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CLIMATOLOGY

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EARTH'S ATMOSPHERE

Atmosphere is a thick gaseous envelope that surrounds the earth and extends thousands of kilometers above the earth's surface. Much of the life on the earth exists because of the atmosphere otherwise the earth would have been barren. In fact, atmosphere directly or indirectly influences the vegetation pattern, soil type and topography of the earth.

Composition of the Atmosphere

The atmosphere is a mixture of several gases. It contains huge amount of solid and liquid particles collectively known as aerosols. Pure dry air consists mainly of Nitrogen, Oxygen, Argon, Carbon Dioxide, Hydrogen, Helium and Ozone. Besides, water vapour, dust particles, smoke, salts, etc. are also present in the air in varying quantities.

The chemical composition of atmosphere up to an altitude of about 90 km is uniform in terms of major gases-Nitrogen and Oxygen. This layer is called ***Homosphere.*** Above 90 km, the proportion of the gases changes with progressive increase in the proportion of lighter gases. This layer is known as ***Heterosphere.***

Nitrogen and Oxygen comprise 99% of the total volume of the atmosphere. But Nitrogen does not easily enter into chemical union with other substances. It serves mainly as an agent of dilution and remains chemically inactive. Oxygen combines with all the elements easily and is most combustible. Carbon dioxide constitutes a small percentage of the atmosphere. It can cause the lower atmosphere to be warmed up by absorbing heat from the incoming short wave solar radiation from the sun and reflecting the long wave terrestrial radiation back to the earth's surface. Carbon dioxide is utilized by the green plants in the process of photosynthesis.

Water vapour and dust particles are the important variables of weather and climate. They are the source of all forms of condensation and principal absorbers of heat received from the sun and radiated from the earth. Water vapour comprises 3-4% of the total volume of air.

Component	Per Cent by Volume
Nitrogen	78.08 %
Oxygen	20.94 %
Argon	0.93%
Carbon dioxide	0.03%
Neon	0.0018%
Helium	0.0005%
Ozone	0.00006%
Hydrogen	0.00005%

However, the amount of water vapour present in the atmosphere decreases from the equator towards the poles. Nearly 90% of the total water vapour lies below 6 km of the atmosphere.

Structure of the Atmosphere

The atmosphere consists of almost concentric layers of air with varying density and temperature.

a) Troposphere:

- Lowest layer of the atmosphere.
- The height of troposphere is 16 km thick over the equator and 10 km thick at the poles.
- All weather phenomena are confined to troposphere (e.g. fog, cloud, frost, rainfall, storms, etc.)
- Temperature decreases with height in this layer roughly at the rate of 6.5° per 1000 metres, which is called ***normal lapse rate.***
- Upper limit of the troposphere is called **tropopause** which is about 1.5 km.

b) Stratosphere:

- The stratosphere is more or less devoid of major weather phenomenon but there is circulation of feeble winds and cirrus cloud in the lower stratosphere.

- Jet aircrafts fly through the lower stratosphere because it provides conducive flying conditions.
- Ozone layer lies within the stratosphere mostly at the altitude of 15 to 35 km above earth's surface.
- Ozone layer acts as a protective cover as it absorbs ultra-voilet rays of solar radiation.
- Depletion of ozone may result in rise of temperature of ground surface and lower atmosphere.
- Temperature rises from -60°C at the base of the stratosphere to its upper boundary as it absorbs ultra-voilet rays.
- Upper limit of the Stratosphere is called ***stratopause.***

c) Mesosphere

- Mesosphere extends to the height of 50-90 km.
- Temperature decreases with height. It reaches a minimum of -80°C at an altitude of 80-90 km
- The upper limit is called ***mesopause***.

d) Thermosphere

- It lies at 80 km to 640 km above the earth's surface.
- It is also known as ionosphere.
- Temperature increases rapidly with increasing height.
- It is an electrically charged layer. This layer is produced due to interaction of solar radiation and the chemicals present, thus disappears with the sunset.
- There are a number of layers in thermosphere e.g. D-layer, E-layer, F-layer and G-layer.
- Radio waves transmitted from earth are reflected back to the earth by these layers.

e) Exosphere

- This is the uppermost layer of the atmosphere extending beyond the ionosphere.
- The density is very low and temperature becomes 5568°C.
- This layer merges with the outer space.

About Ionosphere

At heights of 80 km (50 miles), the gas is so thin that free electrons can exist for short periods of time before they are captured by a nearby positive ion. The number of these free electrons is sufficient to affect radio propagation. This portion of the atmosphere is ionized and contains plasma which is referred to as the ionosphere. In plasma, the negative free electrons and the positive ions are attracted to each other by the electromagnetic force, but they are too energetic to stay fixed together in an electrically neutral molecule.

The Ultraviolet (UV), X-Ray and shorter wavelengths of solar radiation ionizes the atmosphere. In this process the light electron obtains a high velocity so that the temperature of the created electronic gas is much higher (of the order of thousand K) than the one of ions and neutrals. The reverse process to Ionization is recombination, in which a free electron is "captured" by a positive ion, occurs spontaneously. The balance between these two processes determines the quantity of ionization present.

Ionization depends primarily on the Sun and its activity. The amount of ionization in the ionosphere varies greatly with the amount of radiation received from the Sun. Thus there is a diurnal (time of day) effect and a seasonal effect.

The ionosphere is broken down into the D, E and F regions.

The D region is the lowest in altitude, it doesn't have a definite starting and stopping point, but includes the ionization that occurs below about 90km. Ionization here is due to Lyman series-alpha hydrogen radiation at a wavelength of 121.5 nanometres (nm) ionizing nitric oxide (NO). In addition, with high Solar activity hard X-rays (wavelength < 1 nm) may ionize (N_2, O_2). Recombination is high in the D layer, the net ionization effect is low, but loss of wave energy is great due to frequent collisions of the electrons. As a result high-frequency (HF) radio waves are not reflected by the D layer but suffer loss of energy therein.

The E region peaks at about 105 km. It absorbs soft x-rays. Normally, this layer can only reflect radio waves having frequencies lower than about 10 MHz. At night the E layer rapidly disappears because the primary source of ionization is no longer present.

The F layer or region, also known as the Appleton layer extends from about 200 km to more than 500 km above the surface of Earth. It is the densest point of the ionosphere, which implies signals penetrating this layer will escape into space. At higher altitudes the amount of oxygen ions decreases and lighter ions such as Hydrogen and Helium become dominant, this layer is the topside ionosphere. Here extreme ultraviolet (UV, 10-100 nm) solar radiation ionizes atomic oxygen. The F layer consists of one layer at night, but during the day, a deformation often forms in the profile that is labeled F_1. The F_2 layer remains by day and night responsible for most skywave propagation of radio waves, facilitating high frequency (HF, or shortwave) radio communications over long distances.

Actually when a radio wave reaches the ionosphere the electric field in the wave forces the electrons in the ionosphere into oscillation at the same frequency as the radio wave. Some of the radio-frequency energy is given up to this resonant oscillation. The oscillating electrons will then either be lost to recombination or will re-radiate the original wave energy. Total refraction can occur when the collision frequency of the ionosphere is less than the radio frequency, and if the electron density in the ionosphere is great enough.

The critical frequency is the limiting frequency at or below which a radio wave is reflected by an ionospheric layer at vertical incidence. If the transmitted frequency is higher than the plasma frequency of the ionosphere, then the electrons cannot respond fast enough, and they are not able to re-radiate the signal. On a more practical note, the D and E regions reflect AM radio waves back to Earth.

CONCEPT OF WEATHER AND CLIMATE

Weather refers to the sum total of the atmospheric conditions in terms of temperature, pressure, wind, moisture etc of a given place and time. It is very dynamic as it may change several times even in a day. Weather changes each day because the air in our atmosphere is always moving, distributing energy from the Sun. In most places in the world, the types of weather events also vary throughout the year as season's change.

Climate on the other hand, is the average weather condition or atmospheric condition of a region over a considerable period of time. The ***regional climate*** is the average weather in a place over more than thirty years. The climate of a region depends on many factors including the amount of sunlight it receives, its height above sea level, the shape of the land, and how close it is to oceans. Since the equator receives more sunlight than the poles, climate varies depending on distance from the equator.

However, ***Global climate*** is a description of the climate of a planet as a whole, with all the regional differences averaged. Overall, global climate depends on the amount of energy received by the Sun and the amount of energy that is trapped in the system. These amounts are different for different planets. Scientists who study Earth's climate and climate change study the factors that affect the climate of the whole planet. While the weather can change in just a few hours, climate changes over longer time-frames.

Earth's climate has been changing for billions of years

Climatologists have used various techniques and evidence to reconstruct a history of the Earth's past climate. They have found that during most of the Earth's history global temperatures were probably 8 to 15 degrees Celsius warmer than today. In the last billion years of climatic history, warmer conditions were broken by glacial periods starting at 925, 800, 680, 450, 330, and 2 million years before present.

The period from 2,000,000 - 14,000 B.P. (before present) is known as the Pleistocene or Ice Age. During this period, large glacial ice sheets covered much of North America, Europe, and Asia for extended periods of time. The extent of the glacier ice during the Pleistocene was not static. The Pleistocene had periods when the glacier retreated (interglacial) because of warmer temperatures and advanced because of colder temperatures (glacial). During the coldest periods of the Ice Age, average global temperatures were probably 4 - 5 degrees Celsius colder than they are today.

By 5000 to 3000 BC average global temperatures reached their maximum level during the Holocene and were 1 to 2 degrees Celsius warmer than they are today. Climatologists call this period the Climatic Optimum. During the Climatic Optimum, many of the Earth's great ancient civilizations began and flourished. In Africa, the Nile River had three times its present volume, indicating a much larger tropical region.

From 3000 to 2000 BC a cooling trend occurred. This cooling caused large drops in sea level and the emergence of many islands (Bahamas) and coastal areas that are still above sea level today. A short warming trend took place from 2000 to 1500 BC, followed once again by colder conditions. Colder temperatures from 1500 - 750 BC caused renewed ice growth in continental glaciers and alpine glaciers, and a sea level drop of between 2 to 3 meters below present day levels.

During the period from 750 BC - 800 AD warming up of atmosphere took place. During the time of Roman Empire (150 BC - 300 AD) a cooling began that lasted until about 900 AD. At its height, the cooling caused the Nile River (829 AD) and the Black Sea (800-801 AD) to freeze.

From 1550 to 1850 AD global temperatures were at their coldest since the beginning of the Holocene. Scientists call this period the Little Ice Age. During the Little Ice Age, the averages annual temperature of the Northern Hemisphere was about 1.0 degree Celsius lower than today. During the period 1580 to 1600, the western United States experienced one of its longest and most severe droughts in the last 500 years. Cold weather in Iceland from 1753 and 1759 caused 25% of the population to die from crop failure and famine.

The period 1850 to present is one of general warming. Many scientists believe the warmer temperatures of the 20th and 21st centuries are being caused by the human enhancement of the Earth's greenhouse effect.

INSOLATION AND TEMPERATURE

The source of all energy on the earth is the Sun. The Sun acts as a great engine that drives winds, ocean currents, exo-genetic or denudation processes and sustains life on the earth. The energy radiated from the Sun comes from the nuclear fusion process taking place in its core, where the temperature is about 15,000,000°C. The solar energy is transmitted in the form of short wave electromagnetic radiations. They travel at the speed of light (about 2, 98,000 km per second).

Insolation

Insolation is a measure of solar radiation energy received on a given surface area in a given time. Solar radiation is radiant energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. The spectrum of solar radiation is close to that of a black body with a temperature of about 5800 K. About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum.

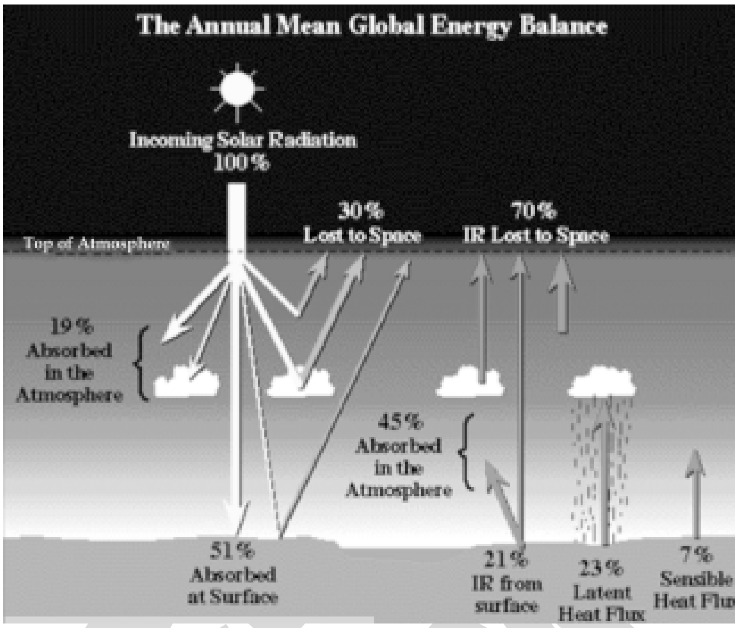
On an average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere.

Factors affecting the distribution of insolation:

- **Distance between the Earth and the Sun-** The solar output received at the top of the atmosphere varies slightly in a year due to the variations in the distance between the earth and the Sun. During its revolution around the Sun, the earth is farthest from the sun (152 million km) on 4th July. This position of the earth is called ***aphelion***. On 3rd January, the earth is nearest to the sun (147 million km). This position is called ***perihelion.*** Therefore, the energy received by the earth on 3rd January is slightly more than the amount received on 4th July.
- **Angle of inclination of the sun's rays-** It depends on the latitude of a place. The higher the latitude the less is the angle it makes with the surface of the Earth, resulting in slanting Sun rays. Hence, the area covered by slanting rays is always higher than that of the vertical rays. Thus, the energy gets distributed in a larger area and the net energy received per unit area decreases. Thus the amount of insolation received at the Earth's surface decreases from equator towards the poles. The total amount of insolation received at the equator is about four times higher than that of the poles.
- **Length of the day-** During the summer season days are longer than the night. The situation is reversed in the winter season. The longer the day, the more is the insolation received by earth.
- **Altitude of land-** Insolation heats up the land which in turn warms the air above it by conduction and convection. As higher land is further away from the main heat source,

it is relatively cooler. Also the density of air decreases with height.

- **Sunspots-** Sunspots are created in the solar outer surface due to periodic disturbances and explosions. The sunspots are cyclic in nature. The increase and decrease of number of sunspots is completed in cycle of 11 years. The amount of insolation received at earth's surface increases and decreases with number of sunspots.



