Compute Dew Point Temperature (Bolton 1980)

es = 6.112 * exp((17.67 * T)/(T + 243.5))

e = es * (RH/100.0)

Td = log(e/6.112)*243.5/(17.67-log(e/6.112))

where:
T = temperature in deg C;
es = saturation vapor pressure in mb;
e = vapor pressure in mb;
RH = Relative Humidity in percent;
Td = dew point in deg C

Compute Relative Humidity (Bolton 1980):

$e_s = 6.112*\exp((17.67*T)/(T + 243.5))$

$e = 6.112*\exp((17.67*Td)/(Td + 243.5))$

$RH = 100.0 * (e/es)$

where:
e_s = saturation vapor pressure in mb
e = vapor pressure in mb
RH = Relative Humidity in percent

Compute Vapor pressure Deficit (VPD):

VPD = e_s (1- RH/100)

Absolute Humidity: The absolute humidity or the total water content *WC* of the air [g/m^3] can be calculated in a simplified way knowing the temperature *T* and relative humidity *RH* as follows,

$$P_{ws} = 6.116441 * 10^{\left(\frac{7.591386*T}{T+240.7263}\right)},$$

$$WC = 2.16679 * \left(\frac{P_{ws} * RH}{293.15}\right).$$

Specific Humidity (Bolton 1980):

$e = 6.112*\exp((17.67*Td)/(Td + 243.5))$

$q = (0.622 * e)/(p - (0.378 * e))$

where:
e = vapor pressure in mb;
Td = dew point in deg C;
p = surface pressure in mb;
q = specific humidity in kg/kg.

(Note the final specific humidity units are in g/kg = (kg/kg)*1000.0)

To compute saturated specific humidity, replace ‘e’ by ‘e_s’

e_s = saturated vapour pressure

Computation of Mixing Ratio

MR = 6.11 X 10 ^ (7.5*DP/(237.7+DP))

SMR = 6.11 X 10 ^ (7.5*T/(237.7+T))

- Where DP is the dew point (C)
- T is the termpature
- MR is the mixing ratio
- SMR is the saturated mixing ratio

Compute U,V Components

U = -sin(wind direction) * wind_speed

V = -cos(wind direction) * wind_speed

Compute Wind Speed and Wind Direction

Wind_speed = square_root(U*U + V*V);

if V < 0 then Wind_direction = arctan(U/V) * 180/PI

Else Wind_direction = arctan(U/V) * 180/PI + 180

Wind direction in degrees

Wind speed in m/s

U= zonal wind in m/s

V= meridional wind in m/s

Computing wind direction and speed from u and v

Meteorological wind direction is the direction from which wind is blowing *from*. Wind direction increases clockwise such that a north wind is 0°, an east wind is 90°, a south wind is 180°, and a west wind is 270°. Because trigonometry uses a polar coordinate system in which 0° is along the x axis, the meteorology angle definition potentially wreaks havoc on typical angle calculations.

Fortunately, it is still easy to compute u and v given the meteorological wind angle. Let ϕ be the meteorology wind direction angle, then the following equations can be applied:

$$u = -|\vec{V}| \sin\phi$$

$$v = -|\vec{V}| \cos\phi$$

$$|\vec{V}| = \sqrt{u^2 + v^2}$$

Note that ϕ must be in radians. If ϕ is in degrees, multiple the angle by $\pi/180$ before using the trig function.

Clouds and Classification

Clouds

"An aggregation of minute drops of water suspended in the air at higher altitudes". The rising air currents tend to keep the clouds from falling to the ground.

WMO cloud classification

The World Meteorological Organisation (WMO) classified the clouds according to their height and appearance into 10 categories. From the height, clouds are grouped into 4 categories (viz., family A, B, C and D) as stated below and there are sub- categories in each of these main categories.

Family A

The clouds in this category are high. The mean lower level is 7 kilometers and the mean upper level is 12 kilometers in tropics and sub-tropics. In this family there are three sub-categories.

1. Cirrus (Ci)
   - ❖ In these clouns ice crystals are present.
   - ❖ Looks like wispy and feathery. Delicate, desist, white fibrous, and silky appearance.
   - ❖ Sun rays pass through these clouds and sunshine without shadow.
   - ❖ Does not produce precipitation.

2. Cirrocumulus (Cc)
   - ❖ Like cirrus clouds ice crystals are present in these clouds also.
   - ❖ Looks like rippled sand or waves of the sea shore.
   - ❖ White globular masses, transparent with no shading effect.
   - ❖ Meckerel sky.

3. Cirrostraturs (Cs)
   - ❖ Like the above two clouds ice crystals are present in these clouds also.
   - ❖ Looks like whitish veil and covers the entire sky with milky white appearance.
   - ❖ Produces "Halo".

