local Mean Time. Since this happens twice a day, it is called semi-diurnal variation of atmospheric pressure.
The average semi-diurnal range is more in the tropics than in middle latitudes



Mean diurnal variation of pressure

**Humidity**

Humidity is the quantity of water vapour pressure in the atmosphere.

**Absolute humidity**

Absolute humidity is the mass of water vapour contained in a sample of air. It is usually expressed in grams per cubic meter (gm/m3).

**Relative humidity**

Relative humidity is the percentage ratio of the actual water vapour contained in a given sample of air, to the maximum quantity of water vapour that the sample can hold at that temperature.

If the temperature of the sample of air is raised, its capacity to hold water vapour increases and, assuming that no water vapour is allowed to come in or go out of the sample of air, relative humidity decreases - the air becomes relatively drier. The opposite happens if the sample of air is cooled – its relative humidity increases.

The **diurnal variation in relative humidity** is approximately inverse to the diurnal variation of temperature. That is the relative humidity will be maximum at about 1400 and minimum at about half an hour before sunrise

**Saturation and dew point**

If a sample of air was progressively cooled, its relative humidity would steadily increase i.e., the air would become relatively more moist. At some temperature, the air would become wet i.e., its relative humidity would become 100%. The air is then said to be saturated and the temperature at which this occurs is called the dew point temperature of that sample of air. Dew point of a sample of air would depend on its temperature & relative humidity.

In other words, Dew point is the temperature at which condensation to water droplets occurs

**Sweat in a cargo hold**

Sweat in a cargo hold is the condensation of water vapour into droplets of water .Sweat can damage the cargo. The formations of sweat lie in the subject of meteorology when sample of air is cooled below its dew point.

**Hoar frost**

Hoar frost is the frozen equivalent of dew. Soft white ice crystals in the form of feathers or tree roots and other surfaces after a clear, calm night, when the air next to the ground has cooled sufficiently for condensation to occur and the temperature near the ground has fallen below 0°C

**Rime**

If temperature of water droplets is below freezing point (super cooled droplets) in contact to any cold object they freeze immediately and called as rime

(Rime is the name given to a deposit of ice that forms on the windward side of an exposed object)

**Latent heat**

Latent heat is the energy absorbed by or released from a substance during a phase change from a gas to a liquid or a solid or vice versa

**Isobars**

Lines joining places having the same atmospheric pressure at the time of observation.It is important to note that atmospheric pressure may change frequently. Hence, its value, when stated, holds good only for that particular time.

Isobars cannot cross or meet because one place cannot have different values of atmospheric pressure at the same time

**Isotherm**

Lines joining places having the same atmospheric temperature at the time of observation

**Pressure gradient**

Pressure gradient is the fall of pressure with distance. If the distance between consecutive isobars is small, the pressure gradient is said to be high and strong winds are expected to blow. If the distance between consecutive isobars is large, the pressure gradient is said to be small and winds of lower speed will be expected

**Barometric tendency (pressure tendency)**

Pressure tendency is the difference between the atmospheric pressure at the time of observation and the atmospheric pressure three hours earlier. (It is rate of change of pressure with time). Pressure Tendency gives the forecaster a good idea of the rate of change of pressure, which is useful for predicting the movement of pressure systems

**Prediction of wind direction**

**Coriolis force**

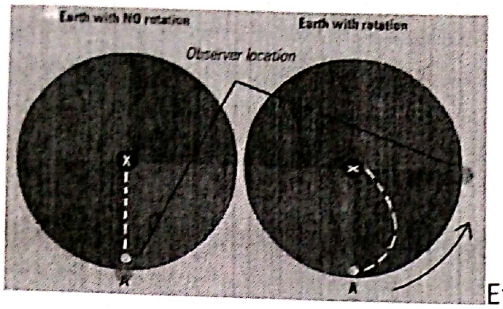
On the surface of the earth, winds always try to blow from an area of high pressure (HP) towards an area of low pressure (LP), because of gradient force

The effect is strongest at the equator than the north and south poles. Regions along the equator, therefore, have the highest temperatures all year round.

Warm equatorial air over very large areas rise up into the atmosphere (low-pressure). This space is filled with cold, dense air, flooding in from the poles (high-**pressure** system).

As the earth is constantly rotating, the winds which are blowing from the north and south towards the equator, is deflected by the earth's rotation. When moving objects are viewed in a reference frame, their path looks curved. This is the Coriolis Effect, and it is simply caused by the earth's rotation. Coriolis force always acts at right angles to the direction in which The wind is blowing. This effect makes wind system to be deflected to their right in the northern hemisphere and to be deflected to their left in the Southern hemisphere

Coriolis force is minimum at the equator and increases as latitude increases, becoming maximum at the poles.



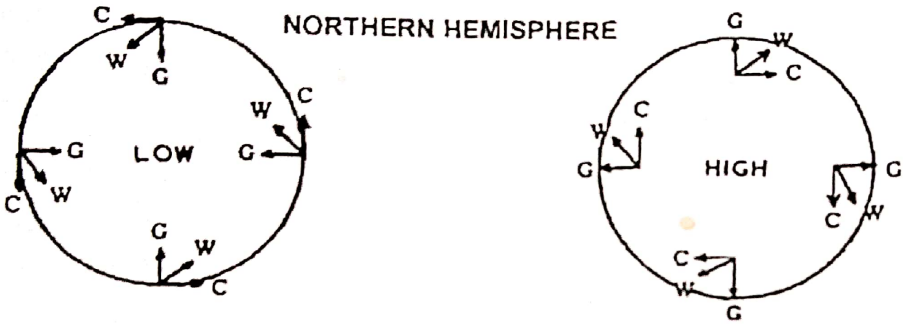
Effect of earth rotation

Winds actually blowing over any area are the resultant of gradient force and Coriolis force

Because of this, it will be observed that:

-Winds blow spirally inwards towards Low Pressure area, anticlockwise in the N.H and clockwise in the SH

- Winds bow spirally outward from the centre of High Pressure area, clockwise in the NH and anticlockwise in the SH.




**The effect of friction**

Friction with the underline area will cause a bit change in the wind direction and also will affect on the wind speed.

