CHAPTER-1

MEANING AND SCOPE OF AGRICULTURAL METEOROLOGY

Meaning of Agro meteorology

Meteorology, climatology, hydrology and physics are the Physical sciences related to agro meteorology**.**

Meteorology: A study in meteorology is mainly concerned with the formation of rain, dew, snow, and water vapour and processes of evaporation, condensation, precipitation etc.

Greek word **"Meteors"** means 'above the earth's surface' (atmosphere) **"logos"** means 'indicating science'. Branch of science dealing with that of atmosphere is known as meteorology. Lower atmosphere extending up to 20km from earth's surface is where frequent physical process takes place.

Climatology: It involves the studies of climatic elements such as rainfall temperature and evapotranspiration which are important for farm operations and agricultural production.

Meteorology is the study of physical processes in the atmosphere that produce weather, whereas climatology is the study of the totality of weather.

Hydrology: It deals with the process of run-off, percolation, storage of ground water and soil water, irrigation and drainage of agricultural lands etc.

Physics of the air and soil forms the foundation of agro meteorology.

An agricultural scientist whose applies all relevant meteorological skill to help the farmers and agricultural workers to make the most efficient use of physical environment for improving agricultural production both in quality and quantity is known as Agro meteorologist. **Agro-meteorology** is the applied branch of meteorology.

Definitions of Agro meteorology:

- A branch of applied meteorology which investigates the physical conditions of the environment of growing plants or animal organisms
- An applied science which deals with the relationship between weather/climatic conditions and agricultural production.
- A science concerned with the application of meteorology to the measurement and analysis of the physical environment in agricultural systems. The word 'Agro meteorology' is the abbreviated form of agricultural meteorology.
- To study the interaction between meteorological and hydrological factors on the one hand and agriculture in the widest sense, including horticulture, animal husbandry and forestry on the other (WMO).
- Agro meteorology is a science investigating the meteorological, climatological and hydrological conditions which are significant for agriculture owing to their interactions with the objects and processes of agricultural production.

- It is the study of those aspects of meteorology which have direct relevance of agriculture.
- Agro meteorology puts the science of meteorology to the service of agriculture to help the sensible use of land, accelerate production of food and to avoid the irreversible abuse of land resources (Smith, 1970).
- Agro meteorology is defined as a branch of meteorology which investigates the relationship of plants and animals to the physical environment.
- Agro meteorology is defined as the study of responses of living organisms to the physical environment (water, air, soil). The living organisms are cultivated plants, livestock, insects and micro organisms.

The objective of Agro meteorology

- To discover and define the meteorological, climatological and hydrological problems which are relevant to agricultural production.
- Apply this knowledge of the atmosphere and soil to practical agricultural use.
- It attempts to enhance agricultural production by controlling physical environment.
- To forecast weather and crop yield accurately.

The control of physical environment consist of prevailing frost, drought, growing wind breaks, adopting flood control measures, modifying and controlling temperature and humidity in crop fields and animal houses.

Relationship of Agro meteorology with agricultural sciences

Agro meteorological study is the important part of individual agricultural sciences, because the growth and development of plants is basically dependent upon the physical conditions of the environment in which they live and grow. So, all the agricultural sciences are incomplete without the incorporation of the information on weather and climatic effects on crops and livestock.

- **Agronomist and horticulturalist:** Need the information on weather and climate which influencing growth, development and yield of their crops. They establish the relationship between weather and climate to crops
- **Soil scientist:** Needs the information on weather and climate factors that influence on soil water, soil moisture storage, soil erosion and intake of nutrients by plant.
- **Plant pathologist:** Needs the information on the weather factors viz., temp., RH, wind velocity, cloud cover, dew, fog etc that affect the spread and intensity of disease.
- **Entomologist:** Needs information on weather and climatic conditions which are related to outbreak and spread of insects and pests.
- **Agril. Engineering:** Need the information for designing agricultural watershed, barns and poultry houses.

These all the agricultural sciences depend upon the conditions made by agro meteorology. Hence, it is on interdisciplinary and multidisciplinary science.

Difference between Agro meteorology and Agro climatology

Agro meteorology	Agro climatology
Agro meteorology deals with the entire field of study including agro climatology, instrumentation and agricultural forecasting.	The study of agro climatology deals partly with the relationship of climatic regimes and agricultural production.

Role of agro meteorologist

- Transfer of laboratory and greenhouse (controlled environment) results to the open field.
- Modification of the field microclimate against adverse weather condition.
- The forecasting of weather with respect to crops and animals.
- To derive agrometeorological indices to delineates climate of a region
- To predict of crop yield for planning purposes.

Scope of agro meteorology

- The scope of agro meteorology is very with its relation with other branches of sciences like physical sciences, atmospheric, agricultural sciences and other sciences. The study of agricultural sciences is incomplete without the incorporation of agro meteorological knowledge and information.
- The objective of agro meteorology is to discover the meteorological, climatological and hydrological problems and apply this knowledge to practical agricultural use.
- The field of interest for agro meteorology studies extends from the soil surface layer to the depth of up to which roots penetrate and in the atmosphere to the height the plants live and grow.
- Specific climatic conditions are required for optimum crop growth. Hence, it attempts to enhance agricultural production by controlling the physical environment and accurate forecasting of weather and predicting crop yields.

Difference between Meteorology and Agro meteorology

Sr.No.	Meteorology	Agricultural Meteorology
1	It is the branch of atmospheric physics.	It is the branch of applied meteorology.
2	It is a weather science.	It is the product of agriculture and meteorology.
3	It is a physical science.	It is a bio-physical science.
4	It aims at weather forecasting.	It aims at improving quantity and quality of crop production through meteorological skills.
5	It is a linking science to the society.	It is a linking science to the farming community.

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CHAPTER-2

EARTH AND ATMOSPHERE

The earth is a planet and the sun is a star. The earth is elliptical in shape. It has four spheres. They are:

1. **Hydrosphere: -** The liquid part, Oceans, seas and other water bodies.
2. **Lithosphere : -** The solid or land part
3. **Atmosphere : -** Various major, minor and variable gaseous part
4. **Biosphere :-** The life forms, plants & animals etc.

Weather, Climate and Seasons

Weather and Climate: Weather means the state of atmosphere at a given time and location where as, climate is the synthesis of weather at a given locations over a period of time (about 30-35 years). Climate, therefore, refers to the characteristic condition of the atmosphere derived from repeated observations over along period. It includes considerations of departures from averages (i.e. variability), extreme conditions and the probabilities or frequencies of occurrences of given weather conditions. The climate represents a generalization where as weather deals with specific events.

Weather has significant influence on every phase of agricultural activity from preparatory tillage to harvesting and storage.

A sound knowledge of the climatic factors and its interactions with crop is essential for successful agriculture.

Weather:- Weather is defined as the physical state of atmosphere with respect to radiation, thermal, moisture and dynamic regime at a given place and at a given instant of time.

Climate: - Climate represents a composite of the day to day weather conditions and of the atmospheric elements for a long period of time.

Difference between weather and climate

	Weather	Climate
1.	Weather is instantaneous physical state of atmosphere at a given time and place.	Climate is average physical state of the atmosphere over a given region and period of time.
2.	It does not include magnitude of extreme values of weather elements. Departures from normal values are expressed to indicate weather.	It includes the extremities of weather elements viz., cyclones, thunderstorms, floods also the frequency of occurrence of special events.
3.	Weather is indicated by measuring weather elements in the observatory.	Climate is derived information on regional basis. Series of observatories extending

	Therefore observatory is a must at a place to describe weather.	across the region is necessary.
4.	Weather constitutes meteorological information	Climate constitutes geographical information.
5.	No special statistical treatment is necessary for weather element. Their values are observed, used and hence always change.	Statistical treatment over a longer period is required. It is more or less stable with few random changes.
6.	Weather can be categorized as fair, unfair, settled, fine, excellent etc.	Climates are classified as desert, continental, marine, savana, tropical, arid, semiarid, humid climate etc.
7.	Weather decides the crop yield in a given season of particular year. Weather decides time of sowing of particular crop.	Climate decides potential yield of the crop in a region. Climatic conditions of a region decide the type of the crop suitable for that region. While introducing new crops, climate of a region is considered.
8.	Adverse weather results into crop failure or loss and compel short term contingent planning.	Climate is considered in long term agricultural planning.

Elements of weather / climatic parameters

Climate and weather are expressed nearly by the same elements.

(1) Solar radiation (2) Temperature (3) Humidity (4) Pressure (5) Wind (6) Precipitation

(7) Evaporation

Climatic controls

The climate or weather of the region/ location is influenced by several factors. These factors are known as climatic controls. Several physical, geographical, edaphic, physiographic and biotic parameters which interact with weather elements determine the climate of a place/ region is called climatic controls.

Some of the important climatic controls/ factors are;

(1) Latitude (2) Altitude (3) Land and sea surfaces (4) Mountain barriers (5) Local topography, ocean currents and (6) Vegetation or forest

(1) **Latitude:**

It is defined as the angular distance of a place from the equator and is expressed in degrees, minutes and seconds. It is a principal control of climate and determines the solar energy received and temperature of a place. Different types of climates according to latitude are equatorial, tropical, sub-tropical temperate and polar climates.

(2) **Altitude:**

It is defined as the height from mean sea level (MSL) and is expressed in meter. Temperature decreases with height. According to altitude there are two type of climate viz mountain climate and plateau climate.

(3) **Land and sea surfaces:** As the distance from sea of a place increases the difference between maximum and minimum temperature during a day and year increases. Depending on land and water bodies there are two types of climate such as maritime and continental climates. In maritime climate humidity is more and moderate temperature prevails. In continental climate the difference between maximum and minimum temperature is highest.

(4) **Mountain barriers:**

Mountains or hills interfere with wind flow controlling the temperature, rainfall and wind. Wind ward side receives more rainfall while leeward side receives less rainfall and remains dry.

(5) **Local Topography:**

Undulation or unevenness of the surface changes the wind velocity which may change the temperature. Hence weather changes and fluctuations are more.

(6) **Vegetation and Forest**:
In forest climate due to evapotranspiration water vapour increases, humidity increases and temperature decreases. It also reduces incoming radiation and wind velocity.

Seasons

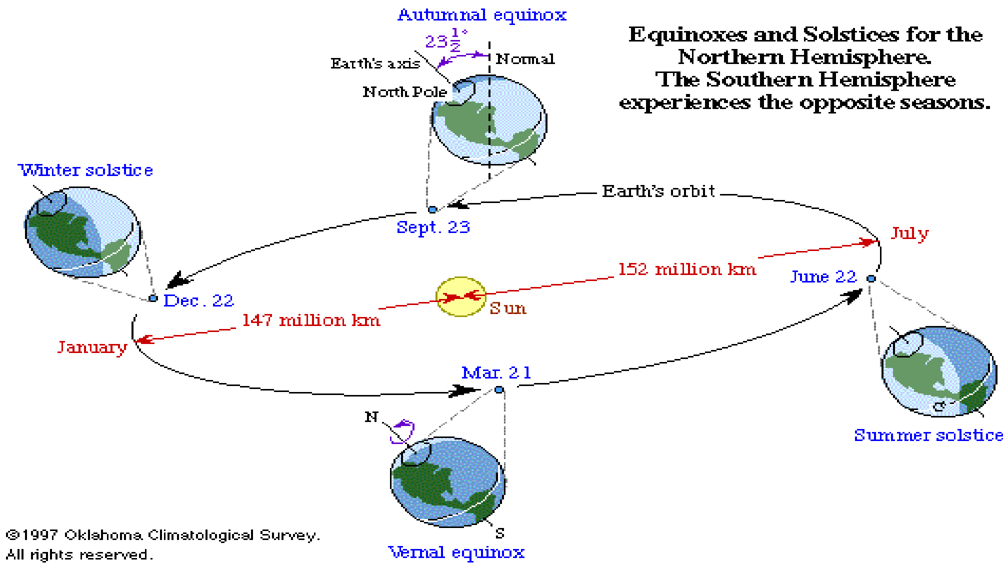
Earth appears to be stationary, but actually it is not so. It has two types of motions: rotation and revolution. It spins on its axis at a speed of about 1600 km/ hour, making one complete rotation in about 23 hours, 56 minutes. The rotation of earth causes day and night. The second motion is around the sun in its elliptical orbit, which takes one year i.e. 365.25 days to complete, is known as **one revolution**. The average velocity of earth in its orbit is nearly **29.6 km/s**. Due to revolution, different seasons occurs on the earth. The earth rotates on its own axis from west to east (anticlockwise). The rotation of earth creates the coriolis force, due to which there is deflection of prevailing wind and ocean currents.