Heat Budget

The Earth's climate is a solar powered system. The earth intercepts only ½ of the billionth fraction of the energy radiated from the Sun. The Earth in turn radiates back the energy received from the sun in the form of long wave terrestrial radiations. As a result, the earth neither warms up nor does it get cooled over a period of time. It maintains its temperature.

This can happen only because the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation. This is known as heat budget of the earth.

Let the solar energy radiated be taken as 100 units. Out of total incoming radiation entering the earth's atmosphere 35 per cent is sent back to space through scattering by dust particles (6%), reflection from clouds (27%) and from the ground surface (2%), 51 per cent is received by the earth's surface and 14 per cent is absorbed by the atmospheric gases and water vapour.

Incoming shortwave solar radiation: equals to 100 units

a) Amount lost to space through scattering and reflection equals to 35% comprises of

- Clouds = 27%
- Reflected by ground = 2%
- Scattered by dust particles = 6%

b) Heat received by earth equals to 51% comprises of

- Through direct radiation = 34%
- Received as diffuse day light = 17%

c) Absorption by the atmospheric gases and water vapour equals to 14%

After receiving energy from the Sun the Earth also radiates energy out of its surface into the atmosphere through long-wave radiation. As we have seen above 51 per cent of heat is absorbed by the earth. Thus at the time of outgoing radiations 23 per cent of the energy is lost through direct long-wave terrestrial radiation (in which 6% absorbed by atmosphere and 17% goes directly to space). About 9 per cent out of 51 per cent is spent in convection and 19 per cent is spent through evaporation. Thus the total energy received by atmosphere from sun and the earth becomes 48 per cent.

The atmosphere receives a total of 14 + 34 = 48 units and this amount is radiated back to space by the atmosphere. The total loss of energy to space thus amounts to 100 units: 35 units reflected by the atmosphere, 17 units lost as terrestrial radiation and 48 units from the atmosphere. In this manner, no net gain or loss of energy occurs in the earth's surface.

Outgoing long-wave terrestrial radiation

a) Reflected by Earth which was equal to 51 per cent as shown above

- 23% from radiation
- 9% through convection
- 19% through evaporation

b) 48% absorbed in atmosphere moved through radiation back into space.

Although the Earth and its atmosphere as a whole have a radiation balance, there are latitudinal variations. The heat energy is transferred from the lower latitudes to the higher latitudes through winds and ocean currents. In the low latitudes (between 400°N and 400°S) heat gained by short wave radiation is far more than the heat loss by long waves through the earth's radiation. In contrast in the higher latitudes more heat is lost by outgoing long wave than it is received in short waves. In view of the imbalances at high and low latitudes, there is large-scale transfer of heat from tropics to high latitudes by atmospheric and oceanic circulation.

Nowadays Green House Gases are disturbing the Earth's heat budget. Carbon dioxide forces the Earth's energy budget out of balance by absorbing thermal infrared energy (heat) radiated by the surface. It absorbs thermal infrared energy with wavelengths in a part of the energy spectrum that other gases, such as, water vapor, do not. Carbon dioxide is a very strong absorber of thermal infrared energy with wavelengths longer than 12-13 micrometers, which means that increasing concentrations of carbon dioxide partially "close" the atmospheric window. In other words, wavelengths of outgoing thermal infrared energy that our atmosphere's most abundant greenhouse gas-water vapor-would have let escape to space are instead absorbed by carbon dioxide.

The absorption of outgoing thermal infrared by carbon dioxide means that Earth still absorbs about 70 percent of the incoming solar energy, but an equivalent amount of heat is no longer leaving. The exact amount of the energy imbalance is very hard to measure, but it appears to be a little over 0.8 watts per square meter.

When increasing greenhouse gas concentrations bumps the energy budget out of balance, it doesn't change the global average surface temperature instantaneously. It may take years or even decades for the full impact of a forcing to be felt. This lag between when an imbalance occurs and when the impact on surface temperature becomes fully apparent is mostly because of the immense heat capacity of the global ocean. The heat capacity of the oceans gives the climate a thermal inertia that can make surface warming or cooling more gradual, but it can't stop a change from occurring.

However, as long as greenhouse gas concentrations continue to rise, the amount of absorbed solar energy will continue to exceed the amount of thermal infrared energy that can escape to space. The energy imbalance will continue to grow, and surface temperatures will continue to rise. This leads to Global Warming.

Temperature

Temperature is the measurement of available heat energy in a system. It is a measure of hotness and coldness of the body. The atmosphere is not heated directly by insolation or the Sun's rays; rather it is heated from below by the warmed surface of the earth, i.e. from terrestrial radiation.

The lower levels of the atmosphere are heated by conduction. The earth's surface is heated during day time after receiving solar radiation. The air coming in contact with the warmer ground surface is also heated because of transfer of heat from the ground surface through the molecules to the air.

The upper levels of the earth get heated by convection. The air coming in contact with the warmer surface of the earth gets heated and expands in volume. The warmer air rose up and forms vertical circulation of air. This mechanism transports heat from the ground surface to the atmosphere, thus helps in heating up of the atmosphere.

Factors controlling the distribution of temperature:

- **Latitude:** In general, average temperature decreases form the equator towards the poles because the sun rays become more and more oblique poleward.

- **Altitude:** the temperature decreases with increasing height from the earth's surface at an average rate of 6.5 °C per 1000 m. The lower layer of air contains more vapour hence it absorbs more heat radiated from the earth's surface than the upper air layers.

- **Mountain Ranges:** In certain areas of the world the existence of high ranges of mountains acts as formidable barrier to the free circulation of air in the lower reaches of the atmosphere. The Himalayas, for example, prevents the monsoon conditions extending further north into the interior of Asia and prevents the extremely cold anticyclonic winter conditions in Central Asia from penetrating Indian subcontinent. Similarly the Western Cordillera (including the Rocky Mountains) of North America prevents the intrusion of the westerly maritime influence of the Pacific into the heartland of the Prairies and Great Plains.

- **Distance from the Sea:** The Sea heats up and cools down much more slowly than the land. The effects of this phenomenon are more noticeable in the temperate latitudes where the warming effect of the sea particularly affects coastal regions in winter. In general, the sea has a moderating effect on the temperatures of the coastal areas throughout the year. On the other hand, regions deep within the interior of land masses experience extreme temperatures. This phenomenon is known as continentality.

- **Ocean Currents:** Ocean currents influence the temperature of the coastal regions particularly where onshore winds carry the influence of warm currents towards coastal regions in winter. Cold currents have a cooling effect on the nearby coasts but have a lesser effect than warm currents due to the fact that they often flow below offshore winds.
- **Clouds:** The presence or absence of clouds in the atmosphere over different regions of the earth's surface has a significant bearing on the temperature of the regions. Clouds have the effect of reducing the amount both of insolation, which reaches the surface of the earth and of outgoing radiation from the earth's surface. As a result, tropical rain forests with dense cloud cover have very little range of temperature, where as, the hot deserts, which have comparatively less cloud cover, have both high diurnal and annual temperature ranges.
- **Prevailing Winds:** Prevailing winds also affect the temperature conditions of the areas. The moderating effects of oceans are brought to the adjacent lands through winds. On the contrary, off shore winds take the effects of warm or cold currents away from land.
- **Local Weather:** Local weather comprises different types of storms, cloudiness, precipitation and other weather conditions. In the equatorial regions, despite the vertical rays of the Sun, large amount of cloudiness obstructs the solar radiation from reaching the earth surface. It is due to the clear sky that near the Tropic of Cancer and the Tropic of Capricorn the amount of solar radiation incident on the earth exceeds that reaching the equatorial regions. Thus, in the subtropical high pressure belt the surface water temperature in the oceans is a little higher. Besides, the incidence of daily afternoon rains in the equatorial regions does not allow the temperatures to rise further, whereas the extremely dry weather and cloudless skies prove helpful in raising the temperatures in the subtropical regions. In the same way in regions of stormy weather the ocean water temperatures are relatively lower.

Concept of Inversion of Temperature

The temperature decreases with the altitudes in the troposphere at an average rate of 6.5 °C per 1000m, this is known as normal lapse rate. But sometimes the temperature increases upward upto a few kilometers from the earth's surface. This is known as inversion of temperature i.e. presence of warm layer of air above the cold layer of air.

Types of inversion of temperature:

1. **Ground surface inversion:** The most common condition for inversion of temperature is through the cooling of the air near the ground at night. Once the sun goes down, the ground loses heat very quickly, and this cools the air that is in contact with the ground. However, since air is a very poor conductor of heat, the air just above the surface remains warm. Conditions that favour the development of a strong surface inversion are calm winds, clear skies, and long nights. Calm winds prevent warmer air above the surface from mixing down to the ground, and clear skies increase the rate of cooling at the Earth's surface. Long nights allow for the cooling of the ground to continue over a longer period of time, resulting in a greater temperature decrease at the surface. Since the nights in the winter time are much longer than nights during the summer time, surface inversions are stronger and more common during the winter months. During the daylight hours, surface inversions normally weaken and disappear as the sun warms the Earth's surface.
2. **Upper air inversion:** The thermal upper air inversion is caused by the presence of ozone layer in the stratosphere. The ozone layer absorbs most of the ultraviolet rays radiated from the sun thus the temperature of this layer becomes higher than the other layers.

Consequences of Temperature Inversions

a) Fog is formed due to the presence of warm air above the cold air. The cold air cools the warm air from below thus forms the tiny droplets around dust particles and smokes during winter season that result in formation of fog.

b) The urban smog is formed by the intensification of fog by pollution. When smog gets mixed with sulphur dioxide it becomes poisonous and deadly for human beings.

c) Inversion of temperature leads to formation of frost. Frost is economically unfavourable weather phenomenon as it damages fruit orchids and crops.

d) The inversion of temperatures creates anticyclonic conditions thus inhibits rainfall and encourages dry conditions.

PRESSURE AND WIND BELTS

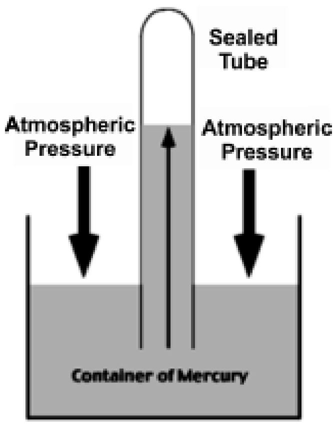
Air Pressure

Air is a mixture of several gases. Gas molecules are in constant state of collision and move freely. Pressure of air at a given place is defined as a force exerted against surface by continuous collision of gas molecules. Air pressure is thus defined as total weight of a mass of column of air above per unit area at sea level. The amount of pressure exerted by air at a particular point is determined by temperature and density which is measured as a force per unit area.

Measuring Atmospheric Pressure

- **Torricelli Barometer**

The instrument that measures air pressure is called a barometer. The first measurement of atmospheric pressure began with a simple experiment performed by Evangelista Torricelli in 1643. In his experiment, Torricelli immersed a tube, sealed at one end, into a container of mercury. Atmospheric pressure then forced the mercury up into the tube to a level that was considerably higher than the mercury in the container. Torricelli determined from this experiment that the pressure of the atmosphere is approximately 30 inches or 76 centimeters (one centimeter of mercury is equal to 13.3 millibars). He also noticed that height of the mercury varied with changes in outside weather conditions.

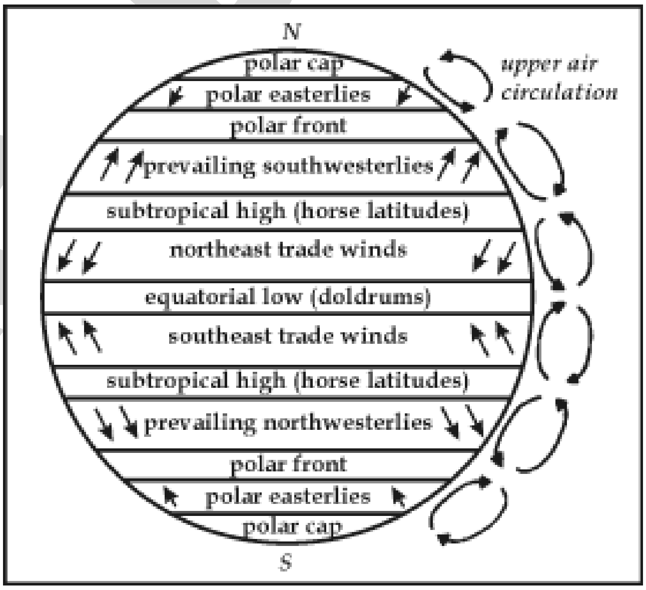


- **Aneroid Barometer**

It is the most common type barometer used in homes. Inside this instrument is a small, flexible metal capsule called an aneroid cell. In the construction of the device, a vacuum is created inside the capsule so that small changes in outside air pressure cause the capsule to expand or contract. The size of the aneroid cell is then calibrated and any change in its volume is transmitted by springs and levers to an indicating arm that point to the corresponding atmospheric pressure.

Standard Sea-level Pressure

For climato-logical and meteoro-logical purposes, standard sea-level pressure is said to be 76.0 cm or 29.92 inches or 1013.2 millibars. Scientists often use the kilopascal (kPa) as their



preferred unit for measuring pressure. 1 kilopascal is equal to 10 millibars. Another unit of force some-times used by scien-tists to measure atmo-spheric pressure is the Newton. One millibar equals 100 newtons per square meter (N/m^2).

Pressure Belts of the World

a) Equatorial Low Pressure Belt:

At the Equator heated air rises leaving a low-pressure area at the surface. This low pressure area is known as ***equatorial low***

pressure. This area extends between 50°N and 50°S latitudes. The zone shifts along with the northward or southward movement of sun during summer solstice and winter solstice respectively. The pressure belt is thermally induced because the ground surface gets heated during the day. Thus warm air expands, rises up and creates low pressure.

b) Sub-tropical High Pressure Belt:

The warm air risen up at the equator due to heating reaches the troposphere and bend towards the pole. Due to coriolis force the air descends at 30-35º latitude thus creates the belt of ***sub-tropical high pressure.*** The pressure belt is dynamically induced as it owes its origin to the rotation of the earth and sinking and settling of winds. This zone is characterized by anticyclonic conditions which cause atmospheric stability and aridity. Thus the hot deserts of the world are present in this region extending between 25-35 degrees in both the hemisphere.

c) Sub-Polar Low Pressure Belt:

This belt is located between 60-65 degrees latitudes in both the hemisphere. This pressure belt is also dynamically induced. As shown in the figure the surface air spreads outward from this zone due to rotation of the earth thus produces low pressure. The belt is more developed and regular in the southern hemisphere than the northern due to over dominance of water in the former.

d) Polar High Pressure Belt:

High pressure persists at the pole due to low temperature. Thus the Polar High Pressure Belt is thermally induced as well as dynamically induced as the rotation of earth also plays a minor role.

