1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	Water in Atmosphere – Part 1
Module Id	kegy_11101
Pre-requisites	Basic knowledge about the general understanding of water cycle, evaporation and condensation
Objectives	After reading this lesson, learners will be able to know about: • Different types of clouds. • Hydrological cycle. • The concept of humidity. • The mechanism of precipitation.
Keywords	Hydrological Cycle, Humidity, Precipitation, Evaporation, Condensation, Clouds, Dew Point,

2. Development Team

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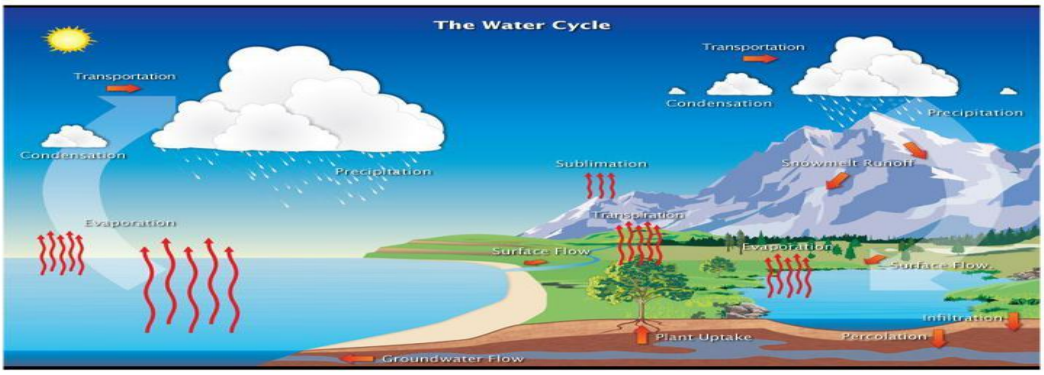
1. Introduction

The air contains water vapour. It constitutes a small fraction of the water on the earth surface and its proportion varies from 0.02% in the dry cold climates to 4% in the hot humid climates and plays an important role in the weather phenomena. Water is present in the atmosphere in three forms namely gaseous (water vapour), liquid (water droplets) and solid (ice crystals).

The sun, which drives the water cycle, heats water in the oceans and seas and other water bodies. Then water evaporates as water vapour into the air. Ice and snow can sublimate directly into water vapour. The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration. Thus, there is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation, which is also termed as.

2. Hydrological Cycle



Source: https://i.ytimg.com/vi/q9o60TDEEC4/maxresdefault.jpg

The amount of water vapour present in the air at a given point of time and place is known as **Humidity:** Water vapour is the gacious state of water and can not be seen by human eys.

Humidity does not include the presence of water droplets or ice-crystals in the atmosphere. It only refers to the condition of the air with regards to water vapour. The humidity are measured in three ways - absolute humidity, relative humidity and specific humidity.

A) Absolute humidity: -The actual amount of the water vapour present per unit volume of air in the atmosphere is known as the absolute humidity and is expressed in terms of *grams per cubic meter*. In simple words, it can be said that it can be calculated by finding the mass of water vapour in an area and dividing it by the mass of air in the same area. The ability of the air to hold water vapour depends entirely on its temperature. It is usually, greater near the equator than the polar region, and greater in summer than in winter. Distance from the source of moisture exercises important control over the amount of water vapour in the air. Absolute humidity is commonly greater over ocean than over the interior of continents. The absolute humidity differs from place to place on the surface of the earth.

(B) Relative humidity: - The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the relative humidity or it can also be said like the amount of water vapour in an area as opposed to how much water vapour could be in that area. With the change of air temperature, the capacity to retain moisture increases or decreases and so the relative humidity also get affected. It is expressed in percentage determined by dividing the absolute humidity by water holding capacity of air. If air is saturated, its relative humidity is 100 percent; if only half saturated, 50 percent. Since the capacity of air for absorbing and retaining moisture varies with temperature, the relative humidity of air mass can be altered by merely lowring its temperature, without changing the actual amount of moisture present in it.

(C) Specific humidity: - It is the ratio of the mass of water vapour to the total mass of the moist air. It can be described as the mass of water vapour per unit mass of the moist air. It is expressed as ***gm/kg*** i.e., gram of water vapour per kilo gram of moist air. Specific humidity is not affected by changes in pressure or temperature.