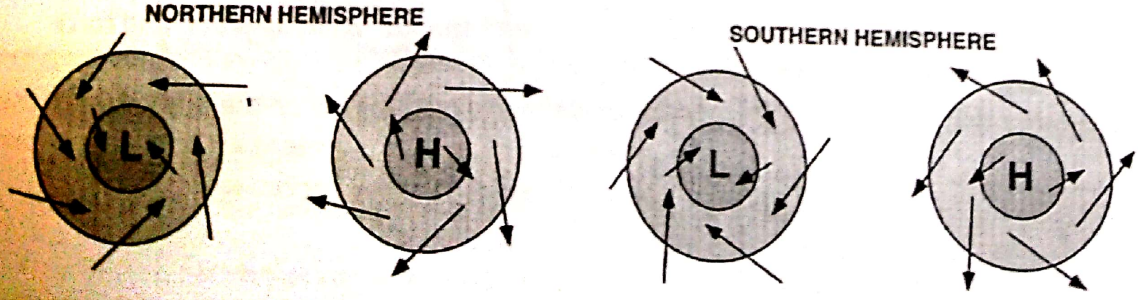
**Cyclone or low** pressure

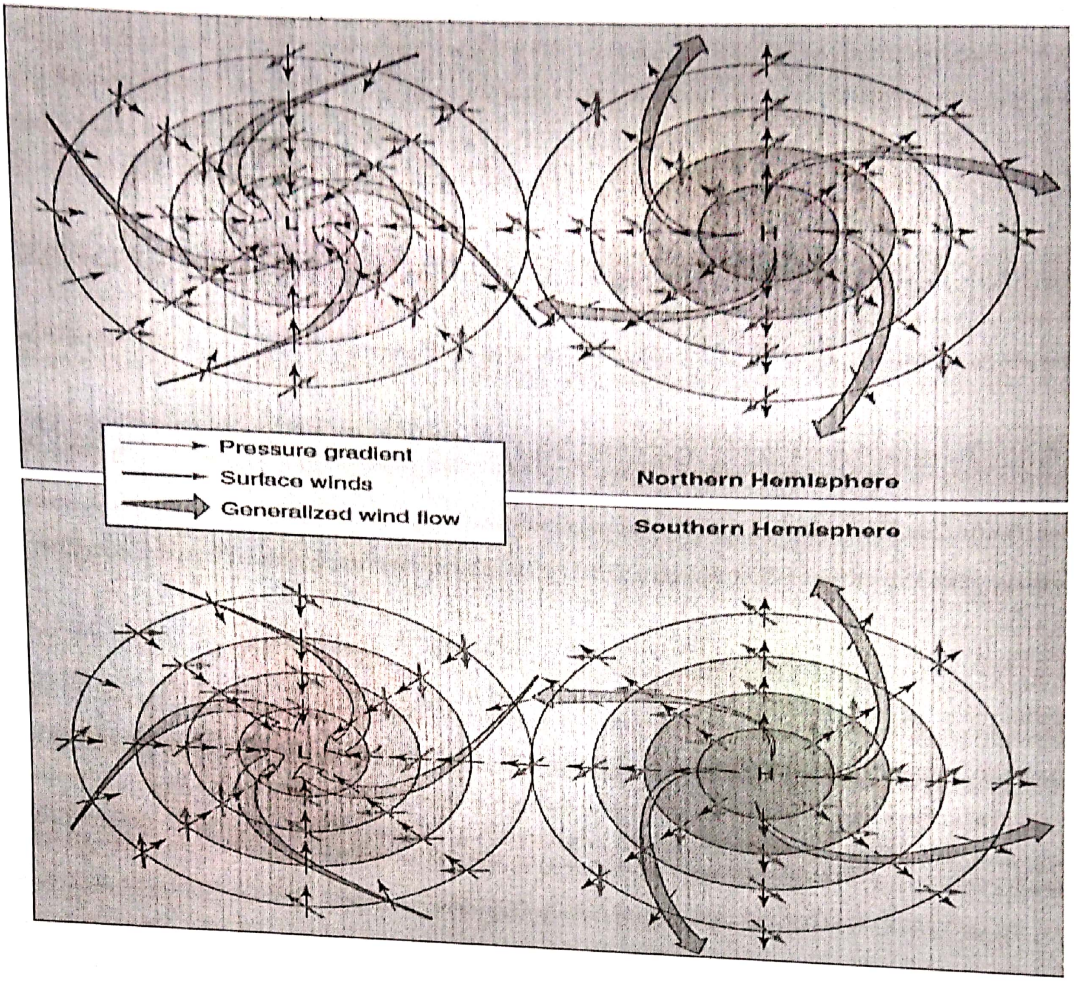
Cyclone or low is an area of relatively low pressure with the closed isobars

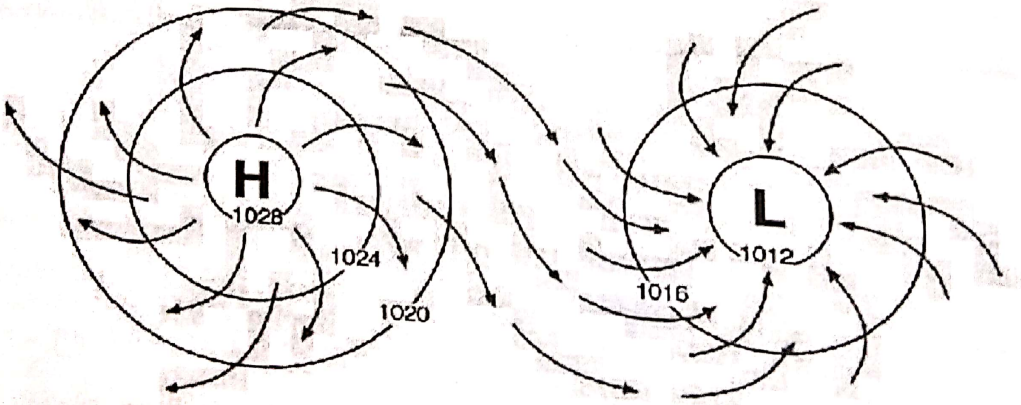
The winds blow spirally inwards, anti-clockwise in the northern hemisphere and clockwise in the southern hemisphere. The pressure gradient is usually high, resulting in strong winds. On reaching the centre, the air moves up as a strong upward current, resulting in clouds of very high vertical extent and heavy precipitation

**Anticyclone or high**

Anticyclone or high is an area of relatively high pressure with closed isobars. The winds blow spirally outwards, clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere. The pressure gradient is usually low resulting in low wind speed



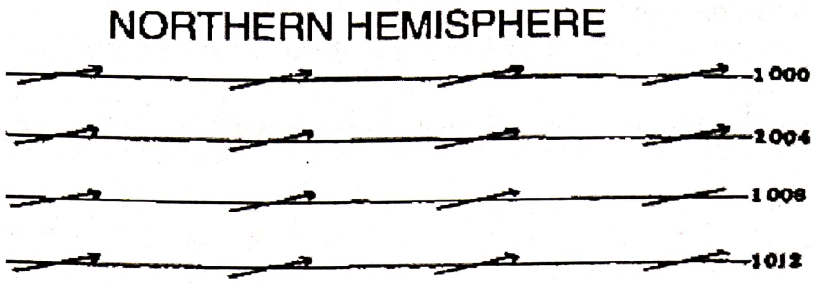



**Straight isobars**

Straight isobars are said to exist when the isobars run straight and nearly parallel for a few hundred miles. The pressure gradient is usually low, resulting in low wind speeds. Wind direction and force remain constant so long as the isobars remain unchanged.

The weather associated with straight isobars cannot be defined as it depends on the properties of the air mass in which these isobars exist. The straight isobars are expected to present in the area far from center of Low or High pressure system and in the warm sector of a frontal depression.




**Buys Ballot's Law**

Face the true wind and the low-pressure area will be on your right in the Northern Hemisphere, and left in the Southern Hemisphere

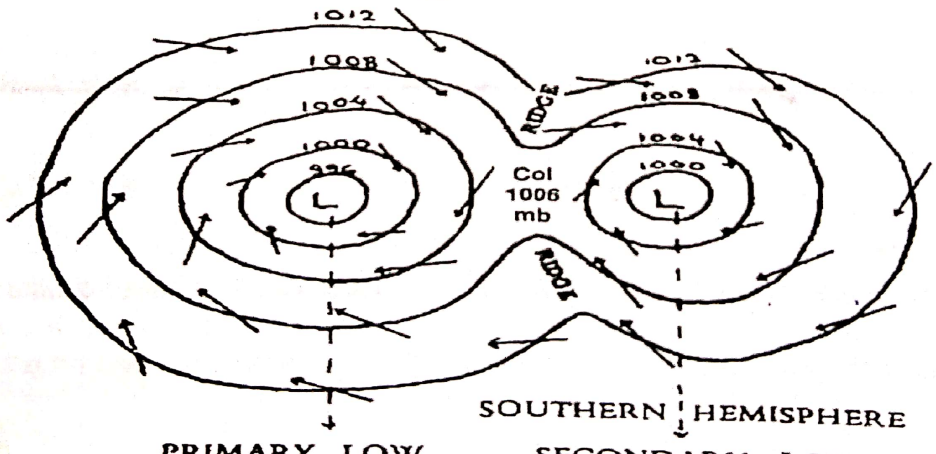
**Caution when applying buys Ballot's Law**