> ***Coriolis Force***
>
> ***The rotation of the Earth creates force, termed Coriolis force, which acts upon wind. Instead of wind blowing directly from high to low pressure, the rotation of the Earth causes wind to be deflected off course. In the Northern Hemisphere, wind is deflected to the right of its path, while in the Southern Hemisphere it is deflected to the left. Coriolis force is absent at the equator, and its strength increases as one approaches either pole. Furthermore, an increase in wind speed also results in a stronger Coriolis force, and thus in greater deflection of the wind.***

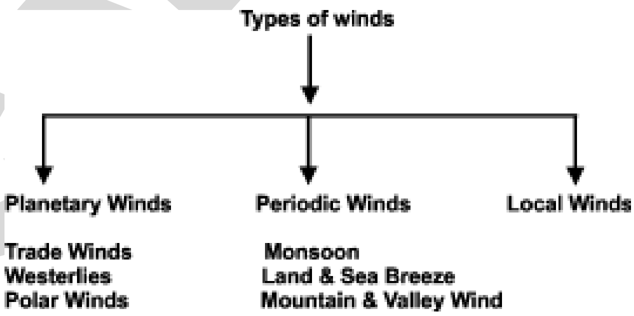
Shifting of Pressure Belts

By late June, when the sun is overhead at the Tropic of Cancer, the doldrums low pressure belts move significantly northwards from the equator with a resultant shift of other belts in the Northern Hemisphere. Similarly, in late December, when the sun is overhead at the Tropic of Capricorn, the belts move southwards.

Winds

When the movement of the air in the atmosphere is in a horizontal direction over the surface of the earth, it is known as the wind. Movement of the wind is directly controlled by pressure.

Horizontally, at the Earth's surface wind always blows from areas of high pressure to areas of low pressure usually at speeds determined by the rate of air pressure change between pressure centres. Wind speed is a function of the steepness or gradient of atmospheric air pressure found between high and low pressure systems. When expressed scientifically, pressure change over a unit distance is called pressure gradient force and the greater this force the faster the winds will blow.



I. Planetary winds:

Planetary winds are major component of the general global circulation of air. These are known as planetary winds because of their prevalence in the global scale throughout the year. Planetary winds occur due to temperature and pressure variance throughout the world.

The planetary winds are discussed below:

(a) Trade wind

Winds blowing from the Subtropical High Pressure Belt or horse latitudes towards the Equatorial Low Pressure Belt or the ITCZ are the trade winds. In the Northern Hemisphere, the trade winds blow from the northeast and are known as the **Northeast Trade Winds**; in the

Southern Hemisphere, the winds blow from the southeast and are called the **Southeast Trade Winds.**

The weather conditions throughout the tropical zone remain more or less uniform. This belt is subjected to seasonal variation due to northward and southward movement of sun.

The equatorward part of the trade wind are humid because they are characterized by atmospheric instability thus causes heavy precipitation.

(b) Westerly Wind

The Westerlies are the prevailing winds in the middle latitudes between 35º and 65º latitude, blowing from the high pressure area in the Sub Tropical High Pressure Belt i.e. horse latitudes towards the sub polar low pressure belt. The winds are predominantly from the south-west to north-east in the Northern Hemisphere and from the north-west to south-east in the Southern Hemisphere.

The Westerlies are strongest in the winter season and times when the pressure is lower over the poles, while they are weakest in the summer season and when pressures are higher over the poles. The Westerlies are particularly strong, especially in the Southern Hemisphere, as there is less land in the middle latitudes to obstruct the flow. The Westerlies play an important role in carrying the warm, equatorial waters and winds to the western coasts of continents, especially in the Southern Hemisphere because of its vast oceanic expanse.

(c) Polar Wind

The winds blowing in the Arctic and the Antarctic latitudes are known as the Polar Winds. They have been termed the **'Polar Easterlies',** as they blow from the Polar High Pressure belt towards the Sub-Polar Low-Pressure Belts. In the Northern Hemisphere, they blow in general from the north-east, and are called the North-East Polar Winds; and in the Southern Hemisphere, they blow from the south-east and are called the South-East Polar Winds. As these winds blow from the ice-capped landmass, they are extremely cold. They are more regular in the Southern Hemisphere than in the Northern Hemisphere.

II. Periodic Winds:

Land and sea breezes and monsoon winds are winds of a periodic type. Land and sea breezes occur daily, whereas the occurrence of monsoon winds is seasonal. Following are periodic winds:

(a) Monsoon winds

(b) Land and Sea Breeze

(c) Mountain and Valley Breeze

(a) Monsoon Winds

Monsoons are regional scale wind systems that predictably change direction with the passing of the seasons. Like land and sea breezes, these wind systems are created by the temperature contrasts that exist between the surfaces of land and ocean. However, monsoons are different from land and sea breezes both spatially and temporally. Monsoons occur over distances of thousands of kilometers, and their two dominant patterns of wind flow act over an annual time scale.

Summer Monsoon

During the summer, monsoon winds blow from the cooler ocean surfaces onto the warmer continents. In the summer, the continents become much warmer than the oceans because of a number of factors. These factors include:

(i) Specific heat differences between land and water.

(ii) Greater evaporation over water surfaces.

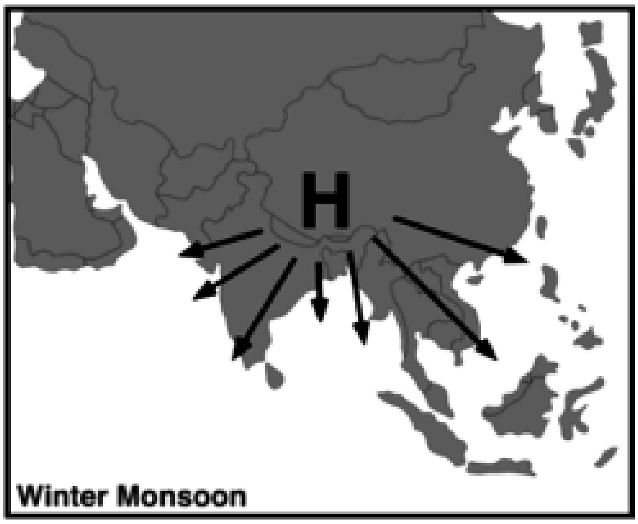
(iii) Subsurface mixing in ocean basins, which redistributes heat energy through a deeper layer.

Precipitation is normally associated with the summer monsoons. Onshore winds blowing inland from the warm ocean are very high in humidity, and slight cooling of these air masses causes condensation and rain. In some cases, this precipitation can be greatly intensified by orographic uplift. Some highland areas in Asia receive more than 10 meters of rain during the summer months.

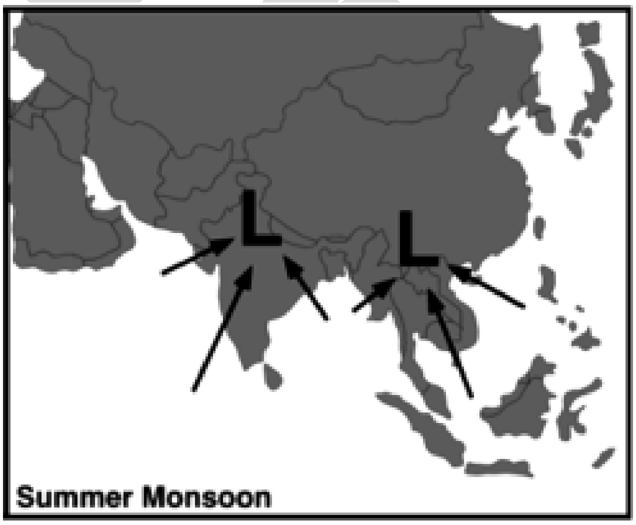
Winter Monsoon

In the winter, the wind patterns reverses, as the ocean surfaces are now warmer. With little solar energy available, the continents begin cooling rapidly as longwave radiation is emitted to space. The ocean surface retains its heat energy longer because of water's high specific heat and subsurface mixing. The winter monsoons bring clear dry weather and winds that flow from land to sea.

World Monsoonal Climate



The Asiatic monsoon is the result of a complex climatic interaction between the distribution of land and water, topography, and tropical and mid-latitudinal circulation. In the summer, a low-pressure centre forms over Northern India and Northern Southeast Asia because of higher levels of received solar insolation. Warm moist air is drawn into the thermal lows from air masses over the Indian Ocean. Summer heating also causes the development of a strong latitudinal pressure gradient and the development of an easterly jet stream at an altitude of about 15 kilometers at the latitude of 25° north. The jet stream enhances rainfall in Southeast Asia, in the Arabian Sea, and in South Africa. When autumn returns to Asia the thermal extremes between land and ocean decrease and the westerlies of the mid-latitudes move in. The easterly jet stream is replaced with strong westerly winds in the upper atmosphere. Subsidence from an upper atmosphere cold low above the Himalayas produces outflow that creates



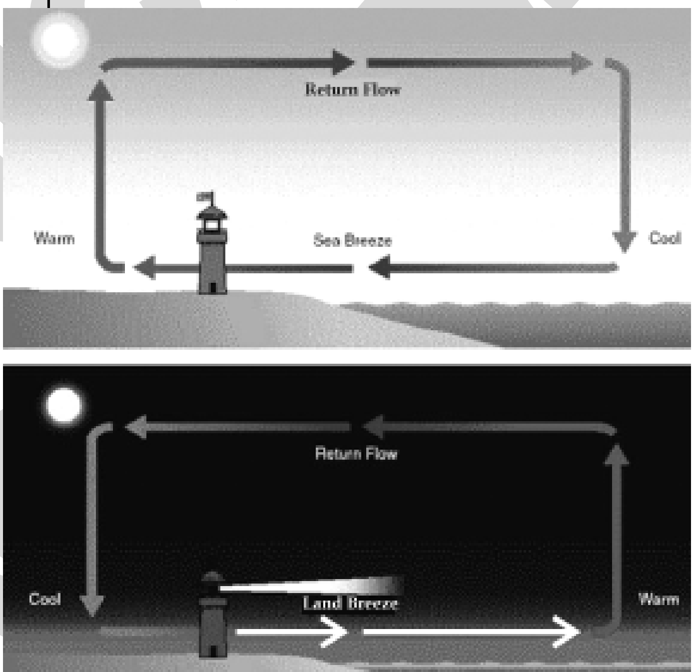
a surface high-pressure system that dominates the weather in India and Southeast Asia.

Besides, Asian continent, monsoon wind systems also exist in Australia, Africa, South America, and North America.

(b) Land and Sea Breezes:

A **land breeze** is created when the land is cooler than the water such as at night and the surface winds have to be very light. When this happens the air over the water slowly begins to rise, as the air begins to rise, the air over the surface of the ocean has to be replaced, this is done by drawing the air from the land over the water, thus creating a sea breeze.

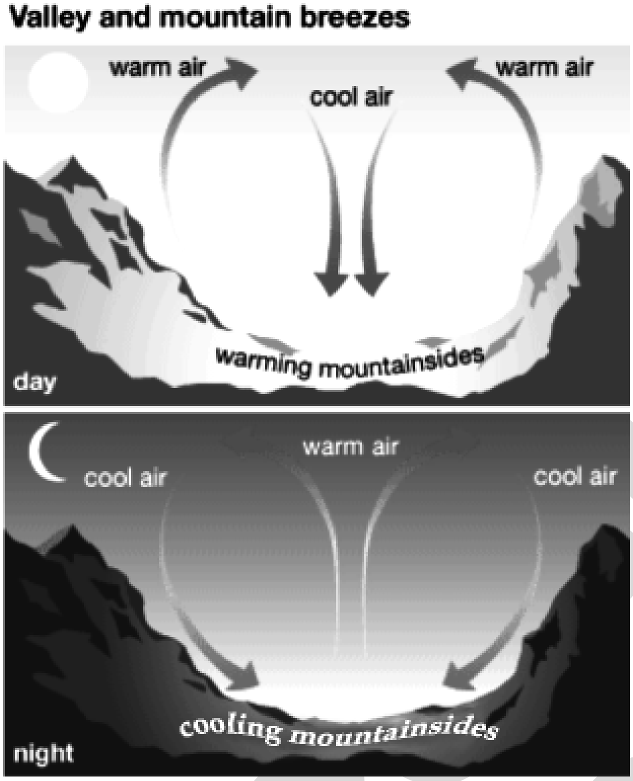
A **sea breeze** is created when the surface of the land is heated sufficiently to start rising of the



air. As air rises, it is replaced by air from the sea; you have now created a sea breeze. Sea breezes tend to be much stronger and can produce gusty winds as the sun can heat the land to very warm temperatures, thereby creating a significant temperature contrast to the water.

(c) Mountain and Valley winds:

Mountain-valley breezes are formed by the daily difference of the thermo effects between peaks and valleys. In daytime, the mountainside is directly heated by the sun, the temperature is higher, air expands, air pressure reduces, and therefore air will rise up the mountainside from the valley and generate a valley breeze. The valley breeze reaches its maximum force at around 2 p.m. After this time, the breeze decreases in power and come to a complete stop by sunset. By nightfall, the mountainside region is able to dissipate heat more quickly, due to its higher altitude and therefore temperature drops rapidly. Cold air will then travel down the mountainside from the top and flow into the valley, forming a mountain breeze.



In daytime, valley breezes carry water vapour to the peak, which will often condense into clouds; these are the commonly seen peak and flag clouds. When the mountain breeze travels down and gathers in the valleys, water vapour will condense. Therefore in valley or basin regions, there are usually clouds and fog before sunrise. During late spring or early autumn, the cold air trapped in the valley and basin will often generate frost. That's why farmers usually plant cold-sensitive plants such as tangerines and coffee on mountainsides.

III. Local Winds

These local winds blow in the various region of the world.

Hot Winds

Sirocco	-	Sahara Desert
Leveche	-	Spain
Khamsin	-	Egypt
Harmattan	-	Sahara Desert
Santa Ana	-	USA
Zonda	-	Argentina
Brick fielder	-	Australia

Cold Winds

Mistral	-	Spain and France
Bora	-	Adriatic coast
Pampero	-	Argentina
Buran	-	Siberia

Descending Winds

Chinook	-	USA
Fohn	-	Switzerland
Berg	-	Germany
Norwester	-	New Zealand
Samun	-	Persia (Iran)
Nevados	-	Ecuador

JET-STEAMS

The JET STREAMS located in the upper troposphere (9 - 14 km) are bands of high speed winds (95-190 km/hr). The term was introduced in 1947 by Carl Gustaf Rossby. Average speed is very high with a lower limit of about 120 Kms in winter and 50 km per hours in summer. The two most important types of jet streams are the ***Polar Jet Streams*** and the ***Subtropical Jet Streams.*** They are found in both the Northern and Southern Hemispheres.