The air containing moisture to its full capacity at a given temperature is said to be ***saturated***. It means that the air at the given temperature is incapable of holding any additional amount of moisture at that stage. The temperature at which saturation occurs in a given sample of air is known as ***dew point***. The dew point is where condensation begins as cooling continues. Normally dew point temperature is lower than the air temperature except when the air is

already saturated. If dew point is above freezing point, condensation will be in the form of rain; if below freezing, it will be in the form of snow.

Measurement of humidity is not as easy as some other elements of weather. ***Hygrometer*** and ***psychrometer*** is an instrument used for measuring the moisture content in the atmosphere.

3. Evaporation

The amount of water vapour in the atmosphere is added due to evaporation. ***Evaporation*** is the process whereby liquid water or ice changes into water vapour. Heat is the main cause for evaporation. The temperature at which the water starts evaporating is referred to as the ***latent heat of vaporization.***

Factors Influencing Evaporation

The rate of evaporation is influenced by number of factors-

i. **Temperature:** Increase in temperature increases water absorption and retention capacity of the given parcel of air. Similarly, if the moisture content is low, air has a potentiality of absorbing and retaining moisture.
ii. **Concentration of the substance:** If the air is already saturated then the rate of evaporation will be low.
iii. **Flow rate of air:** Movement of air replaces the saturated layer with the unsaturated layer. Hence, greater the movement of air, greater is the evaporation.
iv. **Pressure:** If the area is having low pressure then the rate of evaporation is fast.
v. **Surface area:** A large surface area will have faster evaporation.

4. Condensation

The amount of water vapour in the atmosphere is withdrawn due to condensation. The transformation of water vapour into water is called ***Condensation***. Condensation is caused by the loss of heat. When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid or solid form depending upon the temperature. If it directly condenses into solid form, it is known as ***sublimation***. In free air, condensation results from cooling around very small particles termed as ***condensation nuclei.*** Particles of dust, smoke and salt from the ocean are particularly good nuclei as they absorb water. These paricles are termed as ***hygroscopic*** (water seeking) ***nuclei***. Condensation also takes place when the moist air comes in contact with some colder object and it may also take place when the temperature is close to the dew point. Condensation, therefore, depends upon the amount of cooling and the relative humidity of the

air.

Factors Influencing Condensation

Condensation is influenced by the volume of air, temperature, pressure and humidity. Condensation takes place:

i. When the temperature of the air is reduced to dew point with its volume remaining constant
ii. If the volume of the air is incresed without addition of heat. **iii-** when both the volume and the temperature are reduced **iv-** when moisture is added to the air through evaporation.
iii. However, the most favourable condition for condensation is the decrease in air temperature.

Forms of Condensation

After condensation, the water vapour or the moisture in the atmosphere takes one of the following forms ***dew***, ***frost, fog and clouds.*** Forms of condensation can be classified on the basis of temperature at which the dew pont is reached. Condensation takes place when the dew point is lower than the freezing point as well as higher than the freezing point. Whereas white frost, snow and some clouds are formed when temperature is below freezing point. Dew, fog and clouds results when the temperature is above freezing point. Forms of condensation may also be classified on the basis of location, ie. at or near the surface (Dew,white frost,fog and mist) and in free air (clouds).

Dew

When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects such as stones, grass blades and plant leaves, it is known as ***dew***. The ideal conditions for its formation are clear sky, calm air, high relative humidity, and long cold nights. For the formation of dew, it is necessary that the dew point is above the freezing point.

Dew

source: https://cdn.pixabay.com/photo/2016/07/29/15/58/water-1554426_960_720.jpg

Frost

Frost forms on cold surfaces when condensation takes place at or below the freezing point (0°C). The excess moisture is deposited in the form of minute ice crystals instead of water droplets. The ideal conditions for the formation of white frost are the same as those for the formation of dew, except that the air temperature must be at or below the freezing point.