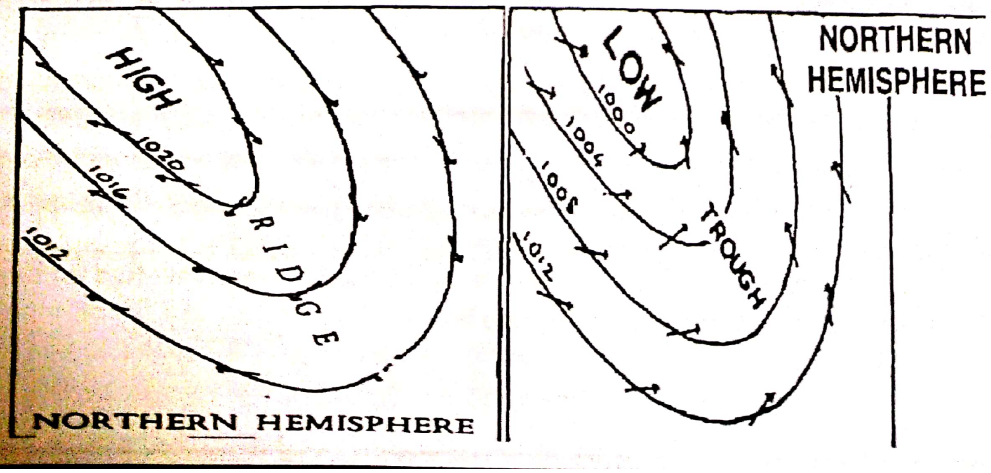
1-Near the equator: Buys Ballot's law should not be applied within a few degrees of the equator. This is because Coriolis force is negligible at the equator and therefore the winds blow directly across the isobars from HP to LP areas.

2-In the vicinity of land, the wind experienced May not be the free unobstructed wind. It may be wind deflected by the land.

**Secondary cyclone or secondary low**

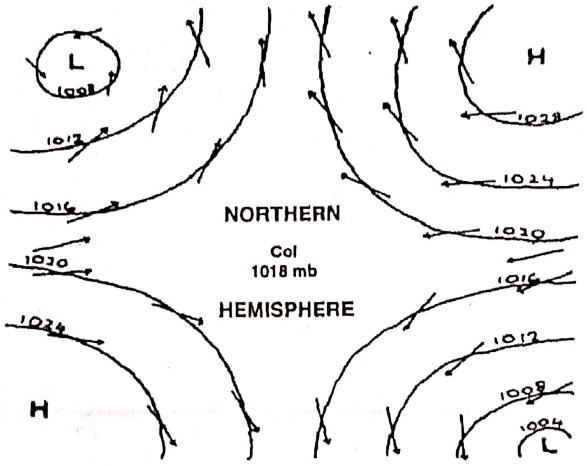
Sometimes a low is closely followed by another, within its pattern of isobars. The first one is called the primary and the second one, the secondary. The latter is so named only because it formed later but it possesses all the qualities of the primary.



**Ridge (wedge) of high pressure**
An enclosed area of high pressure indicated by isobars extending out from anticyclone (high)
**Through of low pressure**
An enclosed area of low pressure indicated by isobars extending out from depression (low)

**COL**
Col is a saddle back area between two high and two low pressure systems. A Col may be situated between a primary low and secondary low
Weather associated with a COL:
-no infinite weather can be associated with a COL
-Light variable winds are experienced but not for long.
-Sudden change of weather is likely.
-Relative humidity is fairly high and lightning may be seen. Fog and thunderstorms may be experience




Beaufort scale
In 1805, Commander Beaufort, of the British Navy, devised a scale for estimating wind speed at sea based on observations of the sea surface and the effect the wind had on the sails of a war ship. He, therefore, used the words 'Wind Force' and not 'Wind Speed'. As a sailor, Beaufort felt there were 13 levels of behavior that mariners could recognize in
0 to 12.
In 1838, the Beaufort wind force scale was made mandatory for log entries in all ships of the Royal Navy.
Subsequently, the WMO (World Meteorological Organization) accepted the Beaufort Wind Scale and internationally standardized the probable wind speeds attached to each Beaufort number.
The Beaufort wind force, and hence the wind speed, may be judged by the appearance of the sea only in open, deep waters. In harbours, rivers, lakes, and other areas close to land, the actual wind speed may be much higher than that estimated by the appearance of the water.
The scale formed basis of wind force effect at sea, beaufort scale has been allotted for range of wind speed and simple conversion of wind speed to scale is possible.

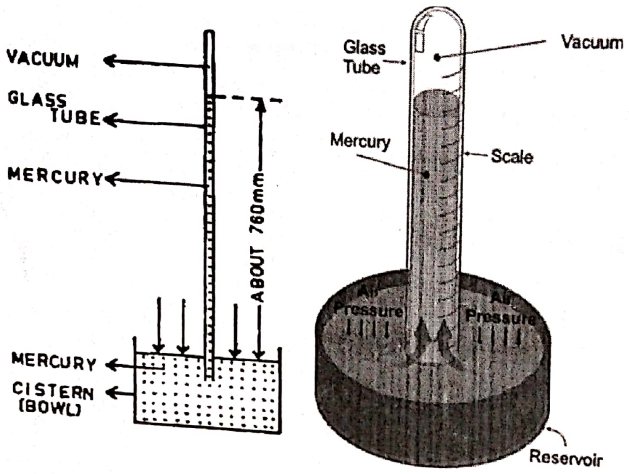
Baeufort wind scale

| Beaufort Number | Descriptive term | Mean Wind Speed Equivalent | | Deep Sea Criterion | Likely mean wave height (m) * | Sea State |
|---|---|---|---|---|---|---|
| | | Knots | m/s | | | |
| 0 | Calm | <1 | 0-0·2 | Sea like a mirror | 0 | 0 Calm |
| 1 | Light Air | 1-3 | 0·3-1·5 | Ripples with the appearance of scales are formed, but without foam crests | 0·1 (0·1) | 1 Calm |
| 2 | Light breeze | 4-6 | 1·6-3·3 | Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break | 0·2 (0·4) | 2 Smooth |
| 3 | Gentle breeze | 7-10 | 3·4-5·4 | Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses | 0.6 (1·0) | 3 Slight |
| 4 | Moderate breeze | 11-16 | 5·5-7·9 | Small waves, becoming longer; fairly frequent white horses | 1·0 (1·5) | 3-4 Slight |
| 5 | Fresh breeze | 17-21 | 8·0-10·7 | Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray) | 2·0 (2·5) | 4 Moderate |
| 6 | Strong Breeze | 22-27 | 10·8-13·8 | Large waves begin to form; the white foam crests are extensive everywhere (probably some spray) | 3·0 (4·0) | 5 Rough |
| 7 | Near Gale | 28-33 | 13·9-17·1 | Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind | 4·0 (5·5) | 5-6 Rough to Very Rough |
| 8 | Gale | 34-40 | 17·2-20·7 | Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks along the direction of the wind | 5·5 (7·5) | 6-7 Very Rough to High |
| 9 | Severe or Strong Gale | 41-47 | 20·8-24·4 | High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple, tumble and roll over; spray may affect visibility | 7·0 (10·0) | 7 High |
| 10 | Storm | 48-55 | 24·5-28·4 | Very high waves with long overhanging crests; the resultant foam, in great patches, is blown in dense white streaks along the direction of the wind; on the whole, the surface of the sea takes a white appearance; the tumbling of the sea becomes heavy and shock-like; visibility affected | 9·0 (12·5) | 8 Very High |
| 11 | Violent Storm | 56-63 | 28·5-32·6 | Exceptionally high waves (small and medium sized ships might be for a time lost to view behind the waves); the sea is completely covered with long white patches of foam lying along the direction of the wind; everywhere the edges of the wave crests are blown into froth; visibility affected | 11·5 (16·0) | 8 Very High |
| 12 | Hurricane | 64 and over | 32·7 and over | The air is filled with foam and spray; sea completely white with driving spray; visibility severely affected | 14 and over | 9 Phenomenal |