Polar Jet Stream: These jet streams are created when cold air from the Polar Regions meets warmer air from the equator. This temperature gradient as a result forms a pressure gradient that increases wind speed. During the winter, these jet streams bring winter storms and blizzards to the United States and in summer, they become weaker and move towards high latitudes. They are found in both the Northern and Southern Hemispheres.

Sub-Tropical Jet Stream: These jet streams are formed as warm air from the equator moves towards the poles that form a steep temperature incline along a subtropical front that like the polar jet streams produce strong winds. In Southeast Asia, India, and Africa, these jet streams help bring about the region's monsoon or rainy climate. As these jet streams warm the air above the Tibetan highlands, a temperature and pressure gradient is formed as the air from the ocean is cooler than that above the continental high lands. This as a result forms on-shore winds that produces the monsoon.

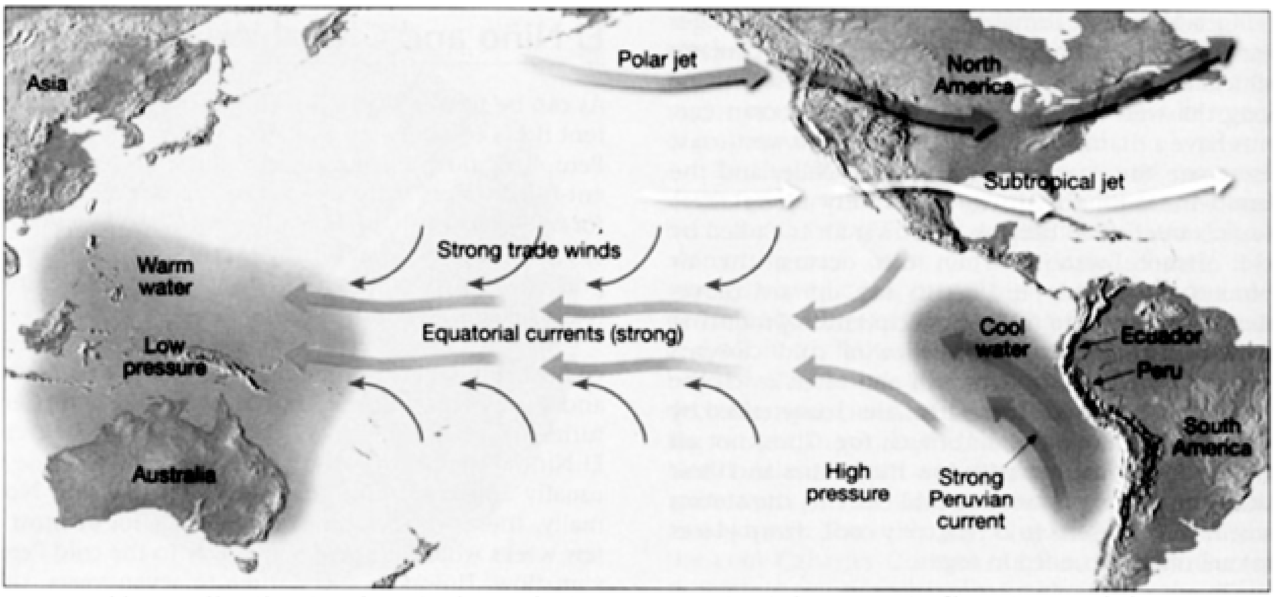
Formation of Jet Stream

Warm air masses in the south meet cool air masses from the north and create temperature and air pressure gradients. In wind speed, the pressure difference between a high and low pressure zone can be very large, thereby creating high winds. Pressure and temperature differences in the jet stream can be large as a global warm front from the south and a cold front from the north meet.

EL NIÑO AND LA NINA SITUATION

Normal condition

In general, the water on the surface of the ocean is warmer than at the bottom because it is heated by the sun. In the tropical Pacific, winds generally blow in easterly direction. These winds tend to push the surface water toward the west also. As the water moves west it heats up even more because it's exposed longer to the sun.



Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

Meanwhile in the eastern Pacific along the coast of South America an upwelling occurs. Upwelling is the term used to describe when deeper colder water from the bottom of the ocean moves up toward the surface away from the shore. This nutrient-rich water is responsible for supporting the large fish population commonly found in this area. Indeed, the Peruvian fishing grounds are one of the five richest in the world.

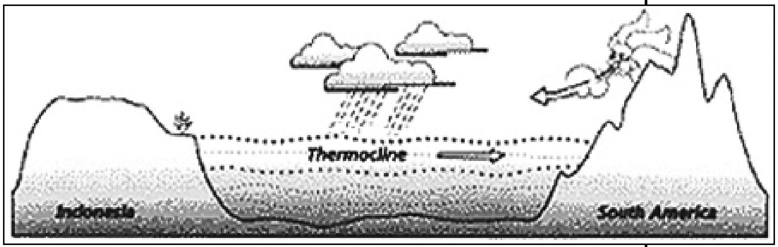
Because the trade winds push surface water westward toward Indonesia, the sea level is roughly half a metre higher in the western Pacific than in the east. Thus forms warmer, deeper waters in the western Pacific and cooler, shallower waters in the east near the coast of South America. The different water temperature of these areas affects the types of weather these two regions experience.

In the east the water cools the air above it, and the air becomes too dense to rise to produce clouds and rain. However; in the western Pacific the air is heated by the water below it, increasing the buoyancy of the lower atmosphere thus increasing the likelihood of rain. This is why heavy rain storms are typical near Indonesia while Peru is relatively dry.

El Niño condition

El Nino happens when weakening trade winds (which sometimes even reverse direction) allow the warmer water from the western Pacific to flow toward the east. This flattens out the sea level, builds up warm surface water off the coast of South America, and increases the temperature of the water in the eastern Pacific.

An El Nino condition results from weakened trade winds in the western Pacific Ocean near Indonesia, allowing piled-up warm water to flow toward South America.



Since fish can no longer access this rich food source, many of them die off. That is why, these conditions are called "El Nino", or "the Christ Child", which is what Peruvian fisherman call the particularly bad fishing period around December. More importantly, the different water temperatures tend to change the weather of the region.

What happens to the ocean also affects the atmosphere. Tropical thunderstorms are fueled by hot, humid air over the oceans. Hotter the air, the stronger and bigger the thunderstorms. As the Pacific's warmest water spreads eastward, the biggest thunderstorms move with it.

The clouds and rainstorms associated with warm ocean waters also shift toward the east. Thus, rains which normally would fall over the tropical rain forests of Indonesia start falling over the deserts of Peru, causing forest fires and drought in the western Pacific and flooding in South America. Moreover the Earth's atmosphere reponds to the heating of El-Nino by producing patterns of high and low pressure which can have a profound impact on weather far away from the equatorial Pacific. For instance, higher temperatures in western Canada and the upper plains of the United States whereas colder temperatures in the southern United States. The east coast of southern Africa often experiences drought during El Nino.

La Nina

If, on the other hand, the surface trade winds strengthen and with it the east-west slopes and along with it the east-west oceanic temperature gradients the resulting weather pattern leads to an anti-El Niño, that is often referred to as La Niña. Such events are characterized by a high positive Southern Oscillation Index (i.e. an increased westward pressure gradient over the equatorial Pacific), stronger surface trade winds over the central Pacific, and cooler SSTs in the eastern equatorial Pacific. Such a weather pattern, on the other hand, is associated with increased cyclone activity in the western Pacific, off shore of eastern Australia, the Phillipines, and the western Atlantic region.

CLOUDS AND PRECIPITATION

Moisture, or water vapour, is an extremely important constituent of the atmosphere. Water vapour present in the air is known as Humidity. The nature and amount of precipitation, the amount of loss of heat through radiation from the earth's surface, latent heat of atmosphere etc depend on the amount of water vapour present in the atmosphere.

Water vapour is derived through the process of evaporation from oceans, seas, rivers, lakes etc. Humidity capacity that is content of water vapour in the air is directly positively related with temperature i.e. higher the temperature higher the humidity capacity. Oceanic and coastal areas record higher humidity capacity. It decreases from equator to pole.

Humidity of a place can be expressed in three ways

Absolute Humidity: The measure of water vapour content of the atmosphere which may be expressed as the actual quantity of water vapour present in a given volume of air is called Absolute Humidity. The absolute humidity is measured in terms of grain per cubic metre air. If the absolute humidity of air at a given place is 10 gm/cu m. it means that 10 grams of water vapour are present in a cubic metre of air. Absolute humidity of the air changes from place to place and from time to time. The ability of air to hold water vapour depends entirely on its temperature. Warm air can hold more moisture than the cold air.

Specific Humidity: Another way to express humidity as the weight of water vapour per unit weight of air or the proportion of the mass of water vapour to the total mass of air is called the specific humidity. Specific humidity is not affected by changes in pressure of temperature.

Relative Humidity: A more useful measure of humidity of the atmosphere is called the relative humidity. This is a ratio expressed as a percentage between the actual quantity of water vapour present in the air at a given temperature and the maximum quantity of water vapour that the atmosphere can hold at that temperature. Relative humidity determines the amount and rate of evaporation and hence it is an important climatic factor. With the same quantity of water vapour, relative humidity will decrease with increase of temperature and vice versa.

Condensation: Concept Related to Climatology

Condensation is the transformation of gaseous form of water into solid form i.e. ice and liquid form i.e. water.

Mechanism of Condensation

The mechanism of condensation depends upon the amount of relative humidity present in the air. When the air achieves 100 per cent relative humidity, it is called as saturated air (no more water vapour can added to it).

The temperature at which air becomes saturated is known as dew point and condensation starts only at this point. If the temperature at dew point is above freezing point condensation occurs in the form of fog, rainfall, etc. On the other hand if the dew point is below freezing point condensation occurs in the form of snow, frost, etc.

How saturation of air is achieved

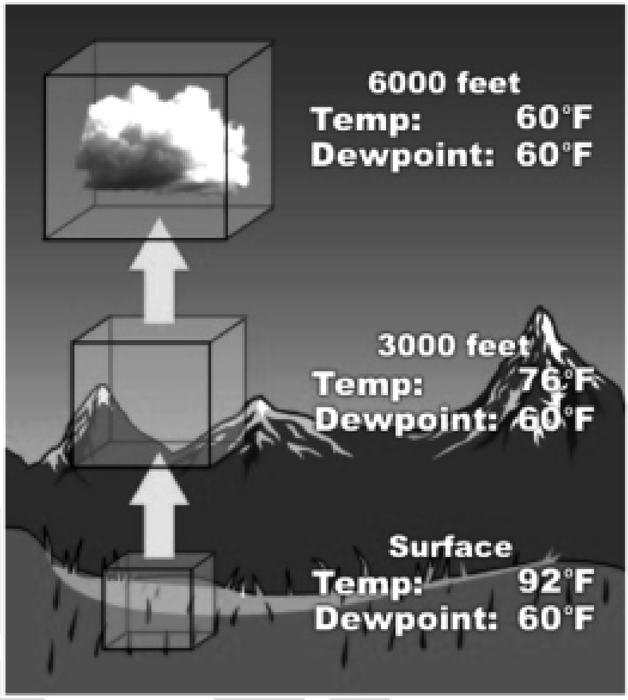
Method 1: When the absolute humidity at a given temperature is raised equal to the humidity retaining capacity of the air.

Method 2: When the temperature of the air is reduced to such an extent that the humidity capacity becomes equal to its absolute humidity.

Concept of Adiabatic change of temperature

If the change in temperature of air takes place by the ascent and descent of air and no addition or subtraction of heat occurs then this process is known as adiabatic change of temperature.

When the air is warmer than the surrounding air-mass, it ascends. Due to upward movement of air, volume increases and the temperature decreases. As the dew point is achieved, condensation process starts and leads to formation of clouds, fog and ultimately leads to precipitation. Thus instability of air causes different weather phenomenon. In the process explained above there is no addition or subtraction of heat and the process is solely due adiabatic change of temperature.



On the other hand if the dew point is not achieved, the air becomes colder than surrounding air. Thus the air descends and becomes cooler. This leads to stability of air and weather phenomenon get hampered.

Clouds and its types

A cloud is a visible mass of liquid droplets or frozen crystals made of water and/or various chemicals suspended in the atmosphere above the surface of a planetary body.

In general, clouds form when rising air is cooled to its dew point (the temperature at which the air becomes saturated). Water vapour normally begins to condense on condensation nuclei such as dust, ice, and salt in order to form clouds. If sufficient condensation particles are not present, the air will become supersaturated and the formation of cloud or fog will be inhibited.

The cloud formation is generally due to ***adiabatic cooling.***

Sources of water vapour

The main sources from which water vapour is added to the air are: wind convergence over water or moist ground into areas of upward motion, precipitation, daytime heating leading to evaporation of water from the surface of oceans, water bodies or wet land and transpiration from plants.

Significance of clouds

Clouds are very significant because:

- They cause all forms of precipitation.
- They play a major role in the heat budget of the earth.
- They reflect, absorb some part of incoming solar radiation as well as some part of long-wave terrestrial radiation re-radiated by the earth.

Types of clouds

1. **Cirrus clouds:** These clouds form above 20,000 feet (6,000 meters) and since the temperatures are extremely low at such high elevations, these clouds are primarily composed of ice crystals. High-level clouds are typically thin and white in appearance, but can appear in a magnificent array of colours when the sun is low on the horizon.

2. **Cirro-cumulus:** These clouds appear as small, rounded white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish. A sky with cirrocumulus clouds is sometimes referred to as a "mackerel sky."

3. **Cirro-stratus:** These clouds are thin, sheet-like high clouds that often cover the entire sky. They are so thin that the sun and the moon can be seen through them.

Cirrus clouds

Cirro-cumulus

Cirro-stratus

4. **Altocumulus clouds:** These are middle level clouds that are made up of water droplets and appear as grey, puffy masses, sometimes rolled out in parallel waves or bands.

5. **Altostratus clouds:** These are grey or blue-grey middle level clouds composed of ice crystals and water droplets. These clouds usually cover the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. Altostratus clouds often forms ahead of storms that produces continuous precipitation.

Altocumulus clouds

Altostratus clouds

6. **Stratus clouds:** These are uniform greyish clouds that often cover the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle. When a thick fog "lifts," the resulting clouds are low stratus.

7. **Nimbostratus clouds:** These form a dark grey, "wet" looking cloudy layer associated with continuously falling rain or snow. They often produce precipitation that is usually light to moderate.