Frost

source: https://c1.staticflickr.com/9/8669/16429317209_ac3a3d6bcd_z.jpg

Fog and Mist

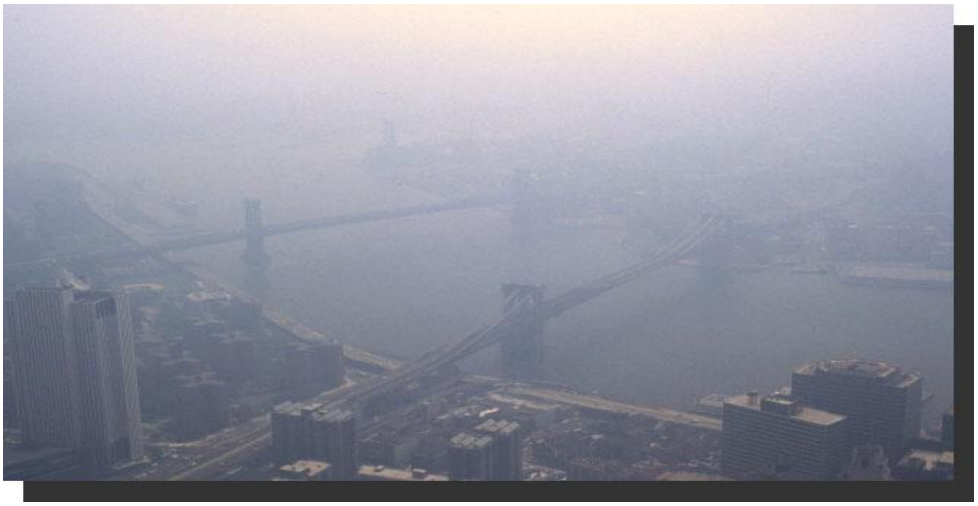
When the temperature of an air mass containing a large quantity of water vapour falls all of a sudden, condensation takes place within itself on fine dust particles. So, the ***fog*** is a cloud with its base at or very near to the ground. Because of the fog and mist, the visibility becomes poor to zero.

Fog

Source: https://upload.wikimedia.org/wikipedia/commons/c/ca/Dense_Seattle_Fog.jpg

In urban and industrial centres, smoke provides plenty of nuclei, which help the formation of

fog and mist. Such a condition *when fog is mixed with smoke is described as* ***smog***.



Smog

Source: https://upload.wikimedia.org/wikipedia/commons/9/96/SmogNY.jpg

The only difference between the mist and fog is that mist contains more moisture than the fog. In mist, each nuclei contains a thicker layer of moisture. Mists are frequent over mountains as the rising warm air up the slopes meet a cold surface.

Mist

Source:http://maxpixel.freegreatpicture.com/static/photo/1x/Man-Hiker-Fog-Adventure-Mist-Foggy-Cold-Hiking-1835353.jpg

Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents. Fogs are mini clouds in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles.

5. Clouds

Cloud is a mass of minute water droplets or tiny crystals of ice formed by the condensation of the water vapour in free air at considerable heights. As the clouds are formed at some height over the surface of the earth, they take various shapes.

Classification of Clouds

According to their height, expanse, density and transparency or opaqueness clouds are grouped under four (i) Cirus (ii) Cumulus (iii) Stratus (iv) Nimbus

Cirrus

Cirrus clouds are formed at high altitude (8,000- 12000m). They are thin and detached clouds having a feathery appearance. They are always white in colour.

Source: https://c1.staticflickr.com/9/8105/8690313402_e5298b34c4_b.jpg

Cumulus

Cumulus clouds look like cotton wool. They are generally formed at a height of 4,000-7,000m. They exist in patches and can be seen scattered here and there. They have a flat base.

Source:https://upload.wikimedia.org/wikipedia/commons/b/b5/Cumulus_clouds_in_fair_weather.jpeg

Stratus

As their name implies, these are layered clouds covering large portions of the sky. These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures.

Source: https://upload.wikimedia.org/wikipedia/commons/4/48/Altostratus_undulatus.jpg

Nimbus

Nimbus clouds are black or dark grey. They form at middle levels or very near to the surface of the earth. These are extremely dense and opaque to the rays of the sun. Sometimes, the clouds are so low that they seem to touch the ground. Nimbus clouds are shapeless masses of thick vapour.

Source: https://upload.wikimedia.org/wikipedia/commons/9/98/Cumulonimbus-tav.jpg

A combination of these four basic types can give rise to the following ***types of clouds***

a) high clouds – cirrus, cirrostratus, cirrocumulus
b) middle clouds – altostratus and altocumulus
c) Low clouds – stratocumulus and nimbostratus and clouds with extensive vertical development – cumulus and cumulonimbus.