## PRESSURE MEASURING INSTRUMENTS

### The mercury barometer

The mercury barometer is an instrument for measuring atmospheric pressure.
In its simplest form, the mercury barometer consists of a glass tube, closed at one end, filled with mercury and inverted into a bowl containing mercury.
It will be noticed that the mercury level in the tube drops by a certain amount and then remains steady. This is because atmospheric pressure, acting on the surface of mercury in the bowl, balances the weight of mercury in the tube. Atmospheric pressure, therefore, is the weight of mercury above the level of mercury in the bowl




### Reasons why mercury is used in barometers

1) Mercury has a high relative density; therefore, a mercury barometer is less than one Meter high whereas a water barometer would have to be over 10 meters high
2) Mercury does not wet. The glass surface as other liquids would.
3) Mercury is easily visible.
4) Mercury has a uniform coefficient of expansion so temperature correction can easily be applied accurately.
5) Mercury cannot escape easily through the leather washer on top of the cistern during transportation of the barometer, owing to its high viscosity
6) Mercury has a low freezing point (about -39°C) and a very high boiling point (over 350°C) and hence is suitable for marine barometers.

### Correction of barometric readings

All barometric readings should be reduced to a common datum - sea level in Latitude 45° with no error due to temperature. All barometric readings should, therefore, be corrected for height, latitude, and temperature and index error before making entries in the Logbook

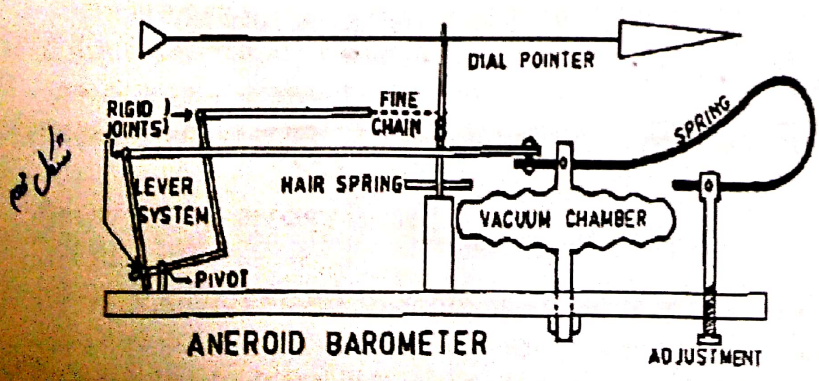
(a) Reason for height correction:
Atmospheric pressure decreases as height increases. The reading on the bridge will, therefore, be lower than the reading at sea level. Since we have the reading on the bridge, but have to report the pressure at sea level, we have to **add** a correction for height to the bridge reading at the rate of 1 milli bar for every 10 meters above sea level.
(b) **Reason for latitude correction:**
Since the earth's polar radius is less than its equatorial radius, the gravitational force at the poles is greater than at the equator, therefore, weighs more at the poles than at the equator.

(c) **Reason for temperature correction:**
Each mercury barometer is constructed to show correct readings at a particular temperature called the standard temperature, which is 0°C (273°K) for modern barometers The standard temperature of the barometer is' mentioned on a brass plate attached to the metal case of the barometer,
If the temperature of the barometer is different from its standard temperature, the pressure indicated by the barometer has to be corrected at the approximate rate of 1 milli bar for 6° difference. The correction is additive if the actual temperature is below the standard temperature and vice versa.

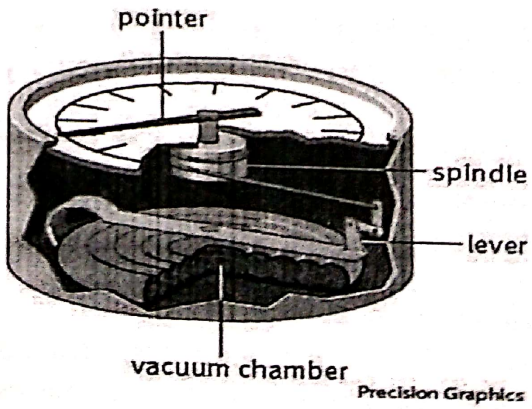
(d) **Index error:**
If a barometer does not give the correct pressure in spite of proper corrections being Applied for height, latitude and temperature, the difference between the corrected barometric pressure and the actual atmospheric pressure is called the index error of the barometer, positive if the former is less and negative if the former is more
e.g. if corrected barometric pressure is 1004.8 mb and the actual atmospheric pressure is 1005.2 mb, the index error is +0.4 mb. Index error should always be applied, as per sign, to the barometric reading.

**Location of a barometer on a ship**
1) In the wheelhouse or chartroom for easy accessibility to the navigating officers.
2) As close to the center line of the ship as practicable →
3) Away from direct gusts of wind →
4) Away from direct sunlight.
5) Away from draughts of air, blowers, heaters, etc. that could cause sudden or abnormal changes in temperature
6) On a bulkhead not subjected to excessive vibration. →
7) Top part of marine tube should be at eye-level or a little lower to allow easy reading.

**The aneroid barometer**
Aneroid means without liquid. A sealed chamber made of very thin metal, having a partial vacuum inside it, is connected by a system of levers and springs to a pointer fitted over a circular, graduated scale. The thin metal has an elastic effect.
When the atmospheric pressure changed, the chamber gets compressed /expanded and the movement is transmitted mechanically to the pointer that then registers a higher/lower reading on the scale. The larger the chamber, the greater the accuracy of the aneroid barometer



ANEROID BAROMETER



Precision Graphics

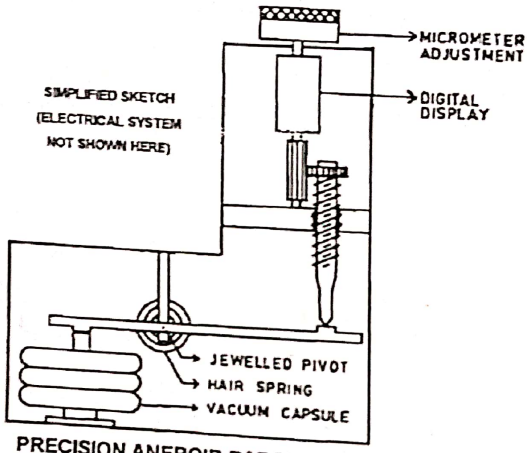
**Precautions when using an aneroid barometer**
**Tap the face of the instrument lightly to release any sticking of levers or pointer due to friction.**

**Advantages of aneroid barometer**

It is a robust and compact instrument. Changes of pressure are easily detectable.
For this purpose, a fixed pointer is provided, attached to the glass face of the instrument. After tapping the instrument, the fixed pointer is aligned with the dial pointer, after some time the instrument is tapped gently again. If the dial pointer now lies to the right of the fixed Pointer, the pressure has risen and vice versa. The amount of rise or fall can also be noted.

**The precision aneroid barometer**

This is a compact (small), robust (strong), accurate, aneroid barometer that has replaced the Large, mercury barometer that was fitted on ships in the earlier days
It has a micrometer arrangement for reading to 0.1 of a milli bar.



PRECISION ANEROID BAROMETER

**The barograph**

The barograph is an aneroid barometer that gives a continuous record of pressure on a paper chart.
Such a chart, with a continuous barograph trace on it, is called a barogram.
For climatic record purposes, the barograph is always set to UTC (GMT) not to ship's time.