Stratus clouds

Nimbo-Stratus clouds

8. **Cumulonimbus clouds:** These are thunderstorm clouds that form if cumulus congestus clouds continue to grow vertically. Their dark bases may be no more than 300 m (1000 ft) above the Earth's surface. Their tops may extend upward to over 12,000 m (39,000 ft). Tremendous amount of energy is released by the condensation of water vapour within a cumulonimbus. Lightning, thunder, and even violent tornadoes are associated with the cumulonimbus.

9. **Cumulus clouds:** These are puffy clouds that sometimes look like pieces of floating cotton. The base of each cloud is often flat and may be only 1000 m (330 ft) above the ground. The top of the cloud has rounded towers. When the top of the cumulus resembles the head of a cauliflower, it is called cumulus congestus or towering cumulus. These clouds grow upward, and they can develop into a giant cumulonimbus, which is a thunderstorm cloud.

Cumulonimbus clouds

Cumulus clouds

Fog

Fog is a cloud in contact with the ground which reduces visibility to less than 1 km. Fog is formed when water vapour condenses on condensation nuclei (or particles) in the air near the ground. When conditions are right these water particles continue to attract more water vapour and grow until the particles become visible.

There are however, several conditions that initiate the process of fog formation. Fog usually develops when relative humidity is near 100% and when the air temperature and dew point temperature are close to one another or less than 4°F (2.5 °C). As a result, the water vapour condenses to form water droplets and fog.

Types of Fog:

a) Radiation Fog

Radiation fog forms when moist air is cooled below its dew-point by contact with a cold land surface that is losing heat by radiation. The ideal conditions are:

- High relative humidity at low levels so that overnight cooling will be sufficient for the air temperature to fall to below its dew point temperature resulting in condensation occurring.
- Cloudless, or near cloudless skies, to allow a large heat loss at the ground, and subsequent cooling of the air in contact with the ground.
- Light winds to promote mixing of this cooled air through a few hundred feet of the surface (a calm wind tends to restrict the fog to low-lying pockets).

b) Advection Fog

Advection fog develops when warm moist air moves over a cooler surface resulting in the cooling of the air to below its dew point temperature, and subsequent saturation and condensation. Radiation processes frequently assist in the formation and maintenance of this type of fog, but it is still usually called an advection fog. A certain amount of turbulence is needed for proper development of advection fog, thus wind between 6-15 knots are commonly associated with advection fog. Not only does the turbulence facilitate cooling through a thicker layer, but it also carries the fog to greater heights. Unlike radiation fogs, advection fogs are often thick and persistent.

c) Sea Fog

Sea fogs are usually advection fogs. They develop when moist air that has been lying over a warm water surface moves over a colder water surface, resulting in the cooling of this air to below its dew point temperature.

d) Steam Fog

Steam fog is caused by evaporation from water into overlying colder air, causes the air to become saturated and condensation to occur. The convection currents above the water give rise to the steaming appearance. The fog may remain in situ but any light wind may advect it many kilometres. This is a common occurrence in areas where large, shallow and warm waterways and dams exist. In coastal areas where cool land breezes have opportunity to flow across warm seas, steam fog can be extensive and lift into low stratus.

e) Frontal Fog

Frontal fog occurs at the boundary of two air masses rather than within a single air mass. It mainly develops due to precipitation falling from relatively warm air above a frontal surface, evaporating into drier and cooler air below, causing this air to saturate and condense. Such fogs usually form rapidly and are very extensive.

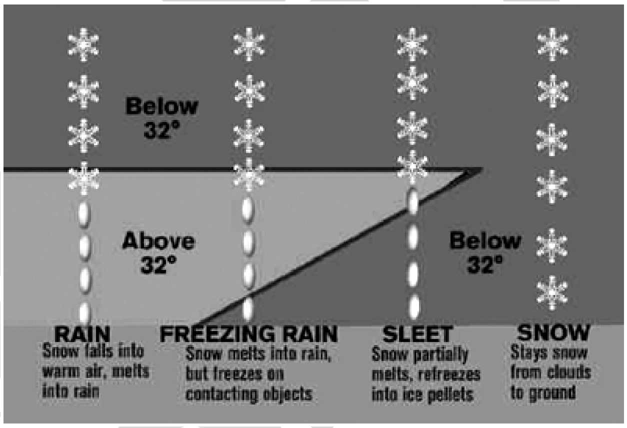
Impacts of fogs

Fog occurrence impacts a wide variety of human activities worldwide. The fog droplets collect the pollutants present near ground surface. These pollutants contain toxic gases like sulphur dioxide, ammonia, hydrochloric acid, nitrogen oxides and radioactive isotopes (natural and anthropogenic). These pollutants frequently stick to the fog droplets, posing threats to health of the people breathing in such environment. The reduced visibility caused by fog, results into economic losses due to its impact on aviation, land and marine transportation.

Precipitation

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail on the Earth's surface.

When air is lifted in the atmosphere, it expands and cools and leads to the formation of clouds. The clouds floating overhead contain water vapour and cloud droplets, which are small drops of condensed water. For precipitation to happen, first tiny water droplets must condense on even tinier dust, salt, or smoke particles, which act as a nucleus. Some vapour freezes into tiny ice crystals which attract cooled water drops. The drops freeze to the ice crystals, forming larger crystals known as snowflakes. When the snowflakes become heavy, they fall as it exceeds the cloud updraft speed. When the snowflakes meet warmer air on the way down, they melt into raindrops.

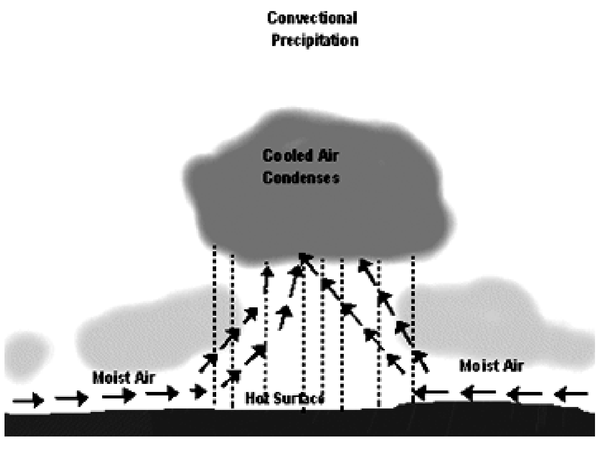


Rainfall and Its Types

Rain is the most common form of precipitation. When minute droplets of water are condensed from water vapour in the atmosphere on to nuclei, they may float in the atmosphere as clouds. If the droplets coalesce, they will form larger drops which will be enough to overcome by gravity and will fall as RAIN to the surface of the earth.

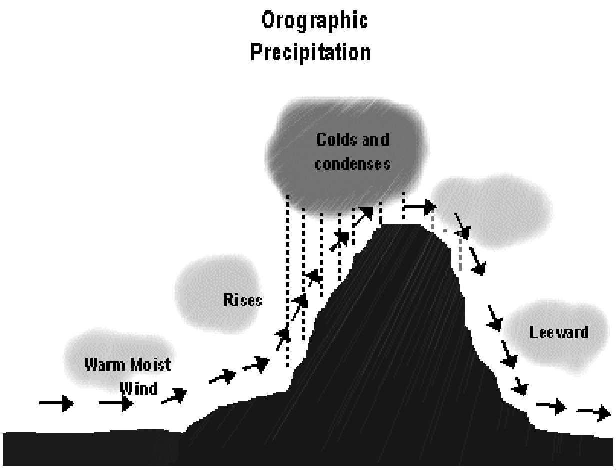
There are three main types of rainfall

a) **CONVENTIONAL RAINFALL:** It occurs when moist air, having been warmed by Conduction from a heated surface, expands, rises and is adiabatically cooled to the Dew Point. Cumulus clouds develop and may fall accompanied by Thunder.



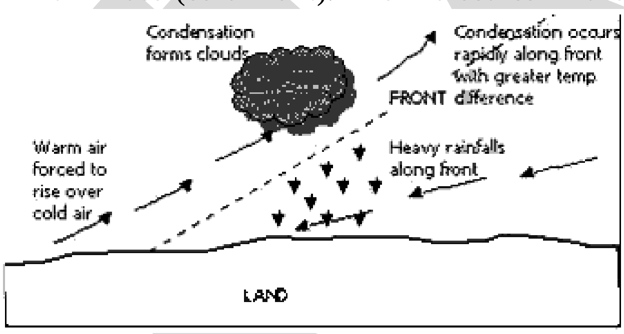
Convectional rainfall occurs commonly during the afternoon near the equator, due to high temperature and high humidity.

b) **OROGRAPHIC RAINFALL:** This type of rainfall occurs when air is forced to ascend



the side of a mountain range. When land barriers such as mountain ranges, hilly regions or even escarpments of plateaus lie in the path of prevailing winds, large portion of the atmospheric air is forced to rise above these barriers. This resultant precipitation is termed as orographic. Because the air has deposited on the windward side of the mountain, there will normally less rainfall on the leeward side which is known as Rain Shadow Area.

c) **FRONTAL RAINFALL:** Cyclonic or Frontal precipitation results when the warm, moist air mass (warm front) meets a cool and dry air mass (cold front). The molecules in the



cold air are more tightly packed together (i.e., more dense), and thus, the cold air is heavier than the warm air. The warmer air mass is forced up over the cool air. As it rises, the warm air cools, the water vapour in the air condenses, and forms clouds and results in precipitation.

This type of system is called Frontal Precipitation because the moisture tends to occur along the front of the air mass.

Global Distribution of Rainfall

The global distribution of precipitation is influenced by the general circulation of the atmosphere, proximity to large bodies of water, and topography.

Factors controlling the distribution of rainfall over the earth's surface are the belts of converging-ascending air flow, air temperature, moisture-bearing winds, ocean currents, distance inland from the coast, and mountain ranges.

The Earth's atmosphere is known to have regions characterized by large scale rising air, and other regions with descending air; these vary by latitude and by season. Rising air is found primarily near the equator and in the mid-latitudes (40° to 60° North and South latitude), so these tend to be wet areas. Descending air dominates in the subtropics (20° to 30° North and South latitude) and the poles. The global distribution of precipitation shows that the wettest areas on Earth are in the "rising air" zones, while the driest areas (subtropical deserts and the even drier polar areas) are in the "descending air" belts.

The Earth revolves around the Sun thus the orientation of its axis relative to the Sun changes. This causes the apparent position of the Sun relative to the Earth to change, and creates distinct seasons. Between March and September, the axis of Earth is tilted toward the Sun, and hence the Sun shines more directly over the Northern Hemisphere, resulting in more sunlight, more heat, and the warmer temperatures of Northern summer. In the other 6 months, the Earth's axis is tilted away from the Sun, and the Sun shines more directly over the Southern Hemisphere, bringing summer to countries south of the Equator (and winter to the north).

The "rising" and "sinking" zones move northward and southward with the Sun's path. Thus, the wet area near the Equator moves northward into the Northern Hemisphere in its summer and southward into the Southern Hemisphere during its summer. Similarly, the dry zones and wet zone at higher latitudes shift northward and southward throughout the year.

The result of these shifting zones is latitude bands with distinctive precipitation characteristics:

0-5° latitude: wet throughout the year (rising zone)

5-20° latitude: wet summer (rising zone), dry winter (sinking zone)

20-30° latitude: dry all year (sinking zone)

30-50° latitude: wet winter (rising zone), dry summer (sinking zone)

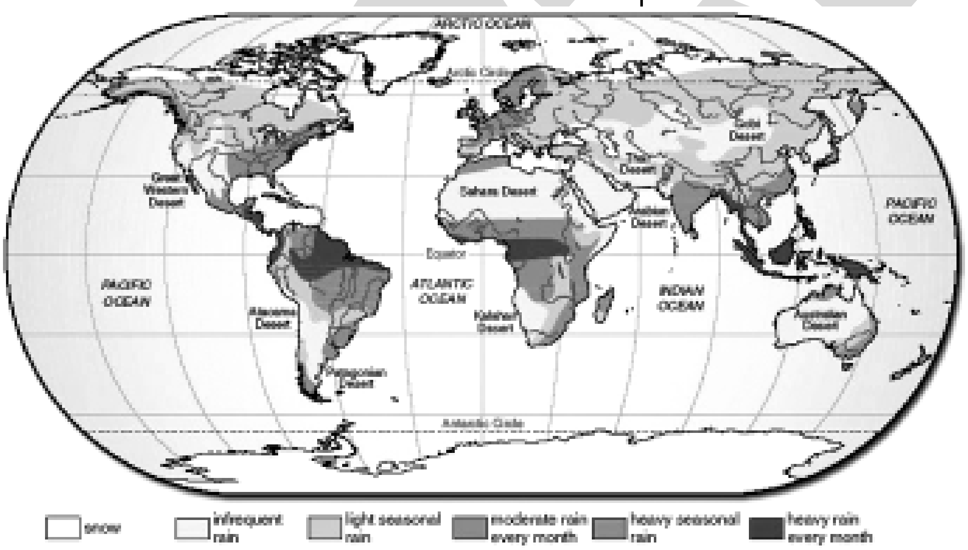
50-60° latitude: wet all year (rising zone)

60-70° latitude: wet summer (rising zone), dry winter (sinking zone)

70-90° latitude: dry all year (sinking zone)

If the Earth had no mountains, and oceans were homogeneous with respect to their heat content, the climate would occur in latitude bands like those listed above. However, due to presence of mountains, strong influence on precipitation exerts.

When moving air encounters a hill or mountain, it is forced to rise. As the rising air cools and condenses, precipitation is heaviest on the upwind side of a mountain, where the air is rising. This process is known as orographic lifting. On the downwind side, air descends, warms, and becomes drier thus forms rain shadow area. One example of a mountainous area receiving frequent rain is Mt. Waialeale on Kauai, Hawaii. It is a sharp peak directly in the path of steady trade winds which blow from the northeast most of the time. On the upwind (northeast) side of Waialeale, the air rises and condenses; resulting in almost constant clouds-nearly every day thus experiences rain. Waialeale is among the wettest places on Earth. In contrast, on the downwind (southwest) side of Mt. Waialeale, the air descends, warms, and dries, in an area known as a "rain shadow." The result is a semiarid area with less than 51 centimeters (20 inches) of rain a year.



The other factor that affects the rainfall distribution is presence of water bodies i.e. oceans, lakes, rivers, etc.