Significance of Clouds

Clouds are meteorologically significant in various ways: -

i. All precipitation occurs from clouds.
ii. It plays an important role in heat budget.
iii. Like a black body, clouds radiate heat continuously in proportion to their temperature.
iv. Convectional currents are limited to the troposphere only and so this part of the atmosphere contains all clouds.
v. It is a useful indicator of various meteorological process.

6. Precipitation

The process of continuous condensation in free air helps the condensed particles to grow in size. When the resistance of the air fails to hold them against the force of gravity, they fall on to the earth's surface. So after the condensation of water vapour, the release of moisture is known as ***precipitation***. This may take place in liquid or solid form. The precipitation in the form of water is called rainfall, when the temperature is lower than the 0°C, precipitation takes place in the form of fine flakes of snow and is called ***snowfall***. Moisture is released in the form of hexagonal crystals. These crystals form flakes of snow. Besides rain and snow, ***other forms of precipitation*** are sleet and hail, though the latter are limited in occurrence and are sporadic in both time and space.

Sleet is frozen raindrops and refrozen melted snow water. When a layer of air with the temperature above freezing point overlies a subfreezing layer near the ground, precipitation takes place in the form of sleet. Raindrops, which leave the warmer air, encounter the colder air below. As a result, they solidify and reach the ground as small pellets of ice not bigger than the raindrops from which they are formed.

Sometimes, drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called ***hailstones***. These are formed by the rainwater passing through the colder layers. Hailstones have several concentric layers of ice one over the other

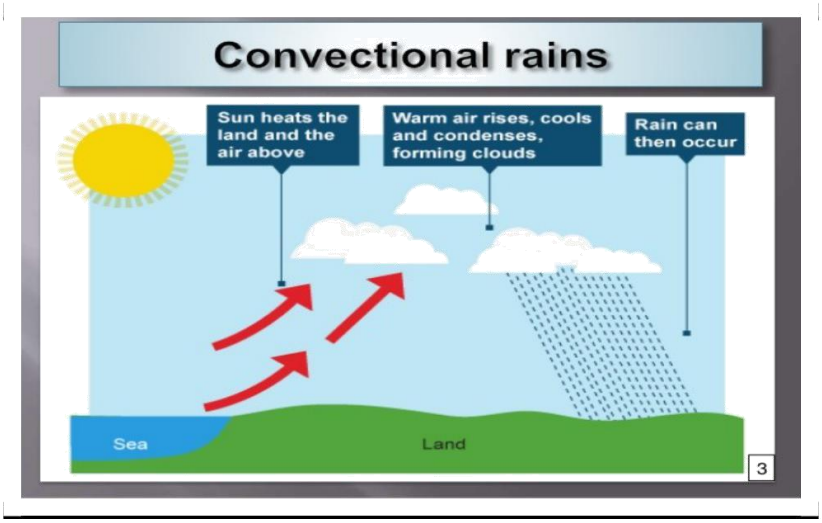
Types of Rainfall

On the basis of origin, rainfall may be classified into three main types-convectional,

orographic or relief and the cyclonic or frontal.

i) Convectional Rain

The, air on being heated by the terrestrial radiation, becomes light, expands and rises up in convection currents. As it rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed. The intensity of the convectional currents depends on the pace at which the air warms. With thunder and lightening, heavy rainfall takes place but this does not last long. Such rain is common in the summer or in the hotter part of the day. It is very common in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere. This type of rainfall may also be experienced in the mid latitudes during summer. In India, this type of rainfall is experienced in the northern plain and the areas, which are close to the equator.