Perihelion and Aphelion

As the earth moves round the sun in an elliptical path, the distance between the sun and the earth vary with time. The earth is nearest to the sun during winter of

Northern Hemisphere (NH). The distance between the sun and the earth is the least or lowest (147×10^6 km) on about January 3 on this day; the earth is known to be in **Perihelion**.

The distance between the sun and the earth is the farthest (152×10^6 km) on about July 4, on this day; the earth is known to be in **Aphelion**. The earth moves around the sun with greatest velocity at perihelion and the lowest velocity at aphelion.



(1) Spring season: March, April, and May: **Vernal Equinox** occurs on 21st March, on that day, day and nighttimes are equal on entire earth.

(2) Summer season: June, July, and Aug: **Summer solstice** occurs on 21st June, longest daytime and shortest nighttime for northern hemisphere but at the same time **winter solstice** for the southern hemisphere.

(3) Autumn season: Sept., Oct. and Nov.: **Autumnal Equinox** occurs on 23rd September, on that day, day and night times are equal on entire earth.

(4) Winter season: Dec., Jan., and Feb.: **Winter solstice** occurs on 22nd December, on that day shortest nighttime and longest daytime for northern hemisphere but at the same time **summer solstice** for the southern hemisphere.

Earth's Atmosphere and its composition, division of atmosphere

(A) Earth's Atmosphere:

Atmosphere

The earth is surrounded by a mixture of gases known as **atmosphere**.

The studies of the atmosphere and the various physical, chemical and dynamical processes which are taking place in it are called as **atmospheric sciences**.

Atmosphere is the physical mixture of gaseous which surrounds the earth on all sides. It is a mobile, compressible and expansible. The height of atmosphere from surface is about 400 km. The density of air decreases, so rapidly with altitude that half of the atmosphere lies within 5.5 km than the surface and nearly 75% of the atmosphere lies up to 11km.

Characteristics of atmosphere

The atmosphere differs from the lithosphere and the hydrosphere in many respects:

1. Air is the colorless, odorless and tasteless substance.
2. Air is a mobile, elastic and compressible.
3. Air is not as dense as land or water. It has weight. The pressure it exerts on the surface of earth is called the atmospheric pressure.

Importance of atmosphere

1. All life forms cannot exist without atmosphere.
2. Living organisms depend on the availability of water.
3. Animals need oxygen and plants need CO_2.
4. It is the atmosphere that provides most of the oxygen and carbon dioxide and maintains the earth system.
5. It is the atmosphere which maintains the temperatures that suit us/ living organism. In the absence of atmosphere there would have been great extremes of temperature to the tune of $260^{O}C$ between day and night.
6. The atmosphere protects living organism from the much of the sun's ultraviolet radiation, which is injurious to plants and animal life.
7. The currents, motion and various other activities of the atmosphere are combining together to produce weather.
8. It regulates heat and mass in earth- atmosphere system

Importance of atmosphere for agriculture

1. It provides oxygen, which is useful for respiration in plants.
2. It provides CO_2 to build biomass in plant through photosynthesis.
3. It provides nitrogen, which is essential for plant growth.
4. It protects life from harmful effects of U.V. rays.
5. It acts as a medium for transformation of pollens.
6. It maintains heat/ temperature to plant life.
7. It provides water to field crops through precipitation, as it is a source of water vapour for condensation, cloud formation etc.

(B) Composition of atmosphere:

Atmosphere is never at rest and is always in a dynamic state i.e. under motion. Therefore, we may always speak of a generalized composition of the atmosphere i.e. composition on an average over a time.

The percentage composition of the atmosphere by volume at the surface of the earth is approximately is given in the following table.

Components	**Percent**
Nitrogen (N_2):	78. 08
Oxygen (O_2)	20.95
Argon (A)	0. 93
Carbon- dioxide (CO_2)	0. 03
Neon (Ne)	0. 0018
Ozone (O_3)	0. 0001
Helium (He)	0. 00052
Methane (CH_4)	0. 00017
Ozone (O_3)	0.00004
Krypton, Xenon, etc.	Trace
Water vapour, dust	Variable

These values are more or less constant in the lower atmosphere below about 50-60 km height and change at greater heights with the appearance oxides of nitrogen and oxygen due to dissociation and ionization of the dominant gases by the solar radiation and also due to differential distribution of denser and lighter gases in the upper atmosphere.

In addition to the above, other particulate matter such as salt particles, smoke particles, pollen, fungal spores etc., are also present in lower atmosphere.

In upper atmosphere, U.V. radiation from the sun is absorbed by gaseous oxygen (O_2). The oxygen molecules break down into atomic oxygen (O). A portion of this atomic oxygen recombines with O_2 to from Ozone (O_3), which in turn is quite unstable. Ozone decomposes to form molecular oxygen and is established and maintained by further absorption of U.V. radiation during daytime.

Role of atmospheric constituents

Nitrogen (N_2)

(1) It is an inert gas and helps in reducing the concentration of oxygen, thereby makes the atmosphere conducive to living organism.

(2) During lightening, oxides of nitrogen are formed. These dissolve in the rainwater and are washed to ground surface increasing the fertility of the soil.

(3) Certain bacteria (Viz. Rhizobium, Azotobactor etc.) are able to fix atmospheric nitrogen for being made available to plants for their growth.

(4) Nitrogen existing in the atomic from in the upper atmosphere is involved in photo-chemical reactions (Aurora borealis, lightening etc.).

<u>Oxygen</u> (O_2)

(1) Oxygen is important to sustain life in the universe, since it is essential for life of man and all natural combustion.

(2) It does not involve itself directly in any physical processes building weather but it takes part in photochemical reactions to produce ozone. This ozone in turn helps to decrease the amount of U.V. radiation reaching earth, which is harmful to organic life on earth.

(3) It is important in maintaining a balance of ozone in the atmosphere.

(4) Its presence in atomic stage in upper atmosphere causes colourful display and the phenomena like Aurora borealis etc., are observed at high latitudes.

<u>Carbon dioxide</u> (CO_2)

(1) Photosynthesis in vegetation is possible because of the presence of CO_2 in the atmosphere.

(2) Photosynthesis and respiration in the vegetation are useful to maintain balance of CO_2 & O_2 in atmosphere.

(3) CO_2 in atmosphere exerts a controlling influence on the atmospheric temperature because it absorbs and emits long wave radiation.

(4) In city areas, the concentration of CO_2 is large. This prevents the escape of long wave radiation and therefore day as wells as nights are warmer in these areas.

(5) In village areas the concentration of CO_2 is less. This prevents the less amount of long wave radiation and therefore the days are less warm and nights are much colder.

<u>Ozone</u> (O_3)

(1) Ozone controls temperature like CO_2 but its proportion being very less, it is less effective than CO_2.

(2) Filters U. V. radiations harmful to life on earth.

(2) Presence of ozone in the lower atmosphere in small quantity makes the atmosphere exhilarating (more lively).

Water vapour

(1) It has a controlling influence on two important agro-meteorological phenomena viz. evaporation and transpiration, if drier the air, more will be the rate of E & T.

(2) It controls temperature of the atmosphere (heat conversion during change of state) i.e. latent heat.

(3) It is responsible for condensation in presence of dust particles and hence for events like dew, fog, frost clouds, rain snow, hail etc.

(4) It affects the efficiency of man.

Dust

(1) Dust is of two types viz. (a) Mineral or inorganic dust-like salts, minerals in smoke etc. (b) Organic dust- like carbon (smoke) micro organisms, stamen and pistil from flowering organs.

(2) It provides the base required for atmospheric condensation.

(3) It influences visibility.

(4) Dust absorbs a part of the incoming solar radiation and is an agent of reflection and scattering. The blue colour of the sky and the red of sunsets are due to selective scattering of the visible solar spectrum by gas molecules and dusts.

Characteristics of atmosphere that influence weather conditions:

(1) Atmosphere remains encircled with earth during its rotation and revolution. Hence during day and night and during different seasons, solar energy received by the earth's surface and the atmospheric air will be different.

(2) The atmosphere is differentially heated i.e. it is heated more at equator and less at poles on account of shape of the earth, its orientation with respect to sun and its distance from the sun.

(3) Atmosphere consists of different elements and air is a mixture of natural elements like O_2, N_2, H_2 etc., chemical compounds like CO_2, H_2O and organic and inorganic impurities called dust. The air, a mixture of gases has weight and exerts pressure, but, because it is compressible, its density decreases rapidly with altitude and therefore, pressure also decreases with height.

(4) Because of differential heating of atmosphere over different places of the earth, conduction and convection currents of heat are developed.

The above-mentioned characteristics of the atmosphere are responsible for physical and dynamic processes going on in the atmosphere giving rise to changes in the weather conditions over a given place.

In atmosphere, Nitrogen and Oxygen make up approximately to 99% by volume and remaining other gases 1%. In addition to gases, it contains large quantities of solid and liquid particles. The lower part of the atmosphere contains water vapour from **0.02 to 4%** by volume, innumerable dust particles, silt particles, smokes, pollens etc, are also present in the atmosphere. They are microscopic and hygroscopic in nature, and play an important role in absorption, reflection and scattering of **insolation** (incoming shortwave radiation at earth's surface).

(C) Divisions or Spheres of atmosphere:

Atmospheric division based on **temperature distribution/ variation** with respect height in the atmosphere.

The atmosphere is divided vertically in to **four** layers.

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere

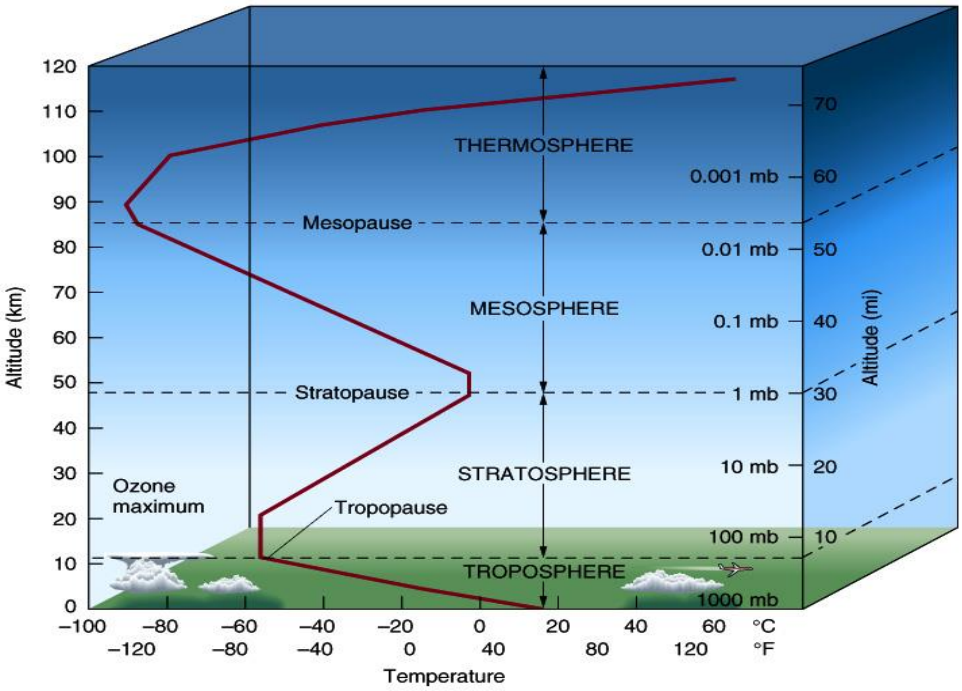


Fig: - Temperature distribution in the atmosphere.