Zonal distribution of rainfall

- **Equatorial zone of maximum rainfall:** this zone extends **upto 10°** latitudes on either side of the equator characterized by warm and moist air masses. Rainfall occurs mainly due to convectional rainfall and mean annual ranges from 1750 mm to 2000 mm.
- **Trade wind rainfall zone:** This zone extends between **10-20 degree** latitudes in both the hemispheres and is characterized by north-east and south-east trade winds. These winds yield rainfall in the eastern part of the continent as they flow over oceans and brings moisture. Thus, the western part of the continents becomes extremely dry and deserts.
- **Subtropical zone of minimum rainfall:** This zone extends between **20-30 degree** latitudes in both the hemisphere where descending air from above induces high pressure and winds thus results in anti cyclonic conditions.
- **Mediterranean rainfall zone:** This rainfall zone extends between **30-40 degree** latitudes in both the hemispheres where rainfall occurs through Westerlies and cyclones during winter season while summer seasons are dry.
- **Mid-latitudinal zone:** This zone extends between **40-50 degrees** latitudes in both the hemispheres where rainfall occurs due to Westerlies and Temperate Cyclones.
- **Polar zone:** It extends from 6**0 degrees to pole** in both the hemispheres. Precipitation mainly occurs in the form of snow.

Terminologies

Hydrologic cycle: The exchange of water between the oceans, the atmosphere and continents through evaporation, transpiration, condensation and precipitation is called hydrologic cycle.

Humidity: It refers to the invisible amount of water vapour present in the air.

Dew point: The temperature at which saturation occurs in a given sample of air is known is dew point.

Evaporation: It is the process by which water is transformed from liquid to gaseous form.

Condensation: It is the process of change of state from gaseous to liquid or solid state.

Latent heat: The amount of energy emitted or absorbed when a body changes its state or phase, without any change of temperature within that body.

Adiabatic change: It refers to the changes of temperature which occurs in a mass of gas (air) when it is compressed (heated) or expanded (cooled) without the aid of any external sources of heating and cooling.

Dew: The moisture deposited in the form of water droplets on the surface of vegetation and other objects located near to ground level.

White Frost: When the dew point is below the freezing point, minute crystals of ice are deposited instead of droplets of water. These crystals of ice are called white frost.

Fog: It is a cloud with its base at or very near the ground. The visibility is less than 1km.

Mist: It is a kind of fog in which the visibility is more than 1km, but less than 2 kms.

Cloud: It is a mass of minute droplets of water or tiny crystals of ice formed by condensation of the water vapour in free air at considerable elevation.

Precipitation: Condensation of water vapour in the air in the form of water droplets and ice and their falling on the ground is called precipitation.

Sleet: Sleet is frozen raindrops and re-frozen melted snow water.

Rain Shadow area: The leeward slope, where no rain occurs and remains dry is known as rain shadow area.

Absolute Humidity: The weight of actual amount of water-vapour present in unit volume of air.

Specific Humidity: The weight of water-vapour per unit weight of air or the proportion of the mass of water-vapour to the total mass of air in units of weight.

Relative Humidity: The ratio of the air's actual water-vapour content to its water-vapour capacity at a given temperature. The relative humidity of the saturated air is 100 per cent.

Haze: Haze is formally formed by water particles that have condensed around nuclei in the atmosphere, but may also be a result of particles of smoke dust or salt in the air visibility to fewer than 2 km but over 1 km.

Frost: Frost forms when air temperatures have fallen below the freezing point. Conditions favourable for frost are a mass of dry cool polar air followed by clear, calm nights during which the surface air may be reduced to below freezing. Frost is common in temperate lands. It is very harmful to plants. Most crops are sensitive to frost.

Hail: When there are strong ascending currents, condensation takes place at high levels at temperatures below freezing point. The ice particles grow in size as they do not fall down due to the force of ascending currents. When the ice particles get larger in size, they fall down owing to their weight. This form of precipitation is known as hail and the large ice particles are known as hailstones.

AIR MASS

An air mass is a large body of air of relatively similar temperature and humidity characteristics, covering thousands of square kilometers. The vertical distribution of temperature and moisture content of the air mass are two basic properties which controls the weather conditions of the area affected by that air mass.

Generally, air masses are classified according to the characteristics of their ***source region*** or area of formation. An air mass originates when atmospheric conditions remain stable and uniform for over a long period so that the air lying above the area attains the temperature and moisture characteristics of the ground surface.

The ***primary classification*** of air masses is based on the characteristics of the source region, giving ***Arctic (A), Polar (P)*** or ***Tropical air (T),*** and on the nature of the surface in the source region: ***continental (c)*** or ***maritime (m).***

- **Warm Air Mass** is that whose temperature is greater than the surface temperature of the areas over which it moves.

  Thus this indicates that the surface underlying the air mass is cold. Due to the presence of cool surface the warm air mass gets cooled from below. The lower layer becomes stable and stops the vertical movement of air. Due to this

No adiabatic cooling of air → formation of cloud halts → precipitation stops → creates anti-cyclonic stable conditions.

Warm air mass can further be divided as ***continental warm air mass*** and ***maritime warm air mass*** (based on the source of origin whether continent or ocean respectively).

- **Cold Air Mass** originates in the polar and Arctic regions. Temperature and specific humidity is very low. Its temperature is lower than the surface temperature of the areas over which it moves.

  Thus the air mass is warmed from below and becomes unstable. Due to heating up of air from below, the air rises vertically and because of adiabatic cooling condensation process starts. This will lead to formation of clouds and finally will result in precipitation.

  But the precipitation will occur only when the air mass is above the warm ocean as it will get the unobstructed supply of moisture whereas if lies above warm continent then leads to clear weather.

Adiabatic cooling of air → formation of cloud→ precipitation occurs→ creates unstable conditions.

Cold air mass can further be divided as ***continental cold air mass*** and ***maritime cold air mass*** (based on the source of origin whether continent or ocean respectively).

Air Mass	Symbol	Characteristics/Comments
Continental Arctic	cA	Form exclusively in the Arctic and Antarctic regions and descent toward the equator. Bitterly cold and extremely dry in the winter, cool and dry during the summer.
Continental Polar	cP	Form over dry lands. Cold and dry during the winter, mild and dry during the winter.
Continental Tropical	cT	Typically hot and dry during the summer and mild and dry during the winter.
Maritime Polar	mP	Marine type humidities with cool or cold weather. Typically provide for miserable, damp, grey days. Mild to cold and humid with low stratus clouds and precipitation is often the rule with Maritime Polar air masses.
Maritime Tropical	mT	Hot, humid, sticky weather. A good example of when mT air masses affect the United States is during the summer with the Bermuda High phenomena. A southerly flow of hot, humid, sticky weather is circulated northward into the US.

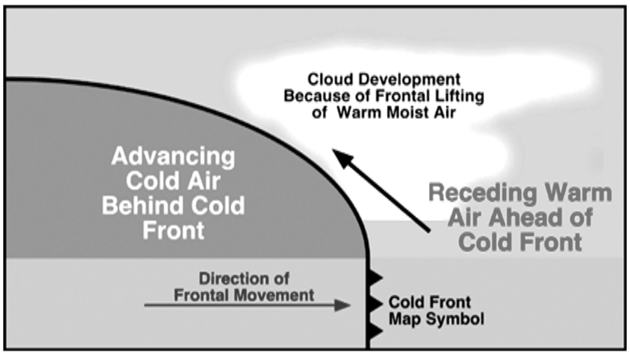
FRONTS AND ITS TYPES

It is a transition zone between two air masses of different densities. It is formed when two air masses with contrasting physical characteristics like temperature, humidity, pressure, etc. converge. The type of front depends on both the direction in which the air mass is moving and the characteristics of the air mass. There are four types of fronts as described below: cold front, warm front, occluded front and stationary front.

- **Cold fronts**

Cold fronts occur when a colder air mass becomes more active and forcibly uplifts the warmer air.

As the warm air rises, it cools, the water vapour in the air condenses out and clouds start to form. Rain associated with cold fronts is usually heavy but short lived and only affects a small distance (about 50 to 70 km). A cold front is associated with bad weather characterized by thick clouds, heavy downpour with hunderstorms and lightning.

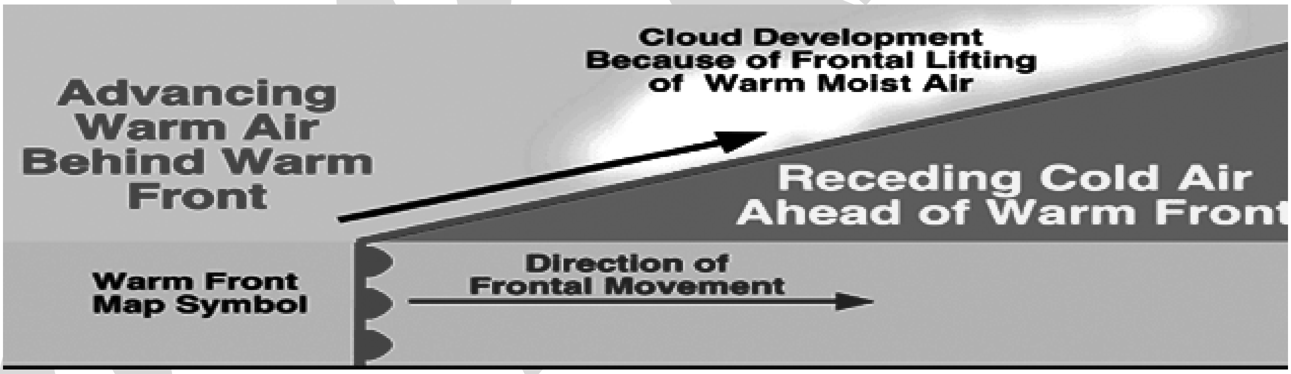


Weather Phenomenon	Prior to the Passing of the Front	Contact with the Front	After the Passing of the Front
Temperature	Warm	Cooling suddenly	Cold and getting colder
Atmospheric Pressure	Decreasing steadily	Levelling off then increasing	Increasing steadily
Winds	South to southeast	Variable and gusty	West to northwest
Precipitation	Showers	Heavy rain or snow, hail sometimes	Showers then clearing
Clouds	Cirrus and cirrostratus changing later to cumulus and cumulonimbus	Cumulus and cumulonimbus	Cumulus

Weather conditions associated with a cold front.

- **Warm Fronts**

A warm front is the transition zone in the atmosphere where an advancing warm subtropical, moist air mass replaces a retreating cold, dry polar air mass. High altitude cirrus, cirrostratus and middle altitude altostratus clouds are formed. These clouds produce precipitation in the form of snow or rain. Between the nimbostratus clouds and the surface location of the warm front, low altitude stratus clouds are found.

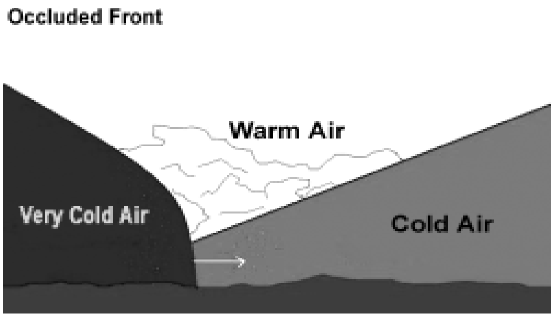


Weather Phenomenon	Prior to the Passing of the Front	Contact with the Front	After the Passing of the Front
Temperature	Cool	Warming suddenly	Warm then levelling off
Atmospheric Pressure	Decreasing steadily	Levelling off	Slight rise followed by a decrease
Winds	South to southeast	Variable	South to southwest
Precipitation	Showers, snow, steel or drizzle	Light drizzle	None
Clouds	Cirrus and cirrostratus altostratus, nimbostratus and then stratus	Status sometimes cumulonimbus	Clearing with scattered stratus, sometimes scattered cumulonimbus

Weather conditions associated with a warm front.

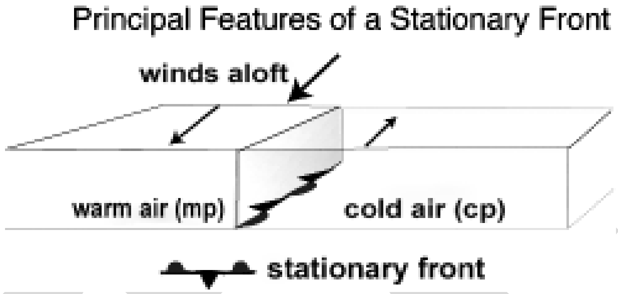
- **Occluded Fronts**

Occluded front is formed when cold front overtakes warm front and warm air is completely displaced from the ground surface. The temperature drops as the warm air mass is occluded, or "cut off," from the ground and pushed upwards.



- **Stationary Fronts**

A stationary front if formed when a cold front or warm front stops moving. This happens when two masses of air are pushing against each other but neither is powerful enough to move the other. Winds blowing parallel to the front instead of perpendicular can help it stay in place.



CYCLONES

Cyclones are well developed low-pressure systems surrounded by closed isobars having increasing pressure outside and closed air circulation towards the centre such that the air blows inward in anticlockwise direction in the northern hemisphere and clockwise in the southern hemisphere.

A. Tropical cyclones

Tropical cyclones are intense cyclonic storms that develop over the warm oceans of the tropics. Surface atmospheric pressure in the centre of tropical cyclones tends to be extremely low. Most storms have an average pressure of 950 millibars.

The main characteristics of tropical cyclones are:-

- Have winds that exceed 34 knots (39 mi/hr)
- Blow clockwise in the Southern Hemisphere and
- Counter-clockwise about their centres in the Northern Hemisphere

This is one of the most devastating natural calamities. They are known as Cyclones in the Indian Ocean, Hurricanes in the Atlantic, Typhoons in the Western Pacific and South China Sea, and Willy-Willies in the Western Australia.

Tropical cyclones originate and intensify over warm tropical oceans. The conditions favourable for the formation and intensification of tropical storms are:

(i) Large sea surface with temperature higher than 27° C;

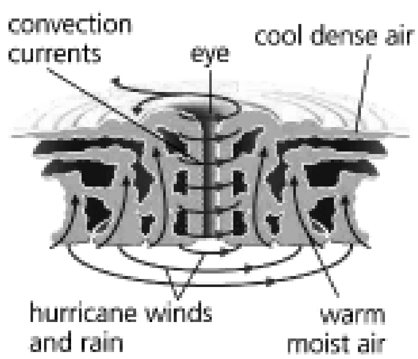
(ii) Presence of the Coriolis force;

(iii) Small variations in the vertical wind speed;

(iv) A pre-existing weak low - pressure area or low - level - cyclonic circulation;

(v) Upper divergence above the sea level system.

The energy that intensifies the storm comes from the condensation process in the towering cumulonimbus clouds, surrounding the centre of the storm. With continuous supply of moisture from the sea, the storm is further strengthened. On rea-ching the land the mois-ture supply is cut off and the storm dissipates. The place where a tropical cyclone crosses the coast is called the landfall of the cyclone. The cyclones, which cross 200N latitude generally, recurve and they are more destructive.



The eye is a region of calm with subsiding air. Around the eye is the eye wall, where there is a strong spiralling ascent of air to greater height reaching the tropopause. The wind reaches maximum velocity in this region, reaching as high as 250 km per hour.