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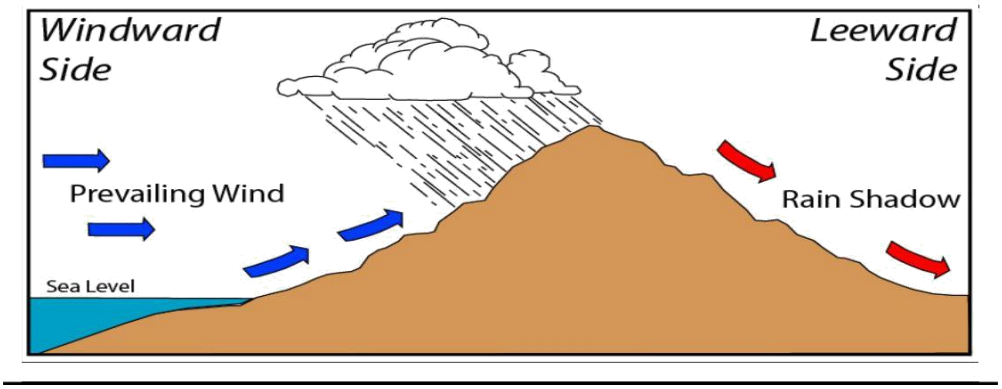
Orographic Rain

This type of rainfall is experienced when an obstruction such as mountains, hills or plateau comes in the way of the moist winds. Due to such type of orographic obstructions in the way, moist wind is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed. The chief characteristic of this sort of rain is that the windward slopes of the hills or the plateaus receive greater rainfall. After giving rain on the windward side, when these winds reach the other slope, that is called the leeward side, they descend, and their temperature rises. Then their capacity to take in moisture increases and hence, these leeward slopes remain rainless and dry. The area situated on the leeward side, which gets less rainfall is known as the rain-shadow area. It is also known as ***the relief rain.*** In India we have good examples of the orographic rainfall:

i. The Western Ghats in south India obstructs the Arabian Sea branch of the southwest monsoon, which causes heavy rainfall in the west coastal plain areas while the Karnataka plateau, Telangana plateau and other areas falling on to the rain shadow area receives very less amount of rainfall.

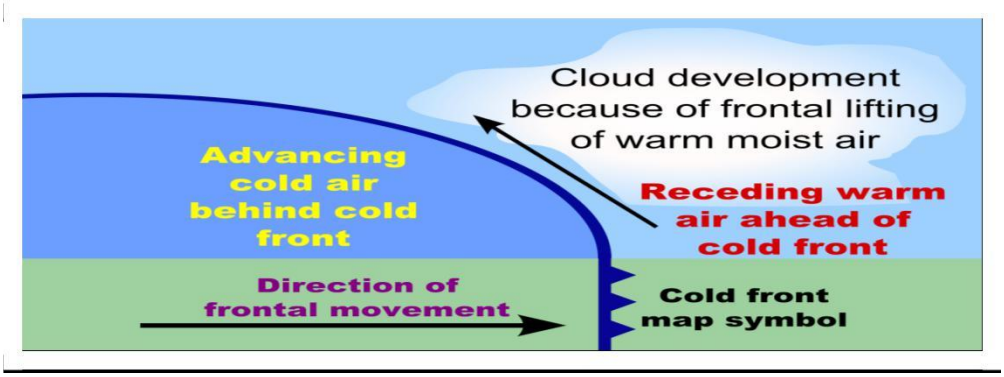
ii. Mawsynram and Cherapunji in Meghalaya are the two places in India receiving the maximum amount of annual rainfall in the world is also due to the orographic effect.



Source: https://c1.staticflickr.com/9/8249/8644087724_bcaca0e8ca_b.jpg

Cyclonic Rain

When the air is heated up either along the fronts or through convergence, cyclonic rainfall occurs. Hence, it is also called frontal or convergence rainfall. This type of rainfall is associated with the tropical and temperate cyclones. Rainfall associated with the temperate cyclones occurs when warm and moist westerly air gradually rises above the front. It cooled adiabatically and gets saturated and condensation begins, causes precipitation in the form of drizzle for a long duration. Whenever it is associated with cold fronts it is always in the form of thundershowers and is of short duration. This type of rainfall is commonly experienced on the eastern coast of India.



Source:

https://upload.wikimedia.org/wikipedia/commons/thumb/0/01/Example_of_a_cold_front.svg/2000px-Example_of_a_cold_front.svg.png

World Distribution of Rainfall

There is great deal of spatial variation in the distribution of rainfall on the earth surface. Different places on the earth's surface receive different amounts of rainfall in a year and that too in different seasons. The average rainfall over the oceans is much higher than the continents. The coastal areas of the world receive greater amounts of rainfall than the interior of the continents because of being great sources of water.Wherever mountains run parallel to the coast, the rain is greater on the coastal plain, on the windward side and it decreases towards the leeward side.