**Construction of the barograph**

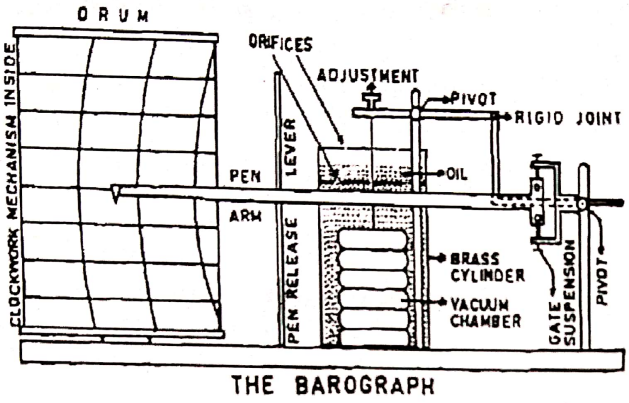
The vacuum chamber consists of a series of metal boxes arranged vertically. Change of atmospheric pressure causes the top of the chamber to ascend or descend and this movement is conveyed by a lever system to a stylus (pen) that moves up or down on the chart.
The chart is fixed on a cylindrical drum that rotates at a uniform speed of one rotation per week.
The tip of the stylus has a detachable pen that contains one drop of slow drying ink, specially Supplied for this purpose.
The entire barograph is provided with a hinged glass cover, to keep out gusts of wind and dust, and is mounted on springs and rubber pads to reduce vibration.

**The chart or barogram**

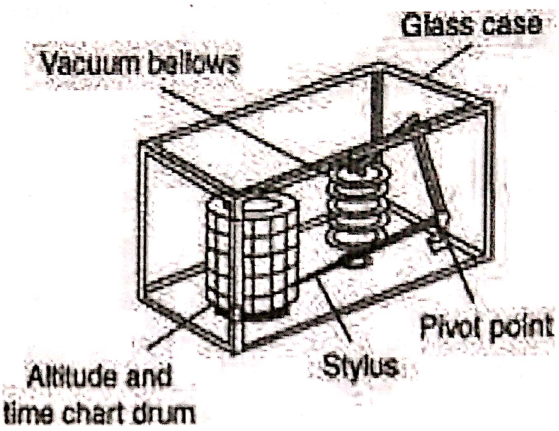
The vertical lines of the barogram that indicate UTC are at two-hour intervals and are curved, So that changes in pressure are recorded without creating an error in time.
The chart is fixed around the drum by means of two clips, one at the top and one at the bottom or one long clamp equal to the height of the drum.

The latter end of the chart should overlap its earlier end so that, in the event of the paper not being changed (due to oversight) at the end of a week, the pen will not catch on the edge of the paper and tear it.

Before handling the chart for renewal, the pen must be pulled clear of the chart by means of a pen release lever, provided for this purpose.



THE BAROGRAPH




**Advantage of barograph**

The barograph gives a continuous record of pressure which can easily be used to check the pressure tendency

**The thermometer**

The thermometer is an instrument for measuring temperature.

**Description**

A tube of glass is attached to a bulb containing mercury, evacuated of air and sealed at its open end. When heated, the mercury in the bulb expands into the tube.

When the temperature increases, the mercury in the bulb expands and the length of mercury in the column gets more. When the temperature decreases, the mercury in the bulb

Contracts and the length of mercury in the column get less.

The tube is graduated with two reference points - the freezing point and the boiling point of water. The graduation differs from type to type.

The World Meteorological Organization has adopted the Celsius type where the freezing point of water is 0 °c and its boiling point, 100°c. The length of the tube between 0° and 100° is divided into 100 equal parts

There are two other types of graduation and they are shown here for academic interest only.

Celsius' Kelvin and Fahrenheit

Freezing point of water 0°c, 273°k, 32°f

Boiling point of water 100°c, 373°k, 212°f

**Reasons why mercury is used**

(i) Easily visible.

(ii) Large, uniform coefficient of expansion.

(iii) Does not wet the glass.

(iv) High boiling point (over 350°c).

(v) Fairly low freezing point (about -39°c).

THE HYDROLOGICAL CYCLE

**Three main stages:**

There are three main stages in the hydrological cycle - Evaporation, Condensation and Precipitation

**Evaporation:** is the transformation of water into water vapour. It is accelerated if the air is Warm and dry

During evaporation, latent heat is absorbed from the surrounding air and from water surface.

**Condensation:** is the transformation of water vapour into water. **It** is the opposite of Evaporation.

During condensation, latent heat is given off to the surrounding air.

Condensation occurs if air is cooled below its dew point. This is usually the result of:

- Contact with cold surface of land or sea.
- Adiabatic cooling when air rises.
- Contact with colder masses of air.

**Precipitation:** is the name given to water drops from clouds, which fall towards the Ground. Whilst falling through different layers of atmosphere, the water drops may freeze into soft ice (snow) or into hard ice (hail).

Mist and fog are not called precipitation because the water droplets remain suspended in the air and do not fall. Sometimes, precipitation evaporates completely, during its transit through the atmosphere, and does not reach the ground. It may then be visible as vertical streamers below clouds and is called "Virga".

Drizzle: Fine drops of water, diameter less than 0.5 mm. Termed heavy or light depending on Intensity o-f precipitation

Rain: Water drops larger than 0.5 mm diameter. Termed heavy or light depending on intensity of Precipitation

Sleet: Sometimes rain and snow fall together or partly melted snowflakes fall. This is called sleet

Hail: Balls of hard ice, 0.5 to 50 mm diameter or more.

**Clouds**

When air is cooled below its dew point temperature, the excess water vapour condenses into Minute (very small) particles of water, which remain suspended in the air. Millions of such particles, close together, become visible as cloud.

Clouds can form at any height 'from sea level up to the tropopause, they are hence grouped According to their height of base above sea level

Low clouds consist entirely of water droplets and have their bases between sea level and 2 km height.

Medium clouds have the prefix "Alto" to their names and consist of both, water droplets and ice Particles, but more of the former.Their bases will be between 2 km and 6 km above sea level.

High clouds have the prefix "Cirro" to their names and consist entirely of ice crystals. Their bases will be between 6 km above sea level and the tropopause.

High level clouds: Cirrus (Ci) – Cirrostratus (Cs) – Cirrocumulus (Cc)

Medium level clouds: Altostratus (As) - Altocumulus (Ac)

Low level clouds: Cumulus (Cu) - Cumulonimbus (Cb)

1. **Cirrus:** Silvery, high clouds appearing like feathers or fibers. Being so high up, they always have a background of blue sky and, during twilight, often appear bright red or yellow. On dark nights, cirrus can be detected only by its dimming effect on stars.

2. **Cirrostratus:** A thin whitish veil of high cloud through which the sun or moon have a watery look. The outline of the sun and moon are sufficiently clear for altitude observations by a sextant.

3. **Cirrocumulus:** A high layer of cloud in the form of small flakes or cauliflowers, white in color with no dark shadows in between.

4. **Altostratus:** A thin greyish or bluish veil of cloud through which the sun or moon appears very dim as if seen through frosted glass. The outline of the sun and moon are hazy and not clear enough for altitude observation by a sextant.

5. **Altocumulus:** Clouds in patch, layer or sheet form, white or grey or both in colour. Have dark shadows in between and in regular patterns aligned in one, or sometimes two, directions.

6. **Stratus:** A low, even layer of dark grey cloud with light and dark patches. It has a dry look and does not cause precipitation. It resembles fog, but is not experienced at sea level. It can obscure the sun completely and can greatly weaken daylight

7. **Nimbostratus:** A low, even layer of dark-grey cloud generally uniform and threatening in Appearance with no light coloured patches. It has a wet look. If precipitation takes place it is continuous not intermittent. It can completely obscure the sun and greatly weaken daylight.

8. **Stratocumulus:** Clouds consisting of a layer or patches of globular masses which appear soft. They are grey in colour with dark shadows. The patches generally align themselves in regular patterns in one, or sometimes two, directions.

9. **Cumulus:** Brilliant white, thick clouds with flat bases and rounded cauliflower-like tops. Dark Shadows are usually seen in them. The outline of each such cloud is very clear cut
They may have very great vertical extent. Precipitation, if any, caused by even, well developed cumulus is light.