The characteristics of each layer are given below:

Sr.	Sphere	Height (km)	Temperature (° C)	Remarks
1	Troposphere	O to 11	15 to -60	Decrease
2	Stratosphere	11 to 50	-60 to 0	Increase
3	Mesosphere	50 to 85	0 to -90	Decrease
4	Thermosphere	Above 85	-90 to +950	Increase

(1) Troposphere

- The word "Tropo" means mixing or turbulence and "sphere" means region or layer.
- This is the lower layer of the atmosphere. The average height of this layer is about 14 km above mean sea level. At the equator it is 16km and at the poles it is 7-8 km height.
- Under normal conditions the height of the troposphere changes from place to place and season to season.
- This is layer is called the " **seat of all weather phenomena**" because various types of clouds, cyclones, storms and anti-cyclones occur in this sphere due to the concentration of almost all the form of water vapour, dust particles etc, in it.
- Generally there is decrease of temperature with increasing height at a normal lapse rate of about 6.5°C per kilometer.
- The wind velocity increases with height and attain the maximum at the top of this layer.
- The troposphere is heated from the below because most of the radiation from the sun is absorbed by the earth's surface.
- In this layer about 75% of total gases and most of the moisture and dust particles are present.
- At the top of the troposphere, there is a narrow layer separating it from the stratosphere, which is known as the "Tropopause". It is a transitional zone and it is a characterized by no major movement of air.

(2) Stratosphere

- This is a layer exists above the tropopause and extends to altitudes of about **50-55** km from the surface. This layer is called as a "**seat of photochemical reactions**".
- In this layer temperature remains practically constant at normal 20 km and is characterized as isothermal because the air is thin, clear, cold and dry.
- In the upper part of the stratosphere the temperature are almost high as those near the earth' surface, which is due to the fact that the ultraviolet radiation from the sun is absorbed by ozone gas in this layer.

- Less convection (upland transport or vertical movement) takes place in the stratosphere because it is warm place at top and the dry and cold at the bottom.
- Wind speed is higher and air circulation pattern exists.
- The upper boundary of the sphere is called the stratopause is the transition zone between troposphere and stratosphere. Above this layer there is a steep decrease in temperature.
- There is a maximum concentration of ozone between 30 and 50 km above the surface of the earth and this layer is known as the ozonosphere.
- The ozone has a property of absorbing ultraviolet rays. If there is no ozone in the atmosphere life would not have existed on the earth.

(3) Mesosphere

- The layer between 50 and 80 km is called as mesosphere.
- In this layer the temperature decreases with height.
- The upper bounding of this layer is called the mesospause. It is the transition zone between stratosphere and mesosphere.

(4) Thermosphere

- The thermosphere also called Ionosphere lies beyond the mesosphere at a height about 80 km above earth's surface and extends up to 400 km.
- The atmosphere in the thermosphere is partly ionized. Enriched ion zones exist in the form of distinct ionized layers. So, this layer is called as the ionosphere.
- According to some climatologists the layer between 80 and 140 km is known as the thermosphere and beyond that Ionosphere exists.
- The ionosphere reflects the radio waves because of multiple reflections of radio wave beams from the ionized shells. So, long distance radio communication is possible due to this layer.
- The outer most layer of the earth's atmosphere is names as the **exosphere** and this layer has beyond 400 and 1000 km. Hydrogen and Helium gases predominate in this outer most region. The density of atoms in this layer is extremely low. So, there is no collision between the neutral practices.

Isotherms: The lines joining places having equal atmospheric temperature on a geographical map.

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CHAPTER-3

ATMOSPHERIC PRESSURE AND WIND, CYCLONES AND ANTI-CYCLONES, LAND AND SEA BREEZES

- Air expands when heated and gets compressed when cooled. This results in variations in the atmospheric pressure.
- The differences in atmospheric pressure cause the movement of air from high pressure to low pressure, setting the air in motion. Atmospheric pressure also determines when the air will rise or sink.
- Air in horizontal motion is wind. The wind redistributes the heat and moisture across latitudes, thereby, maintaining a constant temperature for the planet as a whole.
- The vertical rising of moist air forms clouds and bring precipitation.

Air Pressure

- Since air has mass, it also has weight. The pressure of air at a given place is defined as a force exerted in all directions by virtue of the weight of all the air above it.
- The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the atmospheric pressure. The atmospheric pressure is expressed in various units.

Measurement of Air Pressure

- Atmospheric pressure is the weight of the column of air at any given place and time. It is measured by means of an instrument called **barometer**.
- The units used by meteorologists for this purpose are called **millibars (mb).**
- **One millibar is equal to the force of one gram on a square centimetre. A pressure of 1000 millibars is equal to the weight of 1.053 kilograms per square centimetre.**
- In other words, it will be equal to the weight of a column of mercury 75 cm high.
- The normal pressure at sea level is taken to be about ***76 centimetres (1013.25 millibars).***

Vertical Variation of Pressure

- In the lower atmosphere the pressure decreases rapidly with height.
- At the height of Mt. Everest, the air pressure is about two-thirds less than what it is at the sea level.
- The decrease in pressure with altitude, however, is not constant. Since the factors controlling air density – temperature, amount of water vapour and gravity are variable, there is no simple relationship between altitude and pressure.
- **In general, the atmospheric pressure decreases on an average at the rate of about 34 millibars every 300 metres of height.**

- The vertical pressure gradient force is much larger than that of the horizontal pressure gradient. But, it is generally balanced by a nearly equal but opposite **gravitational force**. Hence, we do not experience strong upward winds.
- Due to gravity the air at the surface is denser and hence has higher pressure. Since air pressure is proportional to **density as well as temperature**, it follows that a change in either temperature or density will cause a corresponding change in the pressure.
- The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas.
- **A rising pressure indicates fine, settled weather, while a falling pressure indicates unstable and cloudy weather.**

Horizontal Distribution of Pressure

- Small differences in pressure are highly significant in terms of the wind direction and velocity. Horizontal distribution of pressure is studied by drawing isobars at constant levels.
- **Isobars** are lines connecting places having equal pressure. In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level for purposes of comparison.
- The spacing of isobars expresses the rate and direction of pressure changes and is referred to as **pressure gradient.**
- Close spacing of isobars indicates a steep or strong pressure gradient, while wide spacing suggests weak gradient. The pressure gradient may thus be defined as the decrease in pressure per unit distance in the direction in which the pressure decreases most rapidly.
- There are distinctly identifiable zones of homogeneous horizontal pressure regimes or **'pressure belts'.** On the earth's surface, there are in all seven pressure belts.
- The seven pressure belts are :

What is wind?

In atmosphere is moving in both directions horizontally as well as vertically. Usually horizontal flow of air is called wind. Air in motion is referred as wind. Vertical motion of air is called current. Wind has both speed and direction.

Different forces which control air motion or forces behind wind or control wind are:

(1)Pressure gradient force: The atmospheric pressure in itself is not a force; however, difference in pressure produces force. The rate of change of atmospheric pressure with respect to distance at same elevation is known as pressure gradient. Pressure gradient is directly proportional to wind speed. It acts in a direction from higher pressure to lower pressure. Thus wind will blow from high to low pressure area. If the isobars are close to each other, the pressure gradient will be more and thus wind speed will be more. If the isobars are widely spaced, the gradient will be less and thus wind speed is mild.

(2) Coriolis force: Because of the rotation of the earth about its axis, there is additional force acting on moving air. This force is known as coriolis force. The main characteristics of coriolis force are:

- It acts only at the right angles to the direction of moving air. It deflects wind to the right in the northern hemisphere and left in southern hemisphere.
- It only affects the direction of air motion/ wind.
- At given latitude the magnitude of coriolis force is directly proportional to the speed of motion.
- Coriolis force is a maximum (100%) at the poles but decreases to zero at the equator.

(3) Frictional force: Whenever air moves relative to the earth's surface, frictional drag tends to slow the air and also alter its direction of movement. The frictional force is greater over rough surfaces such as forest or city but less over the water surface. The effect of friction is most pronounced near the surface. It becomes relatively insignificant at elevation greater than 1 km above the surface. Frictional force acting on air is viscous force which arises when a layer of air moves over another.

(4) Centripetal force: This force arises when air mass is moving in circular system like cyclone and anticyclone. It is a net outward directed force.

(5) Gravity /Gravitational force: The force of gravity always acts downward on a parcel of air. Gravity plays an important role in vertical movement of air.

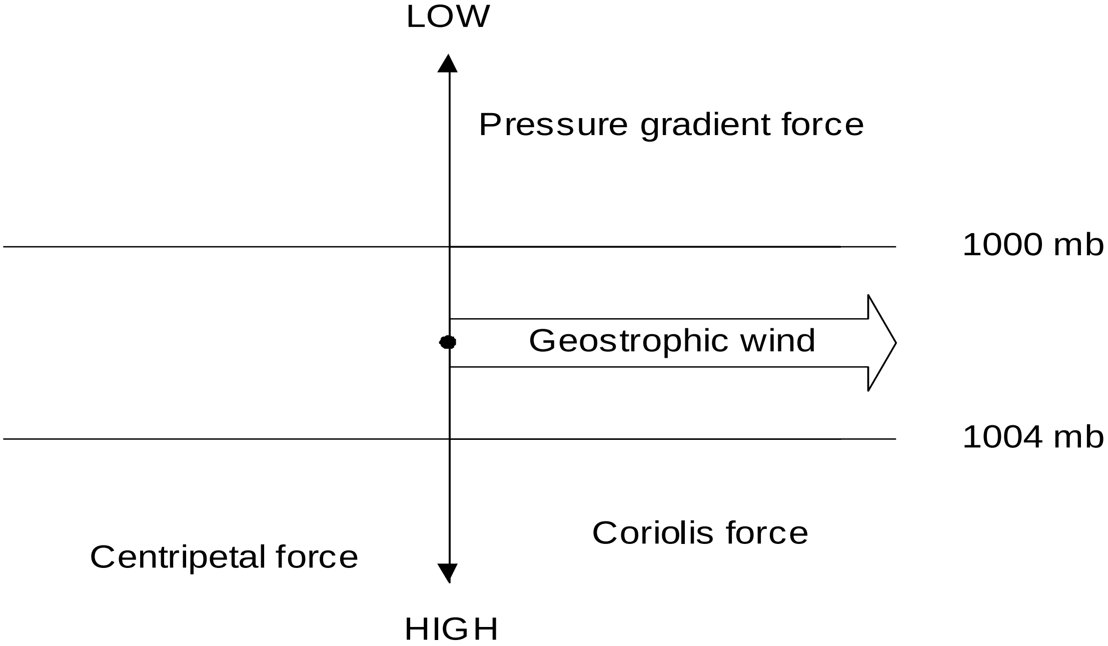
Isobars: It is a line joining places having equal atmospheric pressure on a geographical map.

Types of Winds

Depending on the nature of forces acting on the wind, there are three main types of winds.

- Geostrophic Wind
- Gradient Wind
- Cyclostrophic Wind

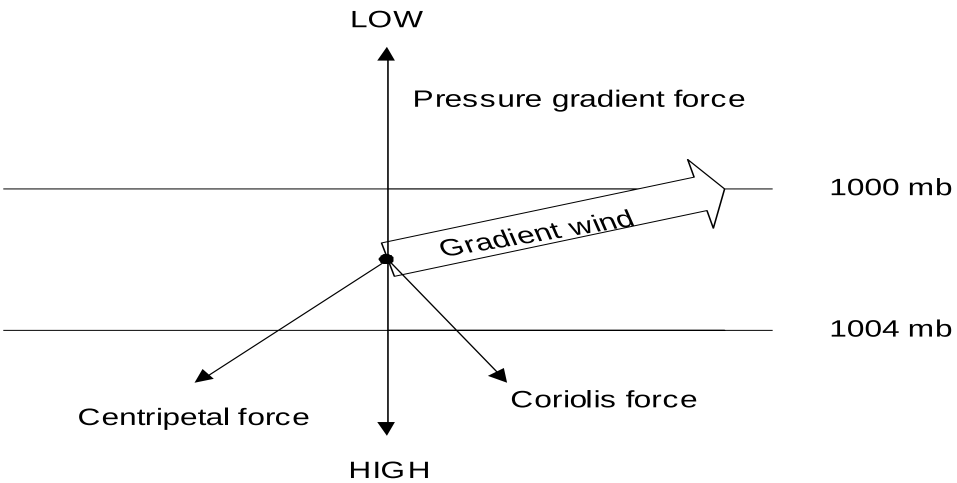
1. **Geostrophic Wind**:
   When the pressure gradient force balances the Coriolis force, the wind blows along the isobars instead across the isobars the resulting wind is known as 'Geostrophic wind'. Geostrophic wind occurs in higher in the atmosphere where the frictional effects are negligible or insignificant.