TYPE	NAME	HEIGHT
High Clouds	Cirrus,Cirrostratus,Cirrocumulus	5-13 Km
Middle clouds	Altostratus, Altocumulus, Nimostratus	2-7 Km
Low clouds	Stratus, stratocumulus	0-2 Km
Vertical cloud	Cumulus, cumulonimbus	0-5 km

Family B

The clouds in this category are middle clouds. The mean lower level is 2.5 kilometers and the mean upper level is 7 kilometers in tropics and sub-tropics. In this family there are 2 sub-categories as details below:

1. Altocumulus (Ac)
   - ❖ In these clouds ice water is present.
   - ❖ Greyish or bluish globular masses.
   - ❖ Looks like sheep back and also known as flock clouds or wool packed clouds.

2. Alto-stratus (As)
   - ❖ In these clouds water and ice are present separately.
   - ❖ Looks like fibrous veil or sheet and grey or bluish in colour.
   - ❖ Produces coronos and cast shadow.
   - ❖ Rain occurs in middle and high latitudes.

Family C

The clouds in this category are lower clouds. The height of these clouds extends from ground to upper level of 2.5 kilometers in tropics and sub-tropics. In this family, like high clouds, there are 3 sub-categorises.

1. Strato cumulus (Sc)

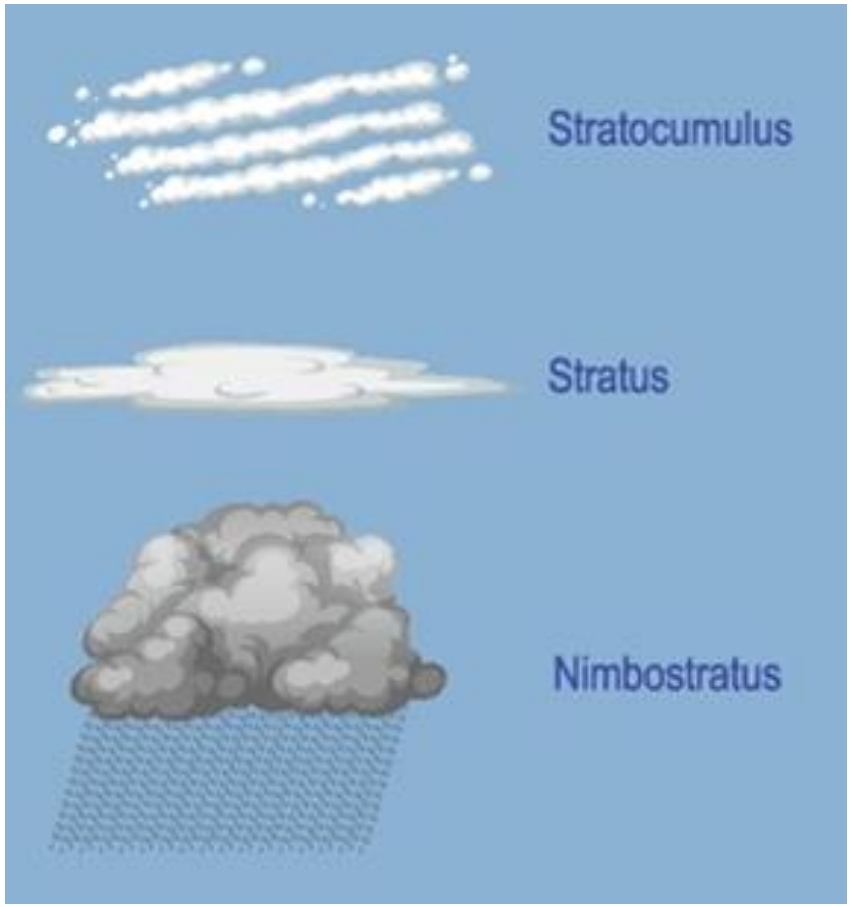
- These clouds are composed of water.
- Looks soft and grey, large globular masses and darker than altocumuls.
- Long parallel rolls pushed together or broken masses.
- The air is smooth above these clouds but strong updrafts occur below.

2. Stratus (St)

- These clouds are also composed of water.
- Looks like for as these clouds resemble grayish white sheet covering the entire portion of the sky (cloud near the ground).
- Mainly seen in winter season and occasional drizzle occurs.

3. Nimbostratus (Ns)

- These clouds are composed of water or ice crystals.
- Looks thick dark, grey and uniform layer which reduces the day light effectively.
- Gives steady precipitation.
- Sometimes looks like irregular, broken and shapeless sheet like.