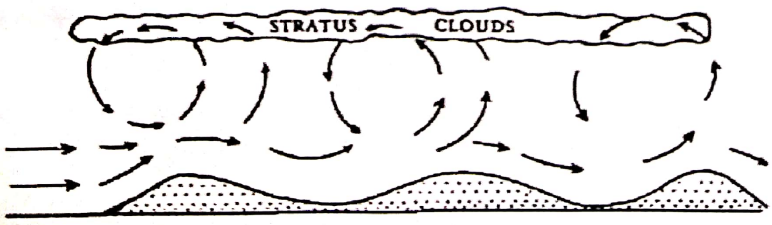
10. **Cumulonimbus:** Mass of grey, heavy cloud having its base in low cloud level, of great vertical Extent, with its top well in high cloud level
The top of a well-developed cumulonimbus cloud will have attached to it, a cap of white cirrus cloud in the shape of an anvil

**FORMATION OF CLOUDS**

Clouds are formed in four main ways:

**(a) Turbulence:**
Strong winds blowing over uneven ground strike against the various obstructions and the Air gets deflected upwards. This cause thorough mixing of the air and, as the air rises, it cools Adiabatically
If during this process, the air gets cooled below its dew point, clouds will form. These clouds will be of an even, layer type (stratus) and their bases will generally be not more than 600m high.

**TURBULENCE CLOUD**



(b) **Orographic lifting:**

When a warm, moist wind blows against a mountain range, it begins to climb up the mountainside. During this ascent, it cools adiabatically and after cooling below its dew point, Orographic clouds are formed. These are of the stratus type. If the mountain is quite high, further Ascent results in nimbostratus and continuous precipitation.

On the windward side of the mountain peak, Clouds are forming steadily whereas on the leeward Side, they are dissipating at the same rate

(c) **Convection:**

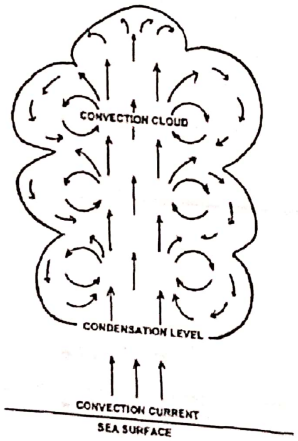
When a parcel of air gets heated due to any local cause, it expands, becomes less dense than surrounding air, and rises. This is called convection current. This local heating can be caused by contact with warm sea or ground. So long as the parcel is warmer than the surrounding air at each level, it will continue to rise (unstable condition of air).

During this ascent, the rising air cools adiabatically and, when cooled below its dew point, condensation takes place resulting in convection clouds

That is why a large island (more than about 10 miles long) in mid ocean may be seen to have a stationary cumulus cloud above it during daytime.

It is for the same reason that, during daytime, the coastline of A large landmass may have a long line cloud above it, parallel to the coast

The greater the ascent of air, the greater the vertical extent of the cloud




(d) **Frontal lifting:**

Where a warm air-mass and a cold air-mass are in contact, their line of separation, at sea Level, is called a front. The boundary between them is not vertical. It is inclined towards the colder air mass because the cold air, being denser, acts like a wedge and lifts up the warm air.

**Visibility**

Visibility is the transparency of the atmosphere and is defined as the maximum distance at which an object can be clearly seen and distinguished in normal daylight.
Visibility can be reduced by liquid or solid particles in the air as in the following cases:
(a) Mist or fog (b) Precipitation (c) Spray (d) Smoke (e) Dust, etc.

**Mist/Fog**

Mist is said to exist when visibility is reduced by water particles that have condensed on dust, minute particles of salt, etc., but are so small that they remain suspended in the air. If mist becomes dense and reduces visibility to 1 km or less, it is called fog. Mist can occur when relative humidity is an low as 80%
Mist is always experienced before and after fog.

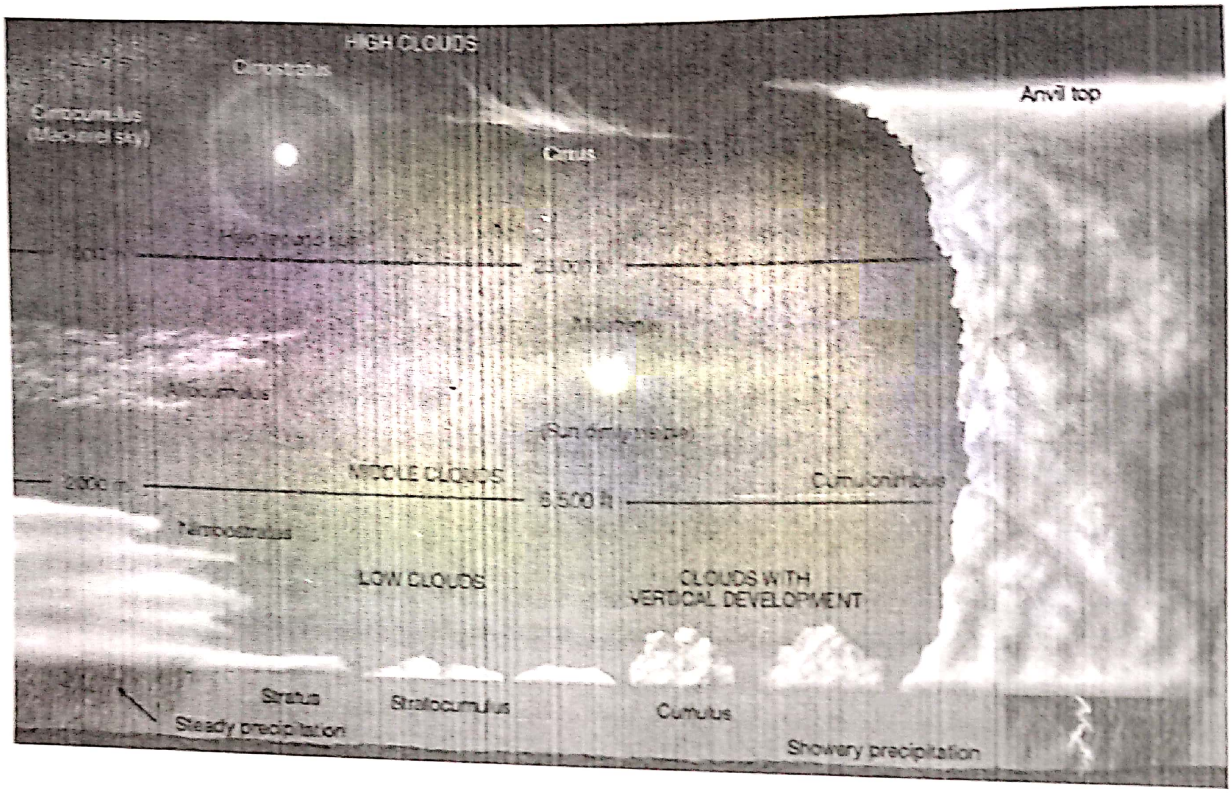
**Haze**

**If** visibility is reduced by solid particles such as dust, sand, volcanic ash, etc., in suspension in the air, Haze is said to exist. Haze can, in rare cases, reduce visibility to 200 meters or less.