Geostrophic wind

2. **Gradient Wind**:

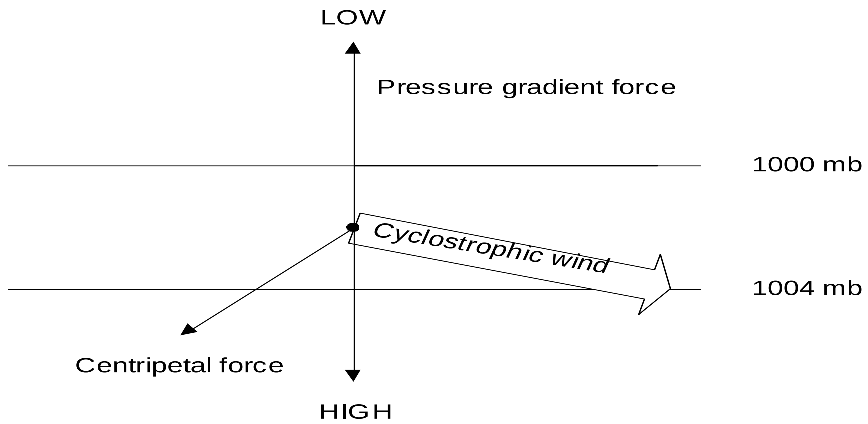
The gradient wind occurs when the wind blows along the curved path as in the case of cyclones. In this case, the pressure gradient force, the Coriolis force and the centripetal force balance each other. In other words, in a low-pressure system (cyclonic circulation) a balanced flow is maintained in a curved path by the excess of the pressure gradient force over the Coriolis force giving the net centripetal acceleration inward. Where as in a high-pressure (anti-cyclonic circulation) system it is the excess of Coriolis force over the pressure gradient that gives net centripetal acceleration inwards. At the equator, since the Coriolis force is not present the gradient wind does not occur.



Gradient wind

3. **Cyclostrophic Wind**:

In this case, the pressure gradient force and the Centripetal force balance each other. The cyclostrophic winds occur near equator since the Coriolis force is absent here.The balance of forces for the above three types of wind systems are shown in the following diagrams for a system of linear isobars.



Cyclostrophic wind

If the isobars are curved rather than linear the balanced motion would be as shown in the figure for cyclonic circulation. For anti-cyclonic circulation, the picture would be very similar. In the first diagram three is no frictional force and the winds blow in curved path but parallel to the isobars. In the second diagram due to frictional force the resultant gradient wind blows at an angle to the isobars rather than parallel to the isobars.

Air Circulation: primary, secondary and tertiary

General Air circulation in atmosphere is mainly caused by following factors:

(i) The large latitudinal variation of atmospheric air heating

(ii) The North-South (N-S) displacement of maximum heating zone during coarse of a year

(iii) The distribution of continents and oceans

(iv) The rotation of the earth

Air Circulation

Wind movement or circulation in the atmosphere may be classified into three broad categories:

(1) Primary circulation: It is a Macro scale air circulation. Primary circulation includes the planetary wind systems, which are related to the general arrangement of pressure belts on the earth's surface. Trade winds, westerlies and polar easterlies together from the primary air circulation.

(2) Secondary circulation: It is a Mecro or Synoptic scale air circulation. Generally Secondary circulations consist of cyclones, anticyclones, monsoons depression, cold and dry air masses.

(3) Tertiary circulation: It is a Micro scale or local scale air circulation. Tertiary circulations include all the local winds, which are produced by local factors and which only affect the weather and climate of a particular small scale locality or area.

(1) Primary circulation/ Primary wind pattern on earth surface:
The earth's Primary / general circulation of wind can be represented by a sample model in Fig.1 – In this model the earth's surface has been considered uniform, means either all lard or all water mass and the effects of local systems have been ignored. The actual wind system is much more complicated. Due to unequal heating of the earth's surface pressure gradients are generated which give rise to wind.

(A) Trade winds

(B) Westerlies

(C) Polar easterlies.

(A) Trade winds

1. The regular high temperature at the equator results in a low pressure forming over the equatorial region.
2. The air is transferred to the north and south word directions until 30º north and 30º south in both hemispheres.
3. Due to this reduction in surface pressure on the equator. There is an increase in pressure at 30ºN and 30ºS, which are known as "horse latitudes". As a result, the winds flow from the horse latitude to the equatorial region.
4. Whole moving, these winds are deflected by carioles force to the right in N-Hemisphere and to the left in the S – hemisphere.
5. These winds blow from 30ºN to the equator in NE direction in then N.H. and from 30ºS to the equator in SE direction in the S. H. These are known as trade winds or tropical winds.

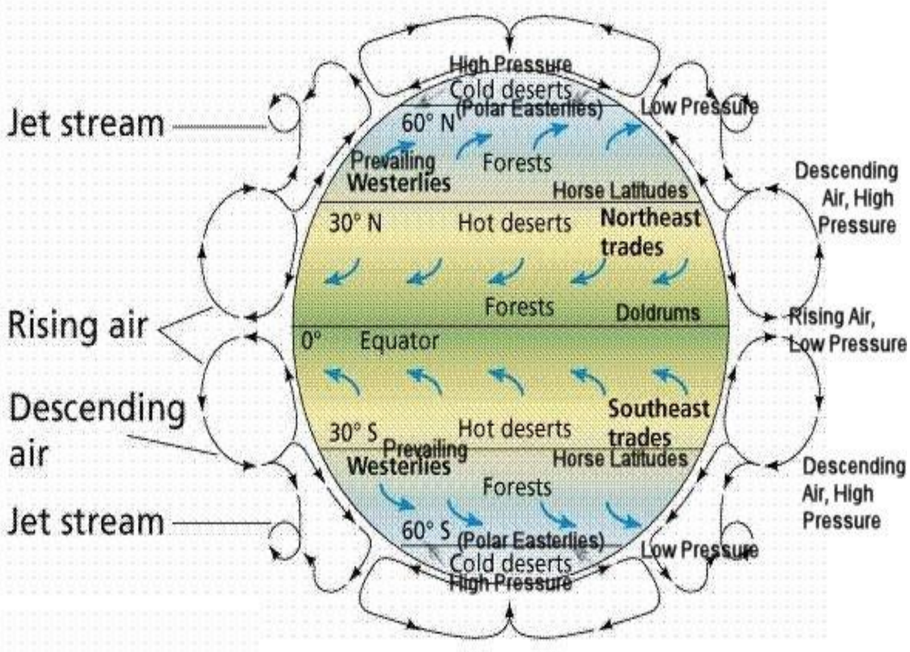


Fig. Primary wind pattern on earth globe

(B) Westerlies

1. The winds that flow from sub-tropical high (30^{O}) to the Sub polar low area at about 60^{O} latitudes in both the hemispheres are known as westerlies.
2. At the surface winds flow in SW direction in the N.H. and in NW direction in the S.H.
3. At the upper level winds flow in NE direction in the N.H. and in SE direction in the S.H

(C) Polar easterlies or polar winds

1. A permanent high pressure exists on the both north and south poles.
2. From these Polar high pressures cold winds flow to Sub polar low areas at about 60º latitude in both the hemispheres.
3. At the surface winds flow in NE direction in the N.H. and in SE direction in the S.H.
4. At the upper level winds flow in SW direction in the N.H. and in NW direction in the S.H

(2) Secondary Circulation:

Most of the day to day weather events are produced by traveling cyclones and anticyclones. These features are classified as secondary air circulation. The horizontal scale of these features is about 300- 3500 km. Their life time usually ranges from 2 to 3 days up to 10 to 12 days. Tropical cyclones whose size ranges from about 300- 600 km is smaller one of the secondary air circulation, where as in the higher range of this scale are extra tropical cyclones and anticyclones which extend from 800- 3500 km.

SN	Cyclones	Anticyclones
1	Lowest pressure at centre and it increases towards the outer rim gradually.	Highest pressure at the centre and it decreases towards the outer rim gradually.
2	RH increases towards centre and being cloudy weather.	RH decreases towards centre and clouds are dissipated giving fair and clear weather.
3	Variety of clouds lies at different heights.	Little clouds with cool, dry air are usually associated.
4	Generally heavy rainfall occurs.	Under fair weather condition not much precipitation occurs because it usually forms over land.
5	**.**Generally formed over sea and travel towards the land areas	Mostly formed over land areas.
6	Wind velocity increases from outer rim to the canter.	Wind velocities are much lesser than cyclones.
7	Horizontal Size of the pressure system is around 150 to 600 km.	Horizontal Size of the pressure system is larger than 500km and extend over 1000 km size.

(3) Tertiary Circulation (Local winds):

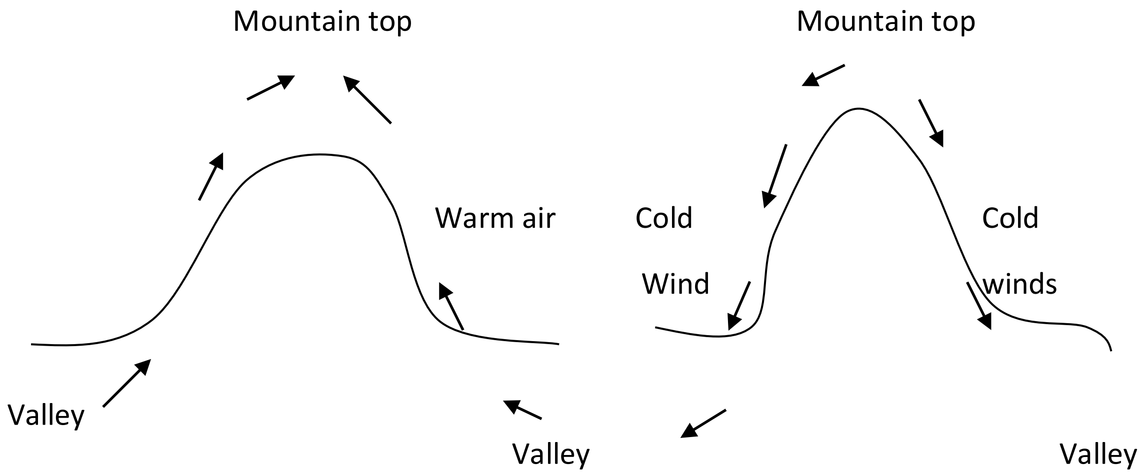
These are local air circulation patterns caused by local variations in the land topography and sea-land surface contrasts. Land and sea breezes and mountain and valley breezes are some of the well known local winds. The atmospheric motions which extend for horizontal distance from 1 to 2 km to 100 km are called the tertiary circulations or local winds. They are developed from local temperature differences and usually affect small areas. Following are the examples of local winds.

(A) Mountain and valley breezes

SN	Mountain breezes / winds	Valley breezes/ winds
1	Blows from mountain slopes to the valley base.	Blows from valley base to the up slope of mountain.
2	Mountain breeze occurs during night-time.	Valley breeze occurs during daytime.
3	Cooling of air close to slope takes place.	Over heating of air adjustment to slope takes place.
4	Also known as “katabolic winds	Also known as “Anabatic winds”.

These winds are found near mountainous regions. During daytime the slops of mountains heat up rapidly because of intensive insolation. The warm air moves up along the slope. This up slope breeze is called as the ‘Valley breezes” or “Valley winds”.

However, at night the temperature difference between mountain slopes and free atmosphere is changed. Radiational cooling during night beings about a more rapid cooling of mountain slopes as a result of which the cool air drains into the valley below. This down-slope wind is called the mountain breezes or the mountain winds. Valley breezes are more intense and persistent as compared to mountain breezes.



Valley breezes **(Day time)** Mountain breezes **(Night time)**

(b) Land and sea breeze

SN	Sea breeze	Land breeze
1	Occurs in day time	Occurs in nighttime.
2	Flows from sea to land.	Flows from land to sea.
3	Have more moisture than land breeze	Do not have more moisture that sea breeze.
4	Stronger than land breeze.	Weaker than sea breeze.
5	Modifies weather on hot summer after noon.	Produces cooler winters and warmer summers.
6	It depends on topography of coastal region.	It depends on the topography of land.