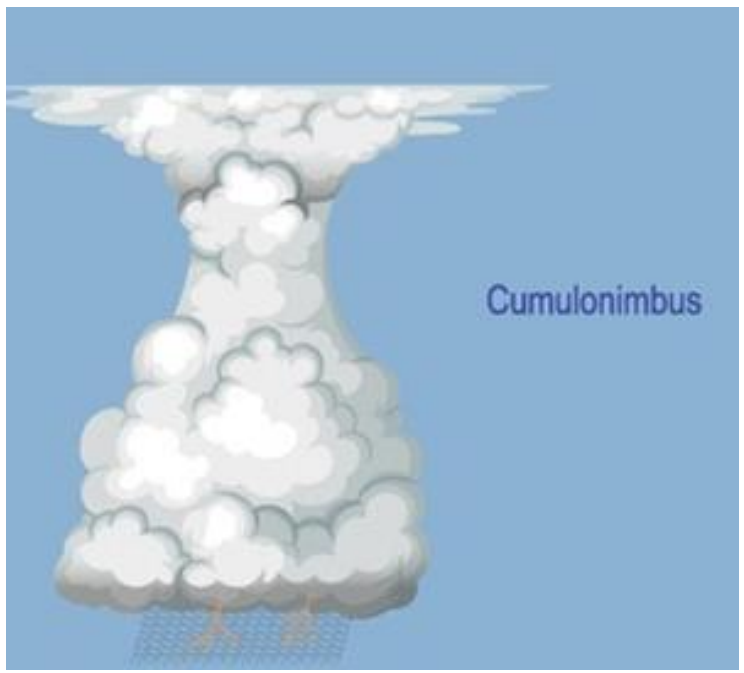
Family D

These clouds form due to vertical development i.e., due to convection. The mean low level is 0.5 and means upper level goes up to 16 kilometers.
In this family two sub-categories are present.

1. Cumulus (Cu)
These clouds are composed of water with white majestic appearance with flat base.
Irregular dome shaped and looks like cauliflower with wool pack and dark appearance below due to shadow.
These clouds usually develop into cumuolo-nimbus clouds with flat base.

2. Cumulonimbus (Cb)

- The upper levels of these clouds possess ice and water is present at the lower levels.
- These clouds have thunder head with towering envil top and develop vertically.
- These clouds produces violent winds, thunder storms, hails and lightening, during summer.



Forms of Precipitation

Rain: It is precipitation of liquid water particles either in the form of drops having diameter greater than 0.5 mm or in the form of smaller widely scattered drops. When the precipitation process is very active, the lower air is moist and the clouds are very deep, rainfall is in the form of heavy downpour. On occasions, falling raindrops completely evaporate before reaching the ground.

Drizzle: It is fairly uniform precipitation composed of fine drops of water having diameter less than 0.5 mm small and uniform size and seems to be floated in the air, it is referred as drizzle. If the drops in a drizzle completely evaporates before reaching the ground, the condition is referred to as 'mist'.

Snow: It is the precipitation of white and opaque grains of ice. Snow is the precipitation of solid water mainly in the form of branched hexagonal crystals of stars. In winter, when temperatures are below freezing in the whole atmosphere, the ice crystals falling from the Altostratus do not melt and reach the ground as snow.

Sleet: It refers to precipitation in the form of a mixture of rain and snow. It consists of small pellets of transparent ice, 5 mm or less in diameter. It refers to a frozen rain that forms when rain falling to the earth passing through a layer of cold air and freezes. This happens when temperature is very low. It is not commonly seen in India expect high ranges, that too in winter, in extreme north and northeast India.

Hail: Precipitation of small pieces of ice with diameter ranging from 5 to 50 mm or something more is known as hail. Hailstorms are frequent in tropics. In India, the period from March to May offers the ideal condition for hailstorms. It is the most dreaded and destructive form of precipitation produced in thunderstorms or cumulonimbus clouds.

Isohyets: Isohyets are the lines connecting various locations, having an equal amount of precipitation.

IMPORTANCE OF MONSOON IN INDIAN AGRICULTURE

In India, Monsoon refers to the rainy season. The humid south-west monsoon winds cause plenty of rainfall during the period between early June and October.

A large portion of Indian farmers still depends upon rain-fall to carry out the agricultural activities. Since, agriculture is one of the most important constituent on Indian economy (contributing around 16 percent of its total GDP), monsoon season has an indirect impact on its economy as well.

India has a tropical monsoon type of climate. So here the temperature in the summer months is high and the rainfall is heavy. High temperature and heavy rainfall in the summer months are important for the growth of different types of kharif crops in different parts of India.