Torrential rain occurs here. From the eye wall rain bands may radiate and trains of cumulus and cumulonimbus clouds may drift into the outer region. The diameter of the storm over the Bay of Bengal, Arabian Sea and Indian Ocean is 600 - 1200 km. The cyclone creates storm surges and they inundate the coastal low lands.

Tropical cyclones Damage and Destruction

Tropical cyclones are the most deadly and destructive type of severe weather event on our planet. The damage that tropical cyclones inflict is caused by high speed winds, heavy rainfall, storm surge, and tornadoes. Wind speed in tropical cyclones is usually directly related to atmospheric pressure. The lower the pressure the faster the winds blow. Wind speed also varies within the storm. High winds inflict damage by blowing down objects, creating choppy waves and high seas, and by inundating coastal areas with seawater. Rainfall within tropical cyclones can often exceed 60 centimeters (24 inches) in a 24-hour period. If this rainfall occurs on land, flooding often occurs.

B. Temperate cyclones

The systems developing in the mid and high latitude, beyond the tropics are called the middle latitude or temperate cyclones.

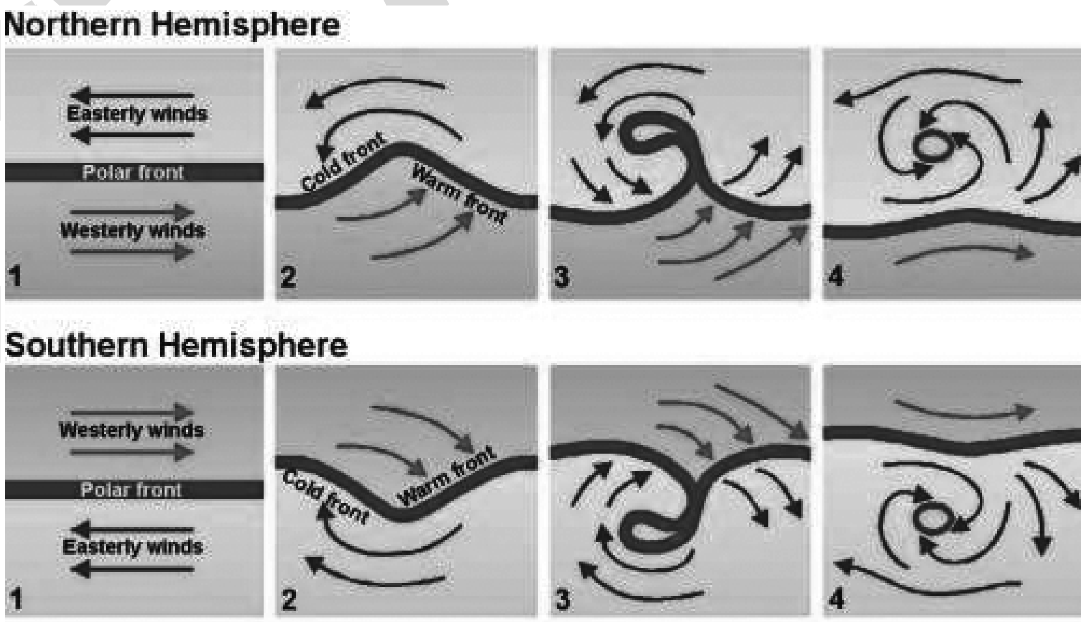
Extra tropical cyclones form along the polar front. Two air masses of contrasting physical properties: one air mass is polar in character and is cold, denser and north-easterly in direction while the other air mass is tropical in origin and is warm, moist, lighter and south westerly in direction.

When south westerly warm air mass enters the territory of cold polar air mass along the polar front, the warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation. The cold front approaches the warm air from behind and pushes the warm air up. As a result, cumulus clouds develop along the cold front. The cold front moves faster than the warm front ultimately overtaking the warm front. The warm air is completely lifted up and the front is occluded and the cyclone dissipates.

They cover a larger area and can originate over the land and sea. Whereas the tropical cyclones originate only over the seas and on reaching the land they dissipate. The extra tropical cyclone affects a much larger area as compared to the tropical cyclone. The wind velocity in a tropical cyclone is much higher and it is more destructive. The extra tropical cyclones move from west to east but tropical cyclones, move from east to west.

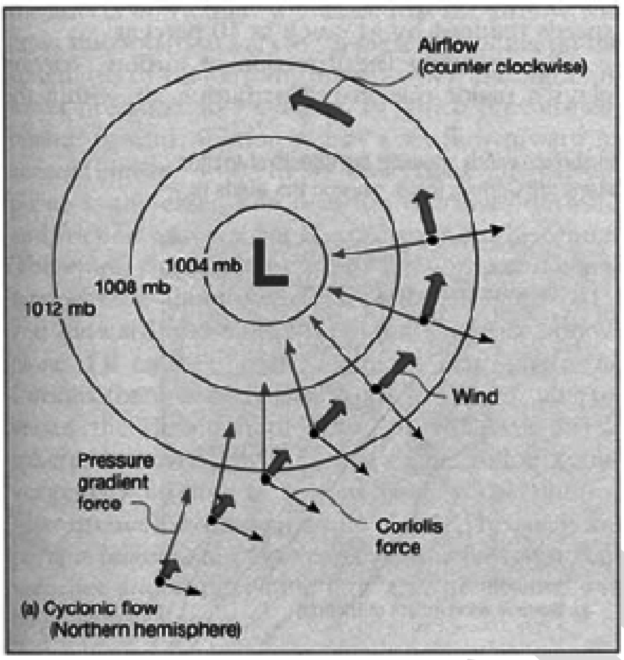
The life-cycle of a mid-latitude cyclone can be divided into 6 stages:

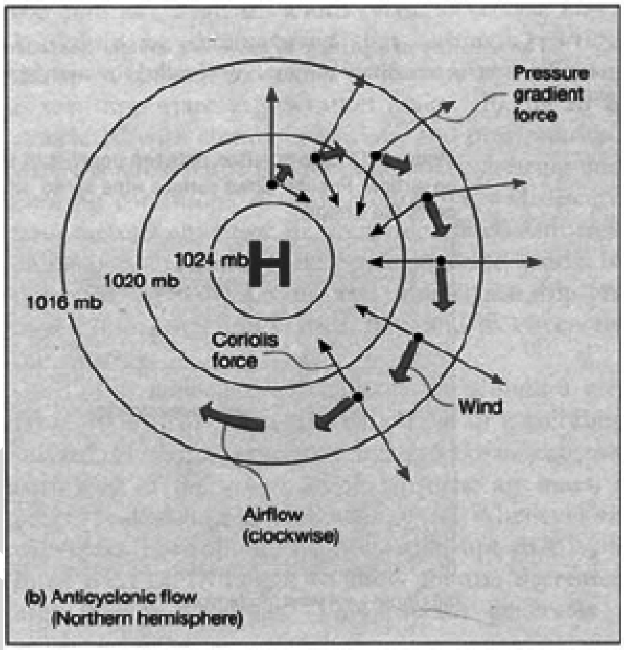
- stationary front, with opposing shear across the front;
- cyclone formation (cyclogenesis) begins as a cyclonic wave develops and amplifies;
- distinct poleward moving warm and equatorward moving cold fronts develop forming low pressure at apex;
- cold front begins to overtake the warm front (occlusion begins);
- Occluded front develops and cyclone reaches maximum intensity;
- Eventually all warm sector is forced aloft and cold air surrounds bottom of cyclone, and pressure gradients weakens and cyclone dissipates.



ANTICYCLONES

Idealized illustration showing expected airflow aloft around low-and high-pressure centers.





An ***anticyclone*** is a region of high atmospheric pressure related to the surrounding air, generally thousands of kilometres in diameter and also known as a ***high*** or ***high-pressure system.*** Winds in an anticyclone form a clockwise out-spiral in the Northern Hemisphere; whereas they form an anti-clockwise out-spiral in the Southern Hemisphere. The subsiding air compresses as it descends, thus causes ***adiabatic*** warming. The eventually warmer and drier air suppresses cloud formation and thus anticyclones are usually associated with fine weather in the summer and dry, cold, and sometimes foggy weather in the winter. Calm settled weather is usually synonymous with anticyclones in temperate latitudes. Anticyclones are typically relatively slow moving features.

THUNDERSTORMS

Thunderstorms are formed when moist, unstable air is lifted vertically into the atmosphere. The lifting of the air results in condensation and thus releases latent heat. The process to initiate vertical lifting can be caused by:

(1) Unequal warming of the surface of the Earth.

(2) Orographic lifting due to topographic obstruction of air flow.

(3) Dynamic lifting because of the presence of a frontal zone.

Immediately as lifting begins, the rising parcel of warm moist air begins to cool because of adiabatic expansion. At a certain elevation the dew point is reached resulting in condensation and the formation of a cumulus cloud. For the cumulus cloud to form into thunderstorm, continued uplift must occur in an unstable atmosphere. With the vertical extension of the air parcel, the cumulus cloud grows into a cumulonimbus cloud. Cumulonimbus clouds can reach heights of 20 kilometers above the Earth's surface. Severe weather associated with some these clouds includes hail, strong winds, thunder, lightning, intense rain, and tornadoes.

Air Mass Storm

The most common type of thunderstorm is the air mass storm. Air mass thunderstorms normally develop in late afternoon hours when surface heating produces the maximum number of convection currents in the atmosphere. The life cycle of these weather events has three distinct stages.

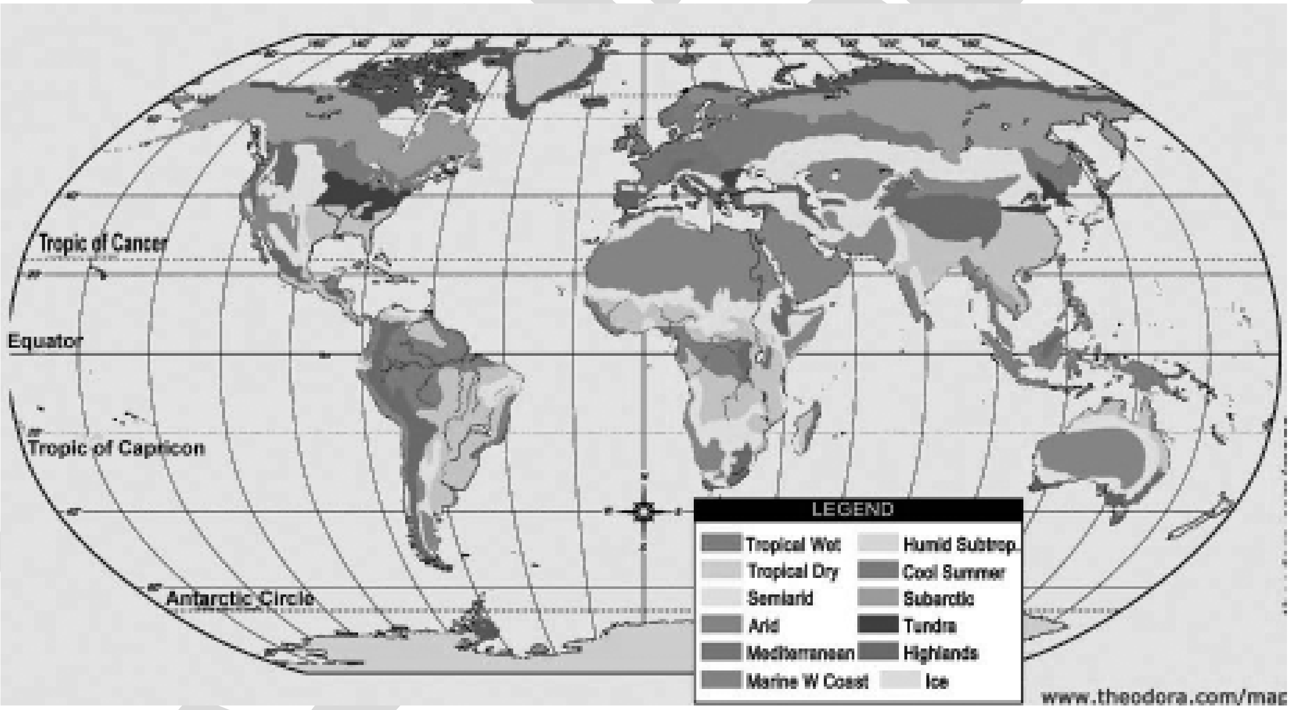
1st Stage- Cumulus Stage: The first stage of air mass thunderstorm development is called the cumulus stage. In this stage, parcels of warm humid air rise and cool to form clusters of puffy white cumulus clouds. The clouds are the result of condensation and deposition which, releases large quantities of latent heat. The added heat energy keeps the air inside the cloud warmer than the air around it. The cloud continues to develop as long as more humid air is added to it from below. Updrafts dominate the circulation patterns within the cloud.

2nd Stage- Mature Stage: When the updrafts reach their maximum altitude in the developing cloud, usually 12 to 14 kilometers, they change their direction 180° and become downdrafts. This marks the mature stage. With the downdrafts, precipitation begins to form through collision and coalescence. The storm is also at its most intense stage of development and is now a cumulonimbus cloud. The top of the cloud takes on the familiar anvil shape, as strong stratospheric upper-level winds spread ice crystals at the top of the cloud horizontally. At its base, the thunderstorm is several kilometers in diameter. The mature air mass thunderstorm contains heavy rain, thunder, lightning, and produces wind gusts at the surface.

3rd Stage- Dissipating Stage: The mature thunderstorm begins to decrease in intensity and enters the dissipating stage after about half an hour. Air currents within the convective storm are now mainly downdrafts as the supply of warm moist air from the lower atmosphere is depleted. Within about 1 hour, the storm is finished and precipitation is stopped.

Thunderstorms form from the equator to as far north as Alaska. They occur most commonly in the tropics where convectional heating of moist surface air occurs year round. Many tropical land based locations experience over 100 thunderstorm days per year. Thunderstorm formation over tropical oceans is less frequent because these surfaces do not warm rapidly. Outside the tropics, thunderstorm formation is more seasonal occurring in those months where heating is most intense.

CLIMATIC ZONES OF THE WORLD



The world has several climatic zones. These are summarized on the map below.

1. Tropical Moist Climate (Af)

This climate is located upto 50 to 100 latitudes on both the hemispheres. The zone is subjected to seasonal shifting due to northward and southward movement of Sun. The tropical climate is characterized by two major properties - uniformly high temperature throughout the year and uniformly adequate rainfall throughout the year by convectional rainfall. The total annual rainfall is often more than 250 cm. Humidity is between 77% and 88%.

The equatorial climate is found in - The Amazon Basin in South America, Congo Basin in Africa, Guinea coast in Africa, Java, Sumatra, Malaysia, etc.