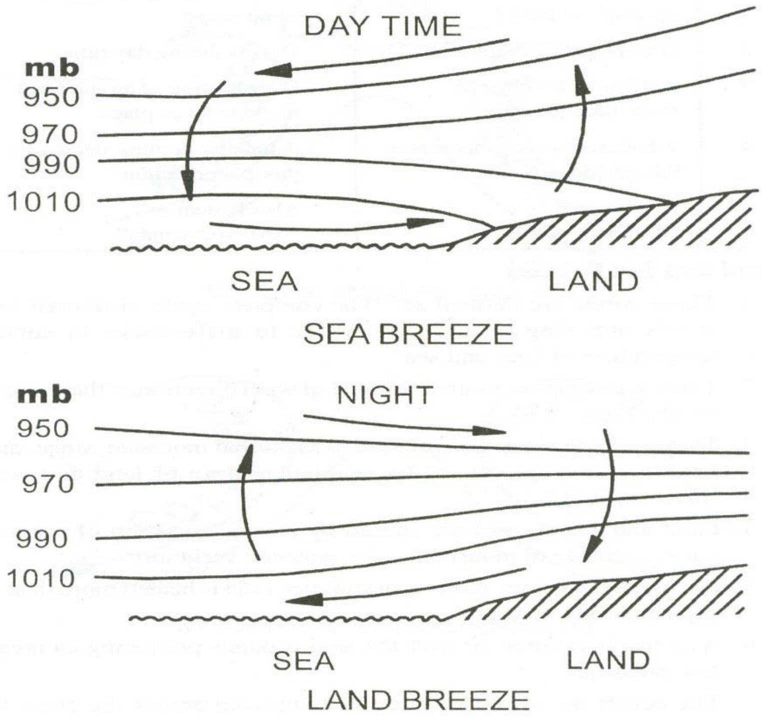


Figure:5.4
LAND AND SEA BREEZES

1. During daytime land is heated more than the adjacent body of water. As a result, warm air over the land expends producing an area of low pressure. The cooler air over the water stands moving across the coastline from sea to land. This is the sea breeze.
2. However, at night because of radiational cooling, land is colder than adjacent sea and the pressure gradient is directed from land to sea. This wind is called "land breeze".
3. These winds are defined as complete cycle of diurnal local winds occurring on seacoasts due to difference in surface temperature of land and sea. That is why they are also referred to as diurnal monsoon. Since, these wind systems are caused by unequal heating of land and water surfaces.
4. Land and sea breezes are caused by diurnal variation of pressure but occurrence of monsoon is by seasonal variation.

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CHAPTER-4

SOLAR RADIATION, DEPLETION OF SOLAR RADIATION AND ENERGY BALANCE

Radiation balance:

The solar radiation while its journey from sun to earth passes through the space and atmosphere comes across several gaseous particles, liquid and solid particles. Thus the magnitude and intensity is either modified or reduced due to absorption, scattering and reflection.

Mathematically this can be represented by the following equation.

$$Q_s = C_r + A_r + C_a + A_a + (Q + q)(1\text{-}a) + (Q + q)_a$$

Where,

Q_s is solar radiation incident on the top of the atmosphere.

C_r is reflection and scattering back to space by clouds.

A_r is reflection and scattering back by air, dust, water vapour etc.

C_a absorbed by clouds

A_a Absorbed by air, dust and water vapour etc.

$(Q + q)_a$ is reflection by the earth where Q and q are direct and diffuse radiation respectively on earth and a is albedo.

$(Q + q)(1\text{-}a)$ is absorption by earth surface.

The global disposition of shortwave radiation in terms of kilo Langley and also as per cent per year is given in following table.

Units of measurement: Watt/m^2, g cal/ cm^2/min, ly/min

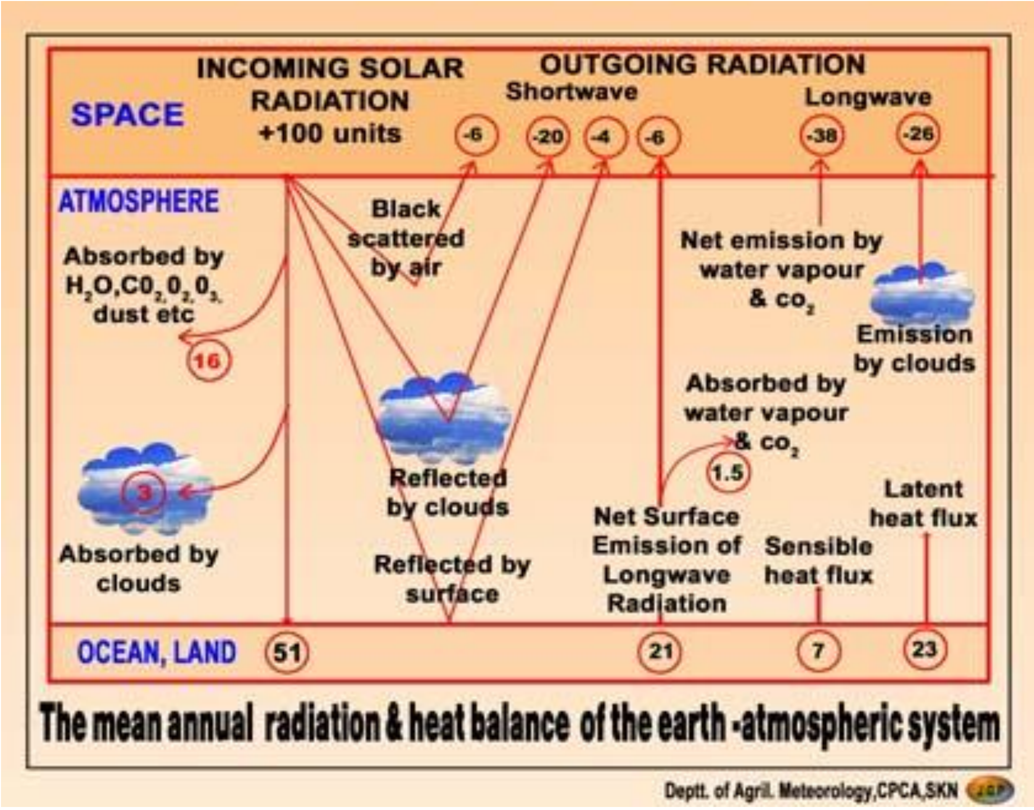
Table: Disposition of solar radiation in earth atmosphere system

Description of solar radiation in Earth-Atmo. system	K ly	%
Q_s is solar radiation incident on the top of the atmosphere	263	100
C_r is reflection and scattering back to space by clouds.	63	24
A_r is reflection and scattering back by air, dust, water vapour etc.	15	6
Total reflection **$C_r + A_r$** by atmosphere	**78**	**30**
$(Q + q)_a$ is reflection by the earth surface	16	6
Total reflection from earth-atmosphere system	**94**	**36**
C_a absorbed by clouds	7	3
A_a Absorbed by air, dust and water vapour etc.	38	14
Total absorption by atmosphere **$C_a + A_a$**	45	17
$(Q + q)(1\text{-}a)$ is absorption by earth surface	124	47
Total absorbed by earth-atmosphere system	**169**	**64**

Instruments for measuring solar radiation:

Direct solar radiation – Pyrheliometer

Sky / Total solar radiation – Pyranometer , Net radiation – Net radiometer



Energy Balance/ Heat budget

The net radiation which is the difference of net incoming short wave radiation and net outgoing long wave radiation is the main source of energy at the earth surface. This available energy is partitioned in different components. Mathematically this can be represented by

$R_n = R_S (1-r) – R_L$

Where, R_n = net radiation

$R_S (1-r)$ = Net incoming shortwave radiation

r- reflectivity of surface

R_L = Net outgoing longwave radiation

Rs = Extraterrestrial radiation and r is reflectivity of underline surface.

The energy balance equation can be written as

$R_n = G + H + LE + P + M$ ………………………(1)

Where, G = Ground heat flux,

H = Sensible heat,

LE = Latent heat,

P= energy used in photosynthesis and

M= miscellaneous energy exchanges.

The magnitude of P & M is negligible in comparison to G, H & LE. Thus, the equation is simplified as

$R_n = G + H + LE$ ……………………………… (2)

The approximate magnitude of individual components of energy balance at ideal bare ground surface is:

- Sensible heat-57%
- Latent heat-30%
- Ground heat-13%

The amount of water presents in soil control the magnitude of different components of energy balance.

Major Components of energy balance

(1) Net Radiation:

The net radiation is the difference of net incoming short wave radiation and net outgoing long wave radiation. It is the main source of radiant energy at the earth surface. When absorbed by surface converted in to the heat energy. It is positive during daytime and negative during nighttime.

(2) Latent heat flux

The amount of energy (heat) necessary to vaporize a unit mass of a liquid is called latent heat of vaporization. i.e. at same temperature the substance changes its phase from liquid to vapour. To transform one gram of liquid water to the gaseous state, nearly 600 cal of heat is required. This heat is not sensed by thermometers. So, it is called as latent heat.

(3) Sensible heat flux

If the addition or subtraction of energy to a body is sensed as a rise or fall in its temperature is referred as sensible heat. Its magnitude is more when the surface is dry. On wet soil latent heat is more than sensible heat.

(4) Ground heat flux

Soil heat flux is small in comparison to H & LE. The heat transfer in soil takes place as thermal conduction.

Daytime & Night time energy exchange/ balance on surface

The incoming solar radiation is available only during day time while the outgoing long wave radiation is continued during day and night. Therefore, the magnitude and direction of various components of energy balance changes during both daytime and night time of day.

(A) Day time energy exchange

During day time earth surface gains radiant energy. So that, R_n is downward and considered as positive

$$R_n = R_S (1-r) – R_L$$

Where, R_n = net radiation

$R_S (1-r)$ = Net incoming shortwave radiation

R_L = Net outgoing long wave radiation

During day time sensible and latent heat fluxes are upward and ground flux is downward in the soil. The net radiation is used to heat the air (sensible heat) used in vaporization (latent heat) and in heating the soil (ground heat flux).

(B) Night time energy exchange

$$R_n = Rs(1-r) - R_L$$

$= 0 - R_L$ (during night time Shortwave radiation is absent so that $R_s = 0$)

$= - R_L$

During night time there is net loss of heat by earth surface. This is balanced by heat flow upward through ground (G), downward from air and condensational heating (if dew formation) or cooling (evaporation).

Energy balance over various agricultural surfaces:

When there is vegetation over soil surface the energy balance equation is modified by following features.

1. Energy and water storage in vegetation system

2. Photosynthesis and CO_2 exchanges.

The detail energy balance equation for soil-plant-air system, may be written as

$$R_n=H+L+G+A+P+M$$

Where, R_n is net radiation,

H - Sensible heat,

L - Latent heat,

G - Ground heat,

A - Advection term,

P - Photosynthesis,

M is metabolic term.

During daytime photosynthesis is + ve (Positive Value). While during night photosynthesis is – ve (Negative Value).

Energy balance equations on different types of fields are:

1.Bare field: $R_n = G + H + LE$

2.Crop field: $R_n = G + H + LE + P + M + A$

3.Water surface : $R_n = H + LE$, G is negligible, but LE > H

4.Irrigated crop field: $R_n = G + H + LE + P$ here LE > H

5.Desert area : $R_n = G + H$ LE is negligible in dry condition

6.Mulched field : $R_n = G + H + LE$ Here LE is less because it is checked by soil mulch.

The land is the uppermost layer, which receives, and gives off radiation. Reflectivity or albedo is a ratio of reflected radiation to that of the incident radiation (insolation). A reflection coefficient or albedo of 0.40 means that the ground surface reflects 40 % and absorbs 60% of the radiation that falls on it.

Albedo of different surfaces:

Ploughed surface	14 -17 %
Moist and dry black soils	8 and 14 %
Moist and dry grey soils	10 to 12 and 25 to 30 %
Desert soils	29 to 43 %
Crop surface (general)	23 to 25 %
Grasses	20 to 25 %
Rice field (flooded)	12 %

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CHAPTER-5

AIR TEMPERATURE AND VERTICAL PROFILE OF TEMPERATURE

The degree of hotness or coldness is known as temperature. When any object receives energy in the form of heat, its temperature increases.

Air or atmosphere receives the heat energy from the sun and its temperature increases.

Due to different amount of heat energy receipt at different places, the air temperatures at different places also vary.

The variations in air temperatures basically result into air motions so as to equalize the energy content of the different regions of the earth.

Thus temperature of air can be regarded as the basic cause for weather changes.