Latitudinal variation in precipitation:

A) In general, as we proceed from the equator towards the poles, rainfall goes on decreasing steadily. The highest average annual rainfall is there between 10° to 20° latitudes on both sides of the equator.

B) Between the latitudes 35° and 40° N and S of the equator, the rain is heavier on the eastern coasts and goes on decreasing towards the west.

C) But, between 45° and 65° N and S of equator, due to the westerlies, the rainfall is first received on the western margins of the continents and it goes on decreasing towards the east.

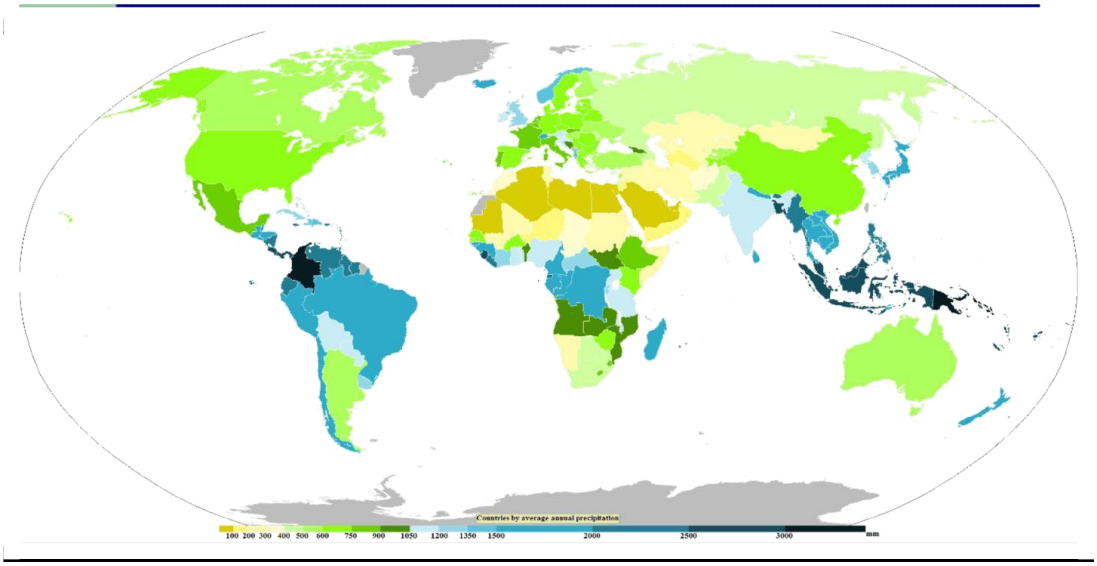
On the basis of the total amount of annual precipitation, major precipitation regimes of the world are identified as follows.

a) The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone and the coastal areas of the monsoon land receive heavy rainfall of over 200 cm per annum.

b) Interior continental areas receive moderate rainfall varying from 100 - 200 cm per annum. The coastal areas of the continents receive moderate amount of rainfall.

c) The central parts of the tropical land and the eastern and interior parts of the temperate lands receive rainfall varying between 50-100 cm per annum.

d) Areas lying in the rain shadow zone of the interior of the continents and high latitudes receive very low rainfall-less than 50 cm per annum.



Source:https://upload.wikimedia.org/wikipedia/commons/d/d0/Countries_by_average_annual_precipitation.png

Seasonal distribution of rainfall

There is seasonal variation of rainfall also in the most parts of the world. It is due to the difference in the temperature and shift in the pressure belts.

A) In some regions of the world such as between 5° and 10° in both the hemispheres in the equatorial belt rainfall is distributed evenly throughout the year, there is no well-marked seasonal difference. Dry season in these latitudes is either absent or extremely short.

B) Between 10° to 20° on both side of the equator, there is a well-marked seasonality and here rainfall occurs mostly during the summer season.

C) Western part of the continents in the sub-tropical areas having dry summer and wet winter.

Seasonal distribution of rainfall provides an important basis to judge the effectivness of precipitation. Even if the precipitation is scanty but concentration in short growing season, as in high latitude, its maximum utilisation is possible. precipitation even in the form of fog, mist or dew in certain parts has an appriciable effect on vegitation. For example The dense fog nourishes vegitation in Kalahari desert, dew and mist in winter nourishes wheat crops in parts of central india.