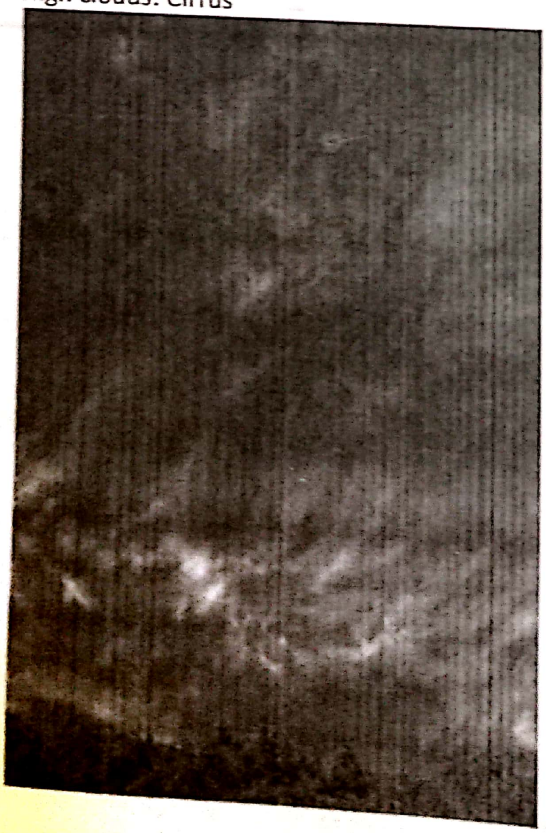
**Spray**

Spray is the name given to small droplets of water driven by the wind, from the tops of waves. Spray affects visibility when the wind force is 9 or more (wind speed of over 40 knots).

Clouds:

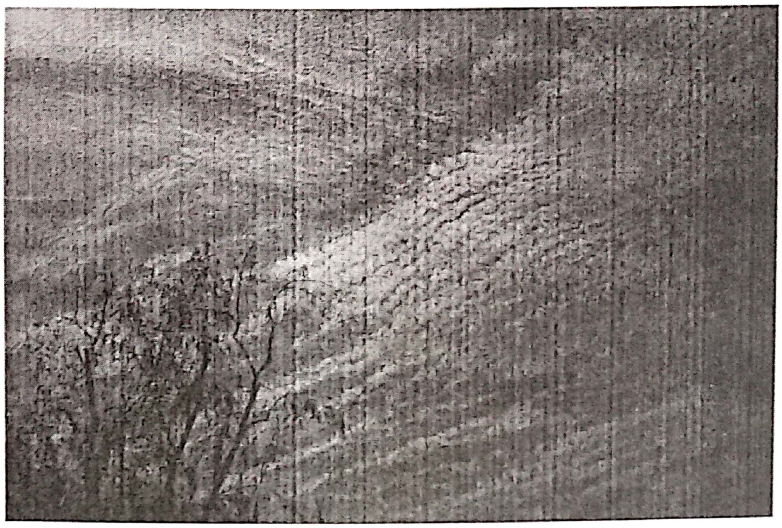



High clouds: Cirrus



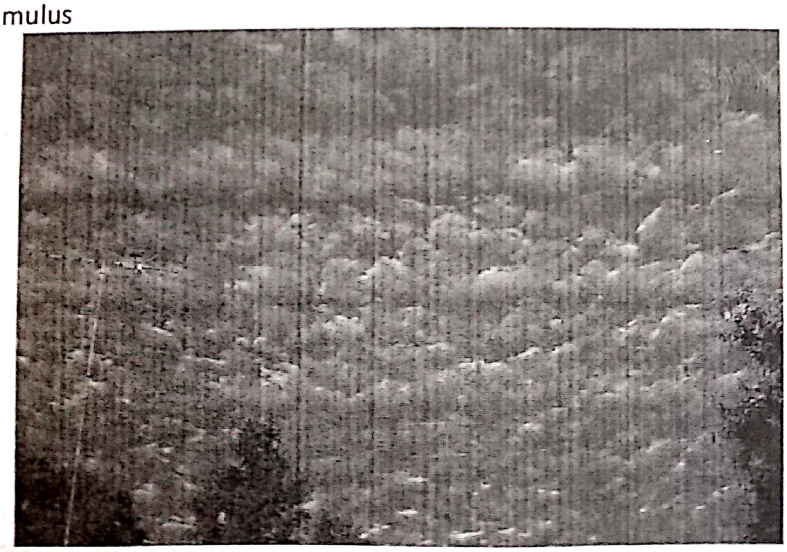
High clouds: Cirrostratus

High clouds: Cirrocumulus

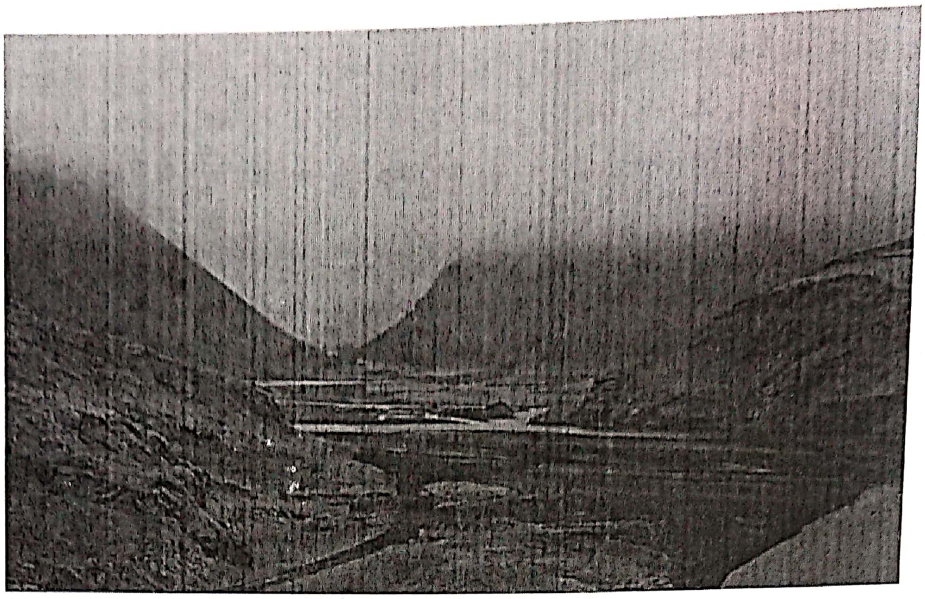


Middle clouds: altostratus

Middle clouds: altocumulus



Low clouds: stratus

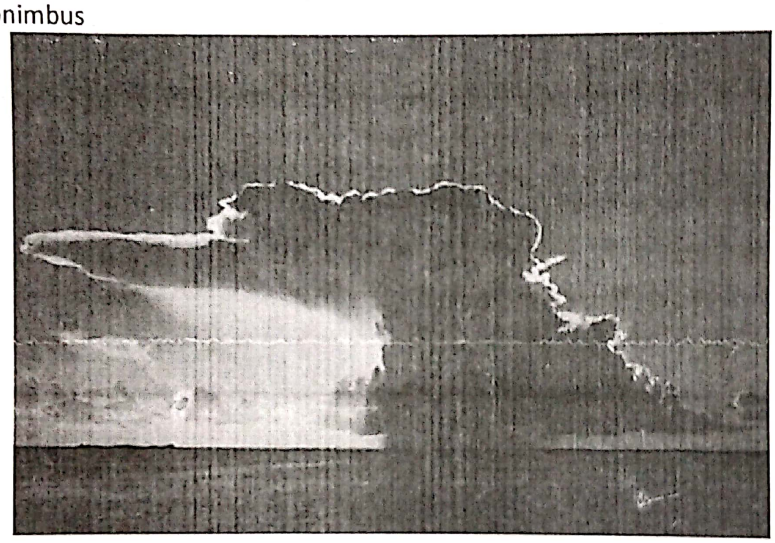


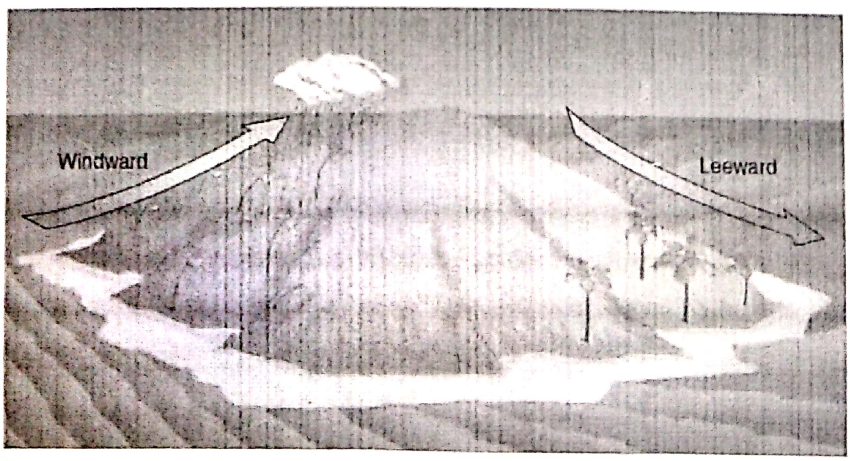
Low clouds: nimbostratus

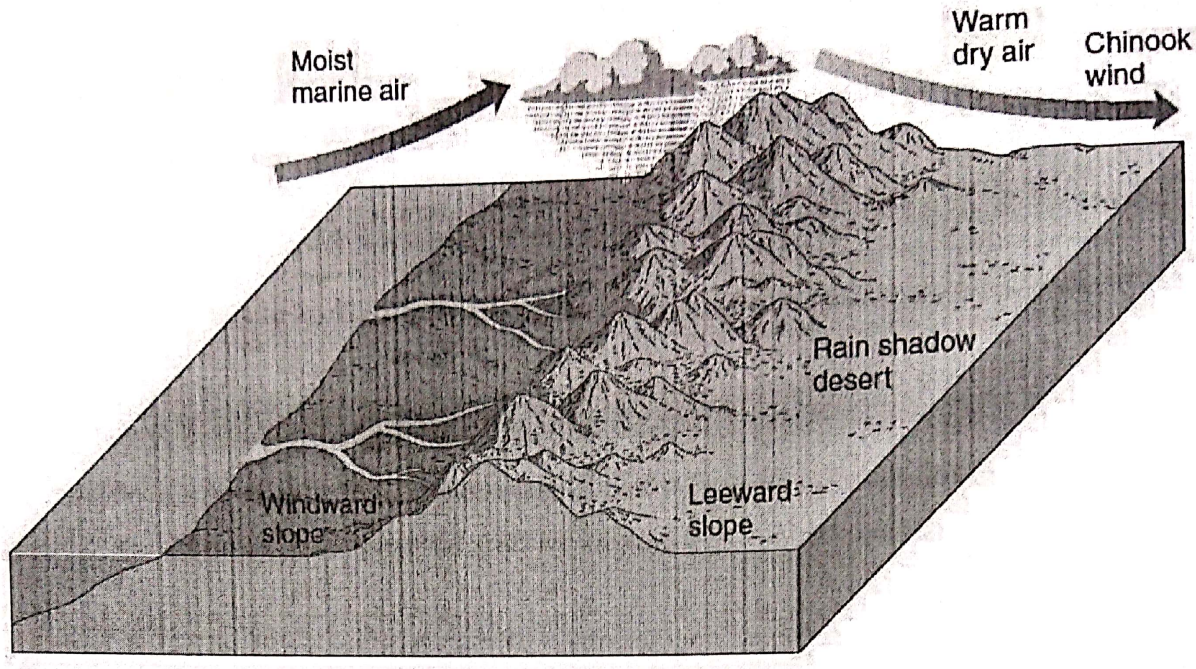
Low clouds: stratocumulus

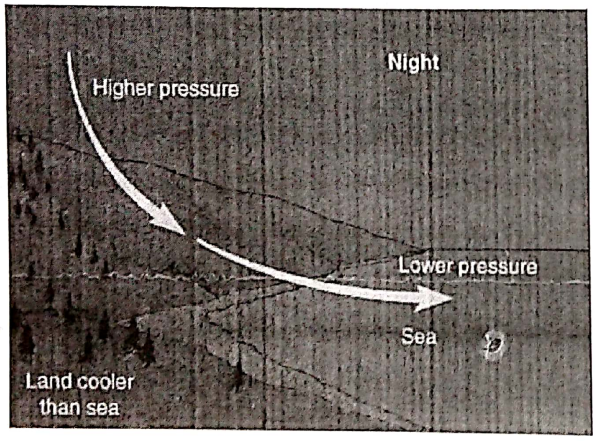
Low clouds: fair-weather cumulus

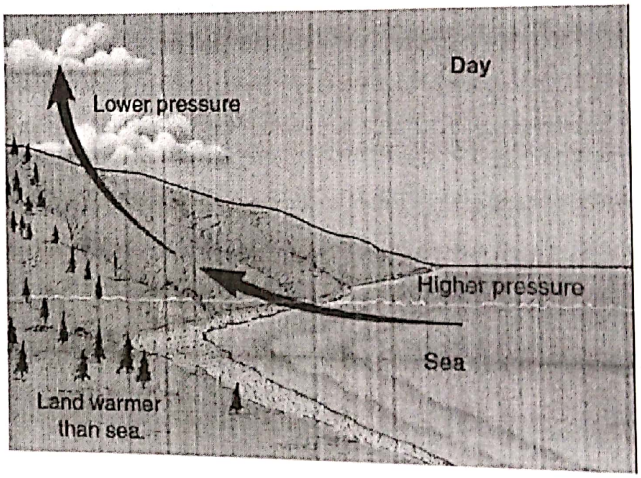
Deep clouds: cumulonimbus

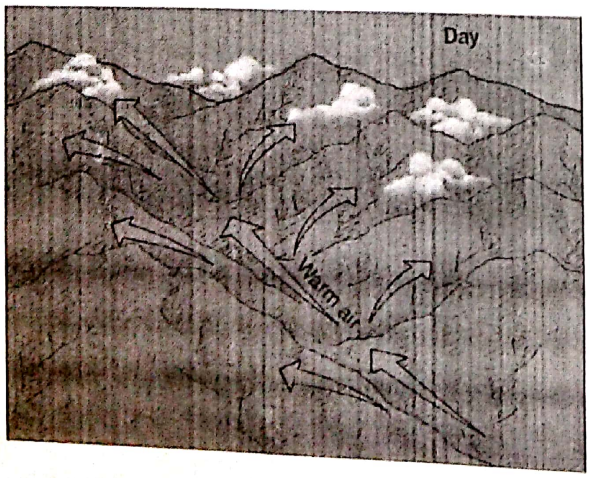


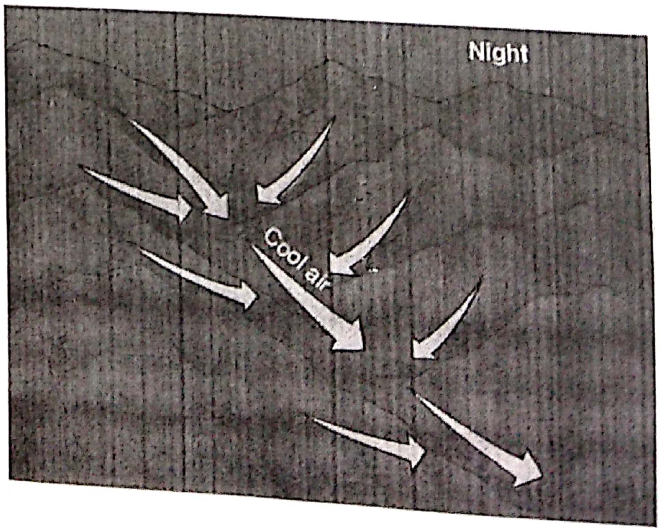



Moist
marine air
Warm
dry air
Chinook
wind
Rain shadow
desert
Windward
slope
Leeward
slope


Night
Higher pressure
Lower pressure
Sea
Land cooler
than sea


Day
Lower pressure
Higher pressure
Sea
Land warmer
than sea


Day
Warm air


Night
Cool air