Factors Affecting the Air Temperature

The distribution of temperature over the earth surface depends on following factors:

1. Latitude:

Highest temperatures are generally at the equator and the lowest at the poles. The temperature decreases with the increase of latitude.

2.Altitude:

Temperature decreases with height in troposphere.

3.Season:

Coldest temperatures are in winter and highest temperatures are in summer seasons.

Distribution of land and water:

Water bodies are great moderators of temperature. Because of high specific heat of water, so on the oceans, the regularity in temperature is more as compared to continents.

4.Topogrtaphy:

Mountain ranges affect the temperature by acting as obstacles to the Flow of cold air cold air near the surface and they often set conditions of warm winds.

5.Ocean currents:

Hot and cold ocean currents affect temperature e.g. Gulag Stream (Warm) in North Atlantic, Benguela current (cold) along West coast of South Africa, Peru Current (cold) along West Coast of South America.

6.Winds:

Various types of wind affect temperature.

7.Clouds and rains:

Clouds by obstructing the heat from the Sun and rains by cooling the Atmosphere, affect the temperature.

8.Color of the soil:

Black color of soils absorbs more radiations and other types reflect them.

9.Slope of the soil:

Black color of soils absorbs more radiations and other types reflect them.

10.Forest and vegetation:

Due to Evapotranspiration and interception of sun – rays, temperatures are moderated

Lapse rates, temperature inversion, stability and instability of atmosphere

What is an adiabatic process?

Any change in volume, pressure and temperature of air when it moves upward or downward which take place without addition or removal of heat from the system is known as adiabatic process or adiabatic change. If these changes occur due to addition or removal of heat from the system is known as non adiabatic process.

Lapse rate

It is the rate of decrease of temperature with respect to height above ground surface is known as lapse rate. As the air ascends upward, it encounters low pressure and gets expanded due to which cooling occurs. It is also called as positive vertical temperature gradient 6.5°C/km. Lapse rate is not constant but varies with **height, location and season of the year**. The lapse rates always vary with time and place. The dry adiabatic lapse rate is always the same.

The following are the different types of lapse rate:

(A) Dry adiabatic lapse rate (DALR)

It is a lapse rate of unsaturated dry air. As dry air rises up, its pressure decreases to equal that of the new environment and its volume increases. The DALR is 9.8°C/km, if a dry air panel is displaced downwards, it undergoes compression, work is done upon it by the surrounding air and its temperature rises at the same rate i.e. 9.8°C/km. DALR is reversible.

(B) Saturated (Wet) adiabatic lapse rate (SALR)

It is a lapse rate of saturated air. Consider a panel of saturated air is being displaced upwards. Hence, it is immediately cooled below its dew point and boiler vapors condenses out with the release of **latent heat**. The latent heat is reduced the rate of cooling of ascending air due to its expansion. Consequently the net loss is smaller and the fall of temperature is less than the DALR. The value of SLAR is 4°C/km. The value of SLAR will increased when the saturated air falls due to compression. SALR is not reversible.

(C) Prevailing lapse rate / Actual lapse rate

It is rate of decreases of temperature with height for a given place and time is known as prevailing lapse rate. It is also denoted as actual lapse rate.

(D) Normal lapse rate

It is the average of all lapse rates observed at different places.

Thus, be find: -

1. Normal or average lapse rate: 6.5°C/km
2. Actual /Prevailing lapse rate : actual values of lapse rate
3. Dry adiabatic lapse rate : 9.8°C/km
4. Wet adiabatic lapse rate : 4.0°C/km

Stability and instability of atmosphere:

Atmospheric stability is defined as that condition in the atmosphere in which vertical motions are absent or definitely restricted. Under such condition air remains stable because buoyancy force is balanced by gravitational force. It is mostly observed in cold condition. In which normal practices of crop are to be carried out.

Atmospheric instability is defined as the state wherein vertical movement is prevalent or present. Voluntary vertical motions are largely absent in stable air. On the other hand, the air is unstable, if displacement results in buoyancy and tendency for further movement away from the original position.

By noting the difference in temperature between the air parcels moving upward and its surrounding atmosphere at any level / height, stability or instability can be determined. In other words, the environmental lapse rate prevailing in the atmosphere makes the atmosphere stable or unstable.

(A) Unstable condition: If the Actual / Prevailing lapse rate is **higher** than dry adiabatic lapse rate, the atmosphere is said to be **unstable**. There will be **instability** in the atmosphere. Such a state of condition promotes vertical motions of air masses in the atmosphere which cause condensation and precipitation.

(B) Stable condition: If the Actual /Prevailing lapse rate is **lower** than the dry adiabatic lapse rate, the atmosphere is said to be **stable.** There will be **stability** in the atmosphere. Such a state of condition resists upward vertical motions in the atmosphere but air masses moves downward direction.

(C) Neutral condition: Sometimes the prevailing lapse rate is equal to dry adiabatic lapse rate is to be said neutral condition of atmosphere. Under such condition air masses are not moves upward or down ward in atmosphere.

The following are the Criteria for Stability and instability of atmosphere:

If the air panel being displaced is not saturated, the criteria for stability, instability and neutrality may be as follows:

1. The column of air is said to be **stable**, when its prevailing lapse rate **(y)** is less than the dry adiabatic lapse rate **(y_d)** i.e. when $y < y_d$
2. The column of air is said to be **unstable** when its prevailing lapse rate is greater than the dry adiabatic lapse rate i.e. when $y > y_d$
3. The column of air said to be in **neutral** equilibrium when it s prevailing lapse rate has the same value as the dry adiabatic lapse rate. i.e. when $y = y_d$

Conditional instability: The column of air has **conditional instability** when its prevailing or actual lapse rate lies between the values for the dry-adiabatic and saturated or wet adiabatic lapse rate. i.e. $y_d > y > y_w$

Where,

y = Actual/ prevailing lapse rate

y_d = Dry-adiabatic lapse rate

y_w = Wet adiabatic lapse rate

Temperature Inversion:

Temperature Inversion is also called as an inverted lapse rate. Under certain condition temperature increases with respect to height in atmosphere form ground level is called temperature inversion.

Temperature inversions near earth's surface may be produced or caused by the following ways:

(1) Radiation inversion (2) Air drainage inversion (3) Frontal inversion (4) Advection inversion (5) Subsidence inversion.

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CHAPTER-6

ATMOSPHERIC HUMIDITY, SATURATION, CONDENSATION, PRECIPITATION AND ITS TYPES, CLOUD FORMATION AND ITS TYPES, ARTIFICIAL RAIN MAKING

Water vapor is the most important atmospheric gas. Why?

- Water vapor is the source of moisture for clouds, rain, frost, etc.
- Water vapor releases latent heat when it condenses.
- Water vapor is a heat-absorbing gas i.e it is green house gas.
- Water vapor influences our sense of temperature.

Humidity

- Humidity is the amount of water vapor in the air
- Specific humidity is the weight of water vapor in grams contained in a kilogram of air
- Relative humidity is the ratio of the water vapor present to its potential water vapor capacity

Saturation

Some water molecules leave (evaporate), others return to the water

- Evaporation increases ***Vapor Pressure*** of air
- Eventually water molecules leaving equals the amount returning
- This is ***saturation*** (filled to capacity)

If air can no longer hold water vapor without condensing, it:

  - Is **saturated**
  - Has a **relative humidity of 100%**
  - Has reached its **dew point temperature**

Water vapor capacity

- The air's capacity to hold water vapor varies with temperature.
- Warm air can hold more water vapor than cold air.
- Air with a specific humidity of 7 grams/kg at 10 °C is saturated (100% RH).
- The same air with 7 grams/kg at 20 °C has a relative humidity of

The atmospheric humidity is measured in various units. The important measures of humidity are; vapour pressure, relative humidity, dew point temperature etc.

- **<u>Vapour pressure</u>:** Air contains different gases and water vapour also behaves as a gas. The pressure of air is the sum of the partial pressures of its component gases. The partial pressure due to presence of water vapour in air is called vapour pressure. The vapour pressure is expressed in c.g.s. Units of pressure viz. milli bars or milli meters of mercury (mm of Hg). The M.K.S unit of pressure is Pascal. The pressure exerted by the water vapour under saturated conditions is called as the saturation vapour pressure (S.V.P.). The saturation vapour pressure depends on the temperature of the air. It increases nearly exponentially with the air temperature. The pressure exerted by water vapour actually present in the air is called as actual vapour pressure of the air or simply, the vapour pressure of air.
- **<u>Saturation deficit</u>:** It is the difference between saturated vapour pressure and the actual vapour pressure present in the atmosphere.
- **<u>Relative humidity:</u>** The ratio of actual vapour pressure to saturation vapour at the prevailing air temperature is called as relative humidity. It is normally expressed in percentage.

- **<u>Dew point temperature</u>:** Dew point temperature is the temperature at which air would become saturated if it is cooled at constant pressure without addition or removal of water vapour. Thus, the actual vapour pressure is equal to the saturation vapour pressure at the dew point temperature. If the dew point temperature is close to the air temperature it means that the air is nearly saturated.

Condensation

Condensation is defined as the process in which **water vapour is converted into its liquid.** This process is inverse or opposite of the evaporation process where the liquid water is converted in to vapour form. In condensation 600 calories of heat is released by each gram of water, where as in evaporation process the same amount of heat is used to convert into vapour form. Thus, the evaporation of water produces cooling effect and condensation gives warming effect. **Sublimation** is the process in which vapour form is directly converted into solid form of water and vice versa. In atmosphere, condensation usually takes place when the air is cooled beyond its dew point temperature. The visible forms of condensed moisture in the atmosphere are known as *Hydrometers.*

Necessary conditions for condensation

The following three conditions must be fulfilled for occurrence of consideration in the atmosphere: -

(A) Presence of sufficient water vapour in air

(B) Presence of condensation nuclei in atmosphere

(C) Cooling of air

(A) Presence of sufficient water vapour

An adequate amount of water vapour is necessary to bring about saturation of air with water vapour. Air can be easily brought to saturation when sufficient moisture is present or decrease in temperature. The dew point shall be reached through this abundance of water vapour to begin condensation.

(B) Presence of condensation nuclei

Sodium chloride (salt particles) injected in the atmosphere by sea-ocean water spray. Some combustion products viz. sulphur dioxides, nitrous oxide etc, released from industries and dust particles in the atmosphere act as 'condensation nuclei'. Water vapour can only deposit and condense on these particles as these are hygroscopic in nature. These particles have water affinity. These particles are also microscopic in size (0.1 to 1 µm) called either "hygroscopic nuclei" or "condensation nuclei". In the absence of these nuclei condensation cannot take place even if air is super saturated and its temperature is below freezing level.

(C) Cooling of air

Air must be cooled to dew point temperature i.e. saturation. Cooling of air up to and below dew point is necessary for saturation of atmospheric air with water vapour. Cooling takes place in atmosphere due to adiabatic cooling of air masses.

The different forms of condensation are:

(1) Dew (2) Frost (3) Fog (4) Smog (5) Rime (6) Mist and (7) Cloud

1. Dew: The deposition of water vapour in the form of tiny droplets on the colder bodies at earth's surface is known as dew. The temperature at which water vapour condenses or dew formation take place is known as dew point temperature. Dew is measured with dew gauge.

- When the objects on the surface of the earth get cooled during night below dew temperature the water vapour is condensed on these surfaces. These surfaces should be good radiators and bad conductors of heat. (Plant leaves, window glass and pieces of paper.)
- Dew forms when condensation takes place **above** freezing point temperature.
- Dew is formed under two conditions (1) clear sky and (2) absence of wind or gentle wind.
- Dew is secondary source of moisture for crops during the non-raising season and plays a vital role in plant growth.
- Dew provides water for direct plant use. Dew deposited on the leaf surface delays the rise in leaf temperature and thereby reduces the rate of evapo-transpiration.
- The amount of dew deposition varies from 0.25 to 0.40mm per day in semi-arid tropics. (Usually from September to April). In semi-arid areas, it may exceed 25- 30 mm per year.

2. **Fog:** The extremely small or microscopic water droplets suspended in the atmosphere above the ground surface is known as "fog". Fog reduces the horizontal visibility of atmospheric air. Restrict visibility between 45 to 900 meters. Under two conditions the fogs are formed are (1) calm wind and (2) the relative humidity should be at least 75%. Fog is also called as "cloud on and near the ground". There are three types of fogs depending on the process of formation, such as (1) radiation fog (2) inversion fog and (3) advection fog.