Unlike other countries in high latitudes, India enjoys long hours of sunshine even during the winter months. So with winter precipitation (supplemented by irrigation) a second rabi crop is easily grown.

The amount of rainfall is the most important determinant of the type of crop raised. Wet crops are raised in wet zone and dry crops in the dry zone.

- Crops like rice, jute, sugarcane, etc. require high temperature and heavy rainfall for their cultivation. So these crops are cultivated in summer.
- Crops like wheat, barley etc. require moderate temperature and rainfall. So these are cultivated in winter.
- Rubber trees require uniformly high temperature and regular rainfall all the year round.
- In the southern parts of the Deccan, the temperature is fairly high all the year round and the rainfall is well-distributed over 6 to 8 months. So rubber is grown in the southern parts of the Deccan.

Monsoon Rainfall Variability

Indian continent receives its annual rainfall by the peculiar phenomenon known as monsoon. It consists of series of cyclones that arise in India Ocean. These travel in northeast direction and enter the Peninsular India along its west coast. The most important of these cyclones usually occur from June to September resulting in summer monsoon or southwest monsoon. This is followed by a second rainy season from October to December. A third and fourth rainy seasons occur from January to February and from March to May respectively. Of the four rainy seasons, southwest monsoon is the most important as it contribute 80 – 95% of the total rainfall of the country.

Two types of monsoon systems are a) South West Monsoon, b) North East Monsoon.

(a) South West Monsoon

Beginning of the year temperature of the Indian Peninsular rapidly rises under the increasing heat of the sun. A minimum barometric pressure is established in the interior parts of the Peninsular by the month of March. Westerly winds prevail on the west Kerala and south winds on the west of northern Circars, Orissa and Bengal. During April and May the region of high temperature is shifted to north viz., upper Sind, lower Punjab and Western Rajasthan. This area becomes the minimum barometric pressure area to which monsoon winds are directed.

The western branch of South West monsoon touches North Karnataka, Southern Maharastra and then it make its way to Gujarat. When the South West Monsoon is fully operating on the Western India, another branch of the same is acting in the Bay of Bengal. It carries rains to Burma, Northern portions of the east coast of India, Bengal, Assam and the whole of North India in general.

b) North east Monsoon

During September end, the South West Monsoon penetrates to North Western India but stays on for a full month in Bengal. On account of the increase in barometric pressure in Northern India, there is a shift of the barometric pressure to the South East and North Easterly winds begin to flow on the eastern coast. These changes bring on heavy and continuous rainfall to the Southern and South Eastern India.

c) Winter Rainfall

It is restricted more to Northern India and is received in the form of snow on the hills and as rains in the plains of Punjab, Rajasthan and central India. Western disturbance is a dominant factor for rainfall during these months in northwestern India.

d) Summer Rainfall:

The summer Rainfall is received from March to May as local storms. It is mostly received in the South East of Peninsular and in Bengal. Western India does not generally receive these rains.

Drought: The term drought can be defined by several ways.

1. The condition under which crops fail to mature because of insufficient supply of water through rains.
2. The situation in which the amount of water required for transpiration and evaporation by crop plants in a defined area exceeds the amount of available moisture in the soil.
3. A situation of no precipitation in a rainy season for more than 15 days continuously. Such length of non-rainy days can also be called as dry spells.

Classification of Drought

Droughts are broadly divided into 3 categories based on the nature of impact and spatial extent.

i. **Meteorological Drought**

If annual rainfall is significantly short of certain level (75 per cent) of the climatologically expected normal rainfall over a wide area, then the situation is called meteorological drought. In every state each region receives certain amount of normal rainfall. This is the basis for planning the cropping pattern of that region or area.

ii. **Hydrological drought**

This is a situation in which the hydrological resources like streams, rivers, reservoirs, lakes, wells etc dry up because of marked depletion of surface water. The ground water table also depletes. The industry, power generation and other income generating major sources are affected. If Meteorological drought is significantly prolonged, the hydrological drought sets in.

iii. **Agricultural Drought**

This is a situation, which is a result of inadequate rainfall and followed by soil moisture deficit. As a result, the soil moisture falls short to meet the demands of the crops during its growth. Since, the soil moisture available to a crops insufficient, it affects growth and finally results in the reduction of yield. This is further classified as early season drought, mid season drought and late season drought.

Flood: Years in which actual rainfall is 'above' the normal by twice the mean deviation or more is defined as years of floods or excessive rainfall. Like droughts, the definition of floods also varies one situation to another and form one region to other. Some of the flood years characterized based on the spatial damage due to high and intense rainfall in India are as follows.

India: 1878,1872,1917,1933,1942,1956,1959,1961,1970,1975,1983,1988.