The climates on eastern sides of continents are influenced by maritime tropical air masses. These air masses flow out from the moist western sides of oceanic high-pressure cells, and bring lots of summer rainfall. The summers are warm and very humid. It also rains a lot in the winter.

A tropical rain forest has more kinds of trees than any other area in the world. Scientists have counted about 100 to 300 species in one 2 1/2-acre (1-hectare) area in South America. Seventy percent of the plants in the rainforest are trees.

About 1/4 of all the medicines we use come from rainforest plants. Curare comes from a tropical vine, and is used as an anesthetic and to relax muscles during surgery. Quinine, from the cinchona tree, is used to treat malaria. A person with lymphocytic leukemia has a 99% chance that the disease will go into remission because of the rosy periwinkle. More than 1,400 varieties of tropical plants are thought to be potential cures for cancer.

All tropical rain forests resemble one another in some ways. Many of the trees have straight trunks that don't branch out for 100 feet or more. There is no sense in growing branches below the canopy where there is little light. The majority of the trees have smooth, thin bark because there is no need to protect the them from water loss and freezing temperatures. It also makes it difficult for epiphytes and plant parasites to get a hold on the trunks. The bark of different species is so similar that it is difficult to identify a tree by its bark. Many trees can only be identified by their flowers.

This climatic region is characterized by broad leaf evergreen dense forests comprising of mahogany, rosewood, bamboos, sandal etc.

- ***Average temperature: 18° C (°F)***
- ***Annual Precipitation: 262 cm. (103 in.)***
- ***Latitude Range: 10° S to 25° N***
- ***Global Position: Amazon Basin; Congo Basin of equatorial Africa; East Indies, from Sumatra to New Guinea.***

2. Wet-Dry Tropical Climate (Aw) (savanna)

This type of climate is located between 50 - 200 latitudes on either side of the equator. This climatic type is bounded by tropical rainforest climate towards the equator and by dry climate towards the poles.

The Savanna type is found in the southern continents and all the regions are to the south of the Tropic of Cancer.

South America: Cuba, Jamaica and the islands in the Pacific.

Africa: The Sudan, large parts of the newly formed Republics - Senegal, Guinea, Mali, Niger, Chad and also in Ghana, Togo, Kenya, Zimbabwe, Tanzania, Angola and Uganda.

Australia: The northern region and Queensland.

The Savanna climate is characterized by distinct wet and dry seasons, mean high temperature throughout the year and high insolation. There is sunshine for 13 to 14 hours and humidity is low, the air is hot, dry and dusty. The average monthly temperature during the dry season ranges between 22°C and 37°C. The highest temperatures are recorded just before the rainy season, for example, in the Sudan the hottest months are April and May. There is a general lowering of temperature during the rainy season when the temperature ranges between 21° and 26°C. Rainfall varies from 25 cm. to 150 cm and is usually unreliable. Coastal regions on the windward side of the mountains get heavier rain. Rainfall decreases as one goes either towards north (in the Northern Hemisphere) or towards south (in the Southern Hemisphere).

Plants of the savannas are highly specialized to grow in this environment of long periods of drought. They have long tap roots that can reach the deep water table, thick bark to resist annual fires, trunks that can store water, and leaves that drop off during the winter to conserve water. The grasses have adaptations that discourage animals from grazing on them; some grasses are too sharp or bitter tasting for some animals, but not others, to eat. The side benefit of this is that every species of animal has something to eat. Different species will also eat different parts of the grass. Many grasses grow from the bottom up, so that the growth tissue doesn't get damaged by grazers. Many plants of the savanna also have storage organs like bulbs and corms for making it though the dry season.

The species found in savannas vary by the geographic location of the biome. Animals native to African savannas include African elephants, zebras, horses, and giraffes. Many animals in the savanna are herbivores, which means they eat plants, and there is plenty of grass in the savanna. During the rainy months animals thrive in the savanna, but the rainy season is only for half the year. During the dry season, surface water from the rain is quickly absorbed into the ground by thirsty soils. The competition for water during the dry season is so intense that most birds and many of the large mammals migrate elsewhere in search of water. Depending on the severity of the drought, the migration may be to a place nearby, or far away. The dry season is often associated with fires. Many insects with short life spans die in these fires, but the birds and larger animals are usually able to fly or run to safety. Although small burrowing animals probably can't outrun the flames, they often survive the fire by digging deep into the ground and remaining there until the flames are gone.

- ***Temperature Range: 16° C***
- ***Annual Precipitation: 0.25 cm. (0.1 in.). All months less than 0.25 cm. (0.1 in.)***
- ***Latitude Range: 15° to 25° N and S***
- ***Global Range: West Africa, southern Africa, South America and the north coast of Australia***

3. Hot Desert Climate

This type of climate is located between the latitudinal belts of 150 - 300 in both the hemispheres. The arid deserts lie close to the tropic of cancer and Tropic of Capricorn in the western margins of continents.

The climatic zone lies in - The Sahara, the Arabia, the Thar, Mohave and Sonoran (South Western U.S.A.), Kalahari and Namib (South Western Africa), Simpson, Gibson, Great Sandy (Australia)

The climate is dominated by the subsidence of air masses and marked stability of the sub-tropical anticyclones and hence nearly rainless. The highest temperatures in the world are recorded here (Aziziya 58.7° C). The greatest daily ranges of temperature of (15° C) are seen here. These areas receive the lowest annual rainfall (12 to 15 cm). Cold currents also influence the climate on the western margins of continents. The aridity is intensified because of these currents which chill the air and further stabilize it.

The vegetation found here is cactus, thorny plants, shrubs, herbs.

Deserts plants have many adaptations to survive in such a dry environment. They are good at storing and finding water. Some plants have seeds that can stay dormant in the sand for a long time, until there is enough rain for them to grow. Cacti have waxy coating, water can't escape and their spines protect them from being desert dinner. Their roots are shallow, and widely spread so that any rain can be absorbed immediately. Some other plants are creosote bush, sagebrush, and ocotillo. Coastal deserts house a variety of plants. These plants must adapt to minimal rainfall by having extensive root systems that come up to the surface to absorb any possible rainfall, and go far down to absorb any water saturated in the ground. These plants also have very thick leaves that can absorb and store water whenever it is available. The plants that live in coastal deserts include salt bush, rice grass, black sage and chrysothamnus. Plants can even live in cold deserts. Plants in cold deserts include algae, grasses, and plants with spiny thin leaves. Usually these plants grow only in the summer.

Some animals that live in the hot desert are cold-blooded, like snakes, insects, and lizards. Mammals that live in the desert are usually small, such as the kangaroo rat and kit fox.

- ***Temperature Range: 16° C***
- ***Annual Precipitation: 0.25 cm (0.1 in). All months less than 0.25 cm (0.1 in).***
- ***Latitude Range: 15° - 25° N and S.***
- ***Global Range: southwestern United States and northern Mexico; Argentina; North Africa; South Africa; central part of Australia.***

4. Steppe Climate

This type of climatic zone is found between 40° and 55° North and South. They lie far away from the influence of the sea, in the heart of continents.

The areas are - Prairies (North America), Pampas (South America), Velds (South Africa), Downs (Australia) and Steppes (Russia)

The climate is not controlled by the subsiding air masses or the sub-Tropical Air masses, like deserts. Instead these are dry lands principally because of their position in the deep interiors of large land masses away from the oceans. The temperature in summer varies from 18° C to 24° C and in winter from - 4° C to 2°C. The range of temperature is large. Rainfalls in spring and early summer and vary between 23 cm. and 65 cm. It is of convectional type but very light.

Grasses dominate temperate grasslands. Trees and large shrubs are rarely found in grassland areas. There are many species of grasses that live in this biome, including, purple needlegrass, wild oats, foxtail, ryegrass, and buffalo grass. Trees appear only on the slopes of mountains. With underground stems and buds, grasses are not easily destroyed by fire. Shrubs and trees that live in temperate grasslands are not as good as grasses at coping with the flames, and often are destroyed by fire. Wildflowers also grow well in temperate grasslands. Popular flowers that you might find growing on grasslands are asters, blazing stars, goldenrods, sunflowers, clovers, and wild indigos.

The dominant vertebrates in grasslands are herbivorous or plant-eating grazers called ungulates. Ungulates are mammals with hoofs, like horses and deer. Their long legs help them run fast to escape grassland predators. The temperate grassland does not have much animal diversity, especially compared to the Savannah. Some animals that inhabit temperate grasslands in North America are bison, antelope, birds, gophers, prairie dogs, coyotes, and insects.

- ***Temperature Range: 24° C (43° F).***
- ***Annual Precipitation: less than 10 cm (4 in) in the driest regions to 50 cm (20 in) in the moister steppes.***
- ***Latitude Range: 35° - 55° N.***
- ***Global Range: Western North America (Great Basin, Columbia Plateau, Great Plains); Eurasian interior, from steppes of eastern Europe to the Gobi Desert and North China.***

5. Monsoon Climate

Monsoon climate is generally related to those areas which register complete seasonal reversal of wind direction and are associated with tropical deciduous forests. The region lies between 10°N to 30°N and 10°S to 30°S latitude.

Climatic zone areas are - Eastern Brazil (S. America), Central American countries, Natal coast (South Africa), India, Pakistan and Bangladesh, South East Asia, including Burma, Thailand, Vietnam and the Philippines, etc., Parts of East Africa including Malagasy, North Australia.

The annual average temperature is about 26°C and the annual range is about 3°C. The maximum temperatures occur in May before the summer rainfall maximum in June and July. The annual rainfall amounts to about 300 cm. The characteristic feature of this type of climate is a reversal in the wind direction with the change of season. During the summer season, the wind is on shore, bring large amount of moisture to the land surface. Rainfall is both orographic and cyclonic in nature. In winter season the wind is off shore and hence is cool and dry. But some parts like Madras coast get rain during this season because winds are on shore there.

Seasonality of its precipitation is the hallmark and most well-known characteristic of the monsoon climate. Many think that the term "monsoon" means wet weather, when in fact it describes an atmospheric circulation pattern.

Though the annual amount of precipitation is quite similar to that of the rain forest, monsoon precipitation is concentrated into the high-sun season.

Maritime equatorial and maritime tropical air masses travel from the ocean on to land during the summer, where they are uplifted by either convection or convergence of air to induce condensation.

Locally, Orographic (Relief) uplift is an important mechanism for promoting precipitation. As air travels into the Indian subcontinent, it is uplifted by the Himalayas, causing cloud development and precipitation.

The low-sun season is characterized by a short drought season when high pressure inhibits precipitation formation.

In the case of the Asian monsoon, the replacement of the thermal low with the subsidence of the Siberian High suppresses uplift. Air masses that dominate this period are dry given their continental origin or stability.

A distinct dry season from October to May, when the temperature is lower, the interior of Asia is a region of high pressure. Wind blows over the land in a north east direction , carrying little or no moisture. These cool , dry North East Monsoon winds blow towards areas of low pressure and do not bring rain.

A wet season from June to September, when the wind changes in direction, the wind blows in the region of low pressure. Winds blow across the equator and blow over the oceans, they are warmer and carry a lot of moisture. They bring alot of rain. Total rainfall can reach upto 600 mm

6. Mediterranean Climate:

This type of climate has developed between 300 - 400 latitudes in both the hemispheres. This is a wet-winter, dry-summer climate. Extremely dry summers are caused by the sinking air of the sub-tropical highs and may last for up to five months.

This climatic region includes European, Asiatic and African lands bordering the Mediterranean Sea. This climate owes its origin to the seasonal shifting of wind and pressure belts due to northward and southward migration of the sun.

In winter they are under the influence of westerlies which are moisture laden thus brings rainfall in winters whereas they come under the influence of subtropical high pressure belt in summers thus associated with anti cyclonic conditions.

Plants have adapted to the extreme difference in rainfall and temperature between winter and summer seasons. Sclerophyll plants range in formations from forests, to woodland, and scrub. Eucalyptus forests cover most of the chaparral biome in Australia. Fires occur frequently in Mediterranean climate zones.

- ***Temperature Range: 7° C (12° F)***
- ***Annual Precipitation: 42 cm (17 in).***
- ***Latitude Range: 30° - 50° N and S***
- ***Global Position: central and southern California; coastal zones bordering the Mediterranean Sea; coastal Western Australia and South Australia; Chilean coast; Cape Town region of South Africa.***

7. Taiga Climate

This climate type has been named after the coniferous forest cover of the same name found in the region. The region extends from 50-55 degrees to 60-70 degrees latitudes in northern hemisphere.

It stretches as an almost continuous belt across southern Canada, northern Europe and Russia. The Tundra region lies on the north and the Temperate Grasslands on the south.

The areas are - Southern Alaska, Southern Canada, parts of Norway, Sweden, Finland, Northern Russia, Northern Siberia, Sakhalin Island.

Winters are very cold and severe for 6 to 7 months with temperatures below freezing. In this region lies Verkhoyansk the "cold pole" becomes colder than the Arctic region. Oimyakon to the south-east has recorded even lower winter temperatures. It has January temperatures of - 50°C and in July the temperature sometimes reaches 15°C, Summers are short lasting for 3 or 4 months but the days are long; at 60°N the sun shines for over 18 hours.

Rainfall varies from 25 to 100cm. There is more rainfall near the coast. Most of the rain comes from cyclonic weather. It falls throughout the year but maximum in summer in frequent showers. In winter it takes the form of snow, which may remain, on the ground from 5 to 7 months.

The vegetation associated with this climate type is the soft-wood coniferous forests.

- ***Temperature Range: 41° C (74° F), lows; -25° C (-14° F), highs; 16° C (60° F).***
- ***Average Annual Precipitation: 31 cm (12 in).***
- ***Latitude Range: 50° - 70° N and S.***
- ***Global Position: central and western Alaska; Canada, from the Yukon Territory to Labrador; Eurasia, from northern Europe across all of Siberia to the Pacific Ocean.***

8. Tundra Climate

The tundra climate is found along arctic coastal areas. Polar and arctic air masses dominate the tundra climate. The winter season is long and severe. A short, mild season exists, but not a true summer season. Moderating ocean winds keep the temperatures from being as severe as interior regions.

Precipitation totals 6-10 inches of rain a year, which includes melted snow. This is almost as little as the world's driest deserts. Coupled with strong and drying winds, the tundra is an extreme weather biome. The tundra seems like a wet and soggy place because the precipitation that falls evaporates slowly, because of the poor drainage caused by the permafrost.

- ***Temperature Range: -22° C to 6° C (10° F to 41° F).***
- ***Average Annual Precipitation: 20 cm (8 in).***
- ***Latitude Range: 60° - 75° N.***
- ***Global Position: arctic zone of North America; Hudson Bay region; Greenland coast; northern Siberia bordering the Arctic Ocean.***

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