The first two types of fogs are formed due to radiational cooling. These two types of fogs occur during night or cold morning. They disappear due to desaturation of air with vapour after the sunrise in the morning. The advection fog occurs when warm moist air mass rises on or over a cold surface of either land or water. The fog occurs at any time of the day.

3. **Smog and haze**: The combined effect of smoke and fog droplets is called **smog**. They also reduce visibility of atmosphere. The combined effect of smog and some solid particles like dust is known as "haze". On some occasions toxic materials present in fog, smog and haze are harmful. All these processes cause difficulty in rail, road, aviation and shipping traffics.

4. Frost: When the temperature of atmospheric air falls below 0ºC before the dew point temperature is reached, the water vapour is directly converted into crystals of ice – called as "frost". This is a form of sublimation, because water vapour is directly converted into ice. Frost is always injurious to agricultural and horticultural crops.

5. Rime: This freezing fog is formed when wet fog having super cooled droplets immediately freezing point.

6. Mist: The suspended microscopic water droplets or wet hygroscopic particles in the atmosphere, which restrict visibility between 1100 to 2200 yards, are known as mist**.** The RH is 75% when mist occurs and it disappears with rising sun.

7. Clouds: Clouds are visible aggregates of very minute droplets of water **or** ice crystals **or** a mixture of both of moist air." Size of clouds and fogs droplets is 20 to 60 micron. It formed and remains **s**uspended in the air at higher altitudes particularly in troposphere due to adiabatic cooling of moist warm air due to buoyancy force. They may be also formed due to orographic ascent caused by mountain barriers and also due to fronts.

WMO cloud classification

The World Meteorological Organization (WMO) classified the clouds according to their height and appearance into 10 categories: -

On the basis of height, clouds are grouped in to 4 categories. Such as

(1) High clouds (2) Middle clouds, (3) Low clouds and (4) Vertical clouds.

Clouds are usually classified into types on the basis of two criteria. These are:

1. Shape, structure, and form or appearance of the cloud.
2. The height at which the cloud occurs in the atmosphere.

According to the W.M.O. (World Meteorological Organisation) classification, there are ten types of clouds details of which are given below.

Type of cloud	Group	Mean height (km)
Cirrus(C_i) Cirro-cumulus (C_c) Cirro-stratus (C_s)	High clouds	5 to 13
Altocumulus (A_c) Altostratus (A_s)	Medium clouds	2 to 7
Strato-cumulus (S_c) Stratus (S_t) Nimbostratus (N_s) Cumulus (Cu) Cumulonimbus (C_b)	Low clouds	Below 2

*These clouds may extend from above the earth's surface to a height of 6000 m. Cumulus and cumulonimbus clouds are therefore often known as clouds with vertical development.

(1) High clouds

These clouds appear at mean height of **7-12 km** above the earth surface. The clouds in this category are:

[i] Cirrus – it does not produce precipitate.
[ii] Cirro-cumulus- looks like waves of the seashore
[iii] Cirro-stratus – these clouds cover the entire sky with milky white appearance.

(2) Middle clouds

These clouds appear at height of is **2.5 to 7 km** in tropics and sub-tropics.
The clouds in this category are:
[iv] Alto-cumulus- grayish or bluish globular masses.
[v] Alto-stratus – rain occurs in middle and high latitudes.

(3) Low clouds

The mean height of these clouds extends from ground up to **2.5 km** in tropics and sub-tropics. These are sub- categories in this family.
[vi] Strato-cumulus -
[vii] Stratus – mainly seen in winter season and occasional chizzes occurs.
[viii] Nimbostratus – gives steady precipitation.

(4) Vertical developing clouds

These clouds form due to vertical development i.e. due to convection of air mass. The mean low level is 0.5 km and means upper level goes up to maximum 16 km in tropical region. Cumulus and cumulonimbus clouds are there often known as clouds with vertical development.
[ix] Cumulus- looks like cauliflower with wool pack and dark appearance. These clouds develop cumulonimbus clouds.
[x] Cumulonimbus – these clouds produce violent winds, thunderstorms, hail and lightning during summer.

Cloud observation

The accuracy of cloud observation depends on the experience of agrometeorologist. Cloud cover is obtained by viewing the fraction of the sky covered by clouds. The amount of cloud is denoted by unit “Okta” It varies from zero to eight numbers. The terms used to express cloud cover are:
0 Okta means clear sky / no clouds;
1 to 7 Okta indicates the fraction of sky covered by clouds and
8 Okta means overcast (entire sky covered by clouds)

Isoneph: The lines joining places of equal cloud cover on a map is isoneph.

Precipitation, forms and types of precipitation

What is precipitation?

Generally the terms precipitation and rainfall are used as synonyms with each other. Precipitation can be defined as “*earthward falling of water droplets or ice particles that have formed by rapid condensation in the atmosphere and are too large to remain suspended in the atmosphere".* In condensation the water droplets is remain suspended in the atmosphere in different forms. Condensation is a first step of precipitation. But in precipitation, those condensed droplets are so big so that they cannot remain in the atmosphere but fall down to the earth surface.

Mechanism of precipitation formation:

As the rate of condensation is different in different parts of the clouds, the size of the drops is not the same in the clouds. As the air moves about, the large and smaller drops do not follow the same path. The droplets, moving upwards overtake larger ones and thus suffer collision resulting into coalescence or combination. These droplets increase in size and fall down with greater terminal velocity. This is known as **collision - coalescence** mechanism.

Process of rain formation:

1. First of all water droplets are formed in the atmosphere by the process of condensation.
2. Then these condensed water droplets increase in size by two mechanisms i.e. by collision and by accretion (addition).

Forms of precipitation:

Precipitated moisture falling on the ground takes various forms

In Liquid form: rain, drizzle, and shower; in Solid form: snow and hail and in Mixed form: sleet and glaze

(A) Rain: - It is defined as precipitation of liquid water particles/ droplets. The size of raindrops is **0.5 mm to 4.0 mm** in diameter. The raindrop has a more than 0.5 mm diameter. The droplets are formed due to rapid condensation of moist air mass.

(B) Drizzle: - It is more or less uniform precipitation of very small and minute raindrops. The diameter of drizzle drop is **less than 0.5 mm**. It falls from low-lying nimbostratus cloud. Fog merges to from drizzle.

(C) Shower: - It is the precipitation lasting for short time with relatively clear intervals. This occurs from passing clouds.

(D) Snow: - Snow is defined as precipitation of white and opaque grains of small or large size ice crystals. It occurs only when the condensation take place below the freezing temperature (0ºC). Snow is generally in the form of individual crystals or in flakes that are aggregate of many crystals. Snowflakes are formed in high clouds. Snow is measured with snow gauge.

(E) Hail: - Hail is a precipitation of small balls or pieces of ice with a diameter ranging from **5 to 50 mm** (in solid form). On a warm sunny day, a strong abrupt convection of air mass in freeze zone may cause the formation of pellets having spherical shape and concentric layers of ice. Hail falls from **cumulonimbus** clouds and is often associated with thunderstorms. Hailstones may achieve even large size as much as cricket ball.

Rainfall associated with the hailstones is called as hailstorm.

(F) Sleet: - Simultaneous precipitation of the mixture of rain and snow is called as sleet.

Isohyets are the lines joining the places having equal rainfall or precipitation on the map.

Types of precipitation/rain:

All precipitation occurs from clouds. The most important cause of clouds is the adiabatic cooling resulting from the upward movement of air. There are three possible ways in which an air mass may be forced to rise, and each of these produces its own characteristic type of precipitation.

Thus, four are four types of precipitation.

[1] Convectional precipitation

[2] Orographic precipitation.

[3] Cyclonic precipitation

[4] Frontal precipitation

(1) Convectional precipitation

This is largely due to the heating of the earth's surface, hence the most favorable conditions for its occurrence are always found in the summer months and in the warmer parts of the day. This type of precipitation is of a very short duration and consists of heavy showers.

- Convective precipitation is less effective for crop growth because much of the water is drained off in the form of surface run-off and a little enters the soil.
- However, in the temperature regions it is most effective for plant growth.
- The peculiarity of this precipitation is that it gives maximum rain with minimum cloudiness.
- Clouds involved in this type of precipitation are the cumulo-nimbus or the clouds with great vertical development.

(2) Orographic precipitation

When mountains or highlands acting as barriers to the flow of air. It forces air mass to rise up. The air cools adiabatically form clouds and precipitation may result. The precipitation thus obtained is referred to as orographic (oros = mountain).

- This type of precipitation is commonly found on the windward sides of mountain ranges lying across the path of prevailing winds. After striking the high land, the air is forced to rise and gets cooled. The moisture is condensed and precipitated as rain or snow. On the other side, the amount of precipitation abruptly decreases. Thus on the leeward slopes of these mountains, there always exists a relatively dry area, which is known as rain shadow.
  In India the S-W monsoon gives copious (plentiful) rainfall on the windward slope of Western Ghats, where as on the leeward side there are rain shadow areas.

- Another salient feature of orographic precipitation is the "**Inversion of rainfall**" that means there is a continuous increase in precipitation on the windward slope up to certain height beyond which the amount of precipitation starts diminishing.
- The belt of heaviest precipitation is depending on the latitude, season and exposure. In the Himalayan ranges the maximum condensation takes place at 1200 m height, where as in Alpas it occurs at about 2000 m.

(3) Cyclonic precipitation

Cyclonic precipitation takes place in **tropical regions**. When currents of air with differing temperature and moisture content meet, the warm and moist air will be forced to rise over the heavier air. Further, when air masses from different directions converge toward a center of low pressure, as is always a case in cyclonic circulation, the air is forced to rise up, as a result cloud formation and precipitation occurs.

In tropical regions, the lifting of warm and moist air mass is almost vertical and is generally accompanied by convection.

(4) Frontal precipitation

Frontal precipitation takes place in **temperate regions.** In temperate regions, frontal precipitation occurs when the warm and moist air gradually rises above a cold air mass at the front created by contact with the edge of cold air.

- Frontal precipitation along the warm front is usually in the form of drizzles.
- It is wide spread and is of a long duration.
- When associated with cold fronts it is always in the form of thundershowers and is of a very short duration.
- Winter precipitation in the north India is a typical example of frontal precipitation. In Europe and North America, most of the winter precipitation is frontal in origin.

Artificial rain making

Rainmaking, also known as artificial precipitation or artificial rainfall or cloud seeding, is the act of attempting to artificially induce or increase precipitation, usually to stave off drought. According to the clouds' different physical properties, this can be done using airplanes or rockets to sow to the clouds with catalysts such as dry ice, silver iodide and salt powder, to make clouds rain or increase precipitation, to remove or mitigate farmland drought, to increase reservoir irrigation water or water supply capacity, or to increase water levels for power generation.

The principle of artificial rain

- In the troposphere, the temperature of the atmosphere descends with altitude. Therefore the clouds in the troposphere are lower in temperature as they rise in altitude and vice versa.
- When the temperature of a cloud is above 0 °C, the cloud is called a warm cloud; when it is below 0 °C it is called a cold cloud.

- Inside a warm cloud, small water drops will become large ones through collision and coalescence, and will finally break the buoyancy of the cloud and fall out of its bottom to become rainfall to the ground.
- Likewise, inside a cold cloud, ice crystals can also grow to a size where they can break the buoyancy and fall out of the cloud's bottom, and when they pass through a temperature of 0 °C they will melt and become rain drops, also providing the ground with rain.
- When the water drops in a cloud are too small or there are not enough ice crystals to create rainfall, we can use artificial ways to create ice crystals or help small water drops grow, and thereby facilitate the formation of precipitation.
- This human influenced weather phenomenon is called artificial rain.
- There are many ways to make rain in a warm cloud, e.g. spraying water drops, hygroscopic powder or liquid (sodium chloride), etc, and letting the water drops grow though collision and coalescence to finally become rain.
- There are also many ways to make rain in a cold cloud, but the most common way is to use dry ice or silver iodide. This is mainly because the temperature of dry ice is -78 °C. Spreading dry ice in a cold cloud lacking ice crystals will rapidly reduce its temperature. Therefore we directly transform super cooled water into ice crystals, which will eventually become rain without the help of ice-crystal nuclei. Silver iodide, on the other hand, is a very effective ice-crystal nucleus. By adding it to a cloud, silver iodide acting as an ice-crystal nucleus can facilitate the solidification of water drops below -5 °C into ice crystals.
- Through the growing process the ice crystals under the coexistence of water drops, the rain will be formed.

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CHAPTER-7

MECHANISM OF MONSOON AND ITS IMPORTANCE

Characteristic of Indian monsoon

According to Byers, Indian monsoon is the ideal monsoon where differential heating of land and ocean subjected to the annual latitudinal cycle of the sun at its Zenith gives rise to immense seasonal wind regimes. However, the mechanism of Indian monsoon is not as simple as they are thought to be. Although, every school boy understands the Indian monsoon, the India Meteorological Department is still in doubt in regards its origin every year. The trade winds which changed their direction are called monsoon winds. The name 'monsoon' is derived from the Arabic word 'mausim' which means season. Monsoon is a large scale seasonal reversal of prevailing wind system.

The Indian monsoon signifies a marked seasonal reversal of wind direction because of its topography. The characteristics of Indian monsoon / monsoonal circulation over India are explained by its topography namely:

1. Vast size of the Indian sub-continent.
2. Very high and extensive mountain system of Himalayas.
3. The East-West alignment of Himalaya mountain chain which forms a formidable physical barrier between tropical and polar air masses, which is of great meteorological significance.
4. The mightily Himalayas produce hydrodynamic effects that determine the type of precipitation in India.

India experiences two distinct monsoon winds namely:

1. South-West monsoon winds (Summer)
2. North-East monsoon winds (Winter)

(1) South–West monsoon: -

During summer (April-May) the intense heating of land results in the formation of low-pressure area in the Northwestern part of the subcontinent. On the contrary, there are high pressure cells formed over the Indian Ocean and Arabian Sea, and there being winter in Australia, a high pressure cell develops over there also. As the pressure over the oceans is high, a sea to land pressure gradient is established during this period. Therefore, the surface airflow is from Sea (high-pressure area) to land (low pressure area).

The main Characteristics of South-West monsoon:

- The S-W monsoon period is called grand period of rainfall in India, 75 % of average rainfall of India (1200 mm) is received during the period from June to September.
- The orographic has pronounced influence on the distribution of rainfall during this season.

For, example the windward side of the Westernghats receives around 2500 mm of rainfall while the leeward side receives only 500 mm.

- The amount of rainfall received in NW India is less than that received in NE India.
  For, example Calcutta receives 1190 mm, Patna 1050 mm, Allahabad 760mm and Delhi 560 mm of RF during this season. The variability of rainfall is highest over northwest India and Rajastan, which receive lowest rainfall.

- Generally the S-W monsoon commences or onset from Kerela normally set on 1st of June every year. The normal duration of S-W monsoon varies from a 100 to 120 days. It begins to withdraw fro northwest India by mid September.
- The monsoon even in the West part is not continuous. There is a break in the monsoon (rainless periods called a dry spell). This phenomenon is closely at the head of Bay of Bengal and their crossing over into the maintained.
- An extension of the seasonal 'low' into the Indo-Gangetic plains is developed during monsoon is known as the monsoon trough.
- The intensity and frequency of these developed depressions are responsible for the overall strength or weakness of the monsoon in a given year.

In India due to peninsula, the S-W monsoon is divided into two branches:

(A) Arabian Sea branch (ASB)   (B) Bay of Bengal branch (BBB)

The Arabian Sea branch moves northwards and the Bay of Bengal branch moves up to Assam, and then deflected towards northwestwards due to obstruction of Himalayas. Both these branches occasionally close near Delhi.

(A) Arabian Sea Branch (ASB):

The Arabian Sea branch strikes on the elevated western ghats of India at right angles. The windward slopes of Western Ghats receive vary heavy orographic rain. The amount of rainfall on the leeward side goes on diminishing with increasing distance from the sea-coast. At Mahabaleswar the rainfall amounts to 6500 mm, while at Panchgani (only 16km away) the amount of rainfall is reduced to 1700 mm.

A few air currents from ASB are diverted northward to Kutch and Thar deserts. In the advances up to Kashmir, these currents do not bring precipitation in Rajsthan, which remains dry. The Aravali hills being parallel to the direction of these monsoon currents fail to block their passage and lift them. That is why Rajsthan remains a desert.

Some of air currents from ASB manage to proceed towards Chhota Nagpur Plateau through the Narmada and Tapti gaps. These currents ultimately unite with the Bay of Bengal branch.

(B) Bay of Bengal Branch (BBB):

This branch flows up between Srilanka and Sumatra and Burma. This branch is more powerful than Arabian Sea branch. One branch of BBB strikes Burma and the other Branch moves towards Assam where Cherapunji is situated on the Southern slope of Khasi hills, recording the highest annual average rainfall of **9650 mm** in the world. Shillong, hardly 40km away from on the top of Khasi hills receives only about **1400 mm** rainfall. Another current of BBB moves westward and advances up the Gangetic plain towards the Punjab. The rainfall occurring in the Gangetic plain is partly controlled by **the relief an parts** by the cyclonic storms.

- The RF decreases from East to West and from North to South.
- The destination of the ASB and the BBB of monsoon is the low pressure center formed over northwestern region of the subcontinent. However, the direction of winds in Peninsular India is predominantly southwesterly. In the northern plains the air movement is generally from southeast to northeast.
- The southern margin of northern plain is the most frequented track of monsoon of the Bay of Bengal. The cyclonic storms move from east to west along the peninsular hills giving copious rainfall on their southern sides.

(2.) North-East monsoon (winter monsoon):

During winter the wind conditions are reversed. In the cold season the entire land mass of Asia becomes the center of very high pressure and the water bodies become low pressure area. The high pressure system develops over Kashmir and the Punjab, controls the prevailing wind direction over the rest of the subcontinent. Contrary to the pressure conditions overland, there are low-pressure centers over the Indian Ocean, the Arabian Sea. In the cold season, therefore there is pressure gradient from land to sea as a result of which winds begin to below from land to sea. These are the North-East or winter monsoons of northern Hemisphere.

The main characteristics of North-Eest monsoon:

- During winter all over the country the wind are light and variable.
- The anticyclonic winds are dry and have no capacity to yield precipitation. Since these winds originated on land and are off-shore, they produce dry and fine weather.
- However, certain areas get winter precipitation. The plains of the Punjab and U.P. are visited by a number of Western disturbances which give moderate to scanty rainfall. The winter precipitation extends up to Patna and disintegrates before they reach Bengal. Higher up in the northern mountainous regions they may be snowfalls.
- By the end of September the rainfall starts decreasing in the northern plains of India until it ceases by the month of October. However, in the South India it continues to rain until the middle of December. The N-E monsoon season is from October to December.

- The southern part of the Indian peninsula receives rainfall from N-E monsoon currents. The onset of N-W monsoon normally over south peninsula (Tamil Nadu, south coastal AP, Rayalseema, interior south Karnataka and south districts of Kerala) is on 15th October and withdraws by 1st December. These currents while traveling over the Bay of Bengal pick up moisture from ocean surface and produce rain along the east coast. The main crop season of the state of T.N. is during the N-E monsoon.

Monsoon in Gujarat state

The state receives rains under the influence of SW monsoon (June to September). However, the onset and withdrawal of monsoon are not uniform throughout the state.

Sr.No.	Region	Onset	Withdrawal
1	South Gujarat	Mid-June	End of October
2	North Gujarat	Third week of June	Mid September
3	Saurashtra region	Second week of June	Second week of September

In South Gujarat the monsoon commences from the middle of June and lasts up to end of October, while in north Gujarat it starts a little later and ends by about the middle of September. In Saurashtra region, it commences from second week of June and lasts up to second week of September. The Indian Meteorological Department (IMD) views Gujarat state as two Sub-divisions, **Gujarat region** consisting of North Gujarat, Middle Gujarat and South Gujarat.and **Saurashtra-Kutch region** consisting of whole of Kutch and Saurastra regions.. The state's annual average rainfall is about 820 mm received in 30 days. The annual average rainfall of Gujarat region is about 970 mm received on average in 43 rainy days, while that of Saurashtra-Kutch region is only 580 mm received in an average in only 23 rainy days. The coefficient of variation (CV %) of rainfall for Gujarat region is 23 % and that of Saurashtra-Kutch region is 35 percent. Considering Bharuch – Deesa line, the rainfall in the state decreases towards west of the line.

Western Disturbance:-

It is the term used in India, Pakistan, Bangladesh and Nepal to describe an extra tropical storm originating in the Mediterranean, that brings sudden winter rain and snow to the northwestern parts of the Indian subcontinent.[1][2] This is a non-monsoonal precipitation pattern driven by the Westerlies. The moisture in these storms usually originates over the Mediterranean Sea and the Atlantic Ocean. Extra tropical storms are a global, rather than a localized, phenomena with moisture usually carried in the upper atmosphere (unlike tropical storms where it is carried in the lower atmosphere). In the case of the subcontinent, moisture is sometimes shed as rain when the storm system encounters the Himalayas.

Western Disturbance causes winter and pre monsoon season rainfall across northwest India. Winter months Rainfall has great importance in agriculture, particularly for the rabi crops. Wheat among them is one of the most important crops, which helps to meet India’s food security. During the season, normally 4-5 western disturbances in a month can be seen over northwest India. Some of the western disturbances bring well-distributed and good rainfall, while some pass with negligible rain or sometimes no rain. The Western disturbance affects day-to-day weather of northwest India especially during winter season. It is usually associated with cloudy sky, higher night temperatures, unusual rain etc. Over the Indo-Gangetic plains, it brings cold wave conditions and occasionally dense fog and cold day conditions. These conditions remain stable until it is disturbed by another Western Disturbances.

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CHAPTER-8

WEATHER HAZARDS, HEAT AND COLD WAVES

There are so many natural calamities or weather / climatic hazards that affect crop production

Some natural hazards are also called as weather abnormalities/ events/ hazards:

1. Tropical & extra tropical cyclones
2. Tornadoes
3. Thunderstorms
4. Lightning
5. Hail storms /Snow storms /Dust storms
6. High winds
7. Freezing rain and frost
8. Fog
9. Drought/ Scanty rainfall
10. Flood/ Landslide/ Avalanches
11. Forest fire
12. Desert locust swarms

Two important weather hazards has a significant on crop production to be covered are

(A) Drought and (B) Frost

(A) Drought:

It is a climatic anomaly characterized by deficient supply of moisture. The drought can be defined in terms of moisture deficiency, which is a balance between the water availability and water demand.

How water supply becomes deficient?

Such deficiency results from,

1) Sub-normal rainfall

2) Erratic rainfall distribution

3) Excessive water need

4) Combination of all the above three factors.

Classification of drought:

According to Thornthwaite (1947) there are four types of droughts,

(a) Permanent (b) Seasonal (c) Contingent and (d) Invisible drought

(a) Permanent drought:

It is found in the desert areas where, in no season the precipitation equals to the water need. Plants therefore are adapted to dry conditions. Agriculture is impossible without irrigation facilities in this region.

(b) **Seasonal drought:**

This drought can be expected in each year. These droughts are resulted from large seasonal air circulation changes. Agriculture is possible during the rainy season or with the use of irrigation in the dry season. Regions of seasonal drought have well defined rainy and dry seasons.

(c) Contingent drought:

This drought results from the irregular and variable rainfall. They occur in any season and are usually more severe during greatest water need periods. This drought is unpredictable.

(d) Invisible drought:

This can occur at any time, even during period with rainfall, when the daily rainfall fails to meet the daily water need of plants. As a result, there is a slow drying of the soil and plants fail to grow at their optimum rate.

According to National Commission of Agriculture (NCA) (1976) there are three types of droughts

(1) Meteorological drought

(2) Hydrological drought

(3) Agricultural drought

(1) Meteorological drought:

It is a situation where there is significant decrease from normal precipitation over an area. The meteorological drought over an area for a year has been defined by 'India Meteorological Department (IMD)' defines drought as a situation when the seasonal rainfall over the area or place is less than 75 per cent of its long term average or the normal. It is further classified, as moderate drought if the rainfall deficit is between 25 to 50 per cent and severe drought when it is less than 25% of the normal. Meteorological drought can be local or regional or sub divisional. In temporal scale it can last for a few weeks longer in the season.

(2) Hydrological drought:

Meteorological drought if prolonged, results in hydrological drought with marked depletion of surface water and subsequent drying up of reservoirs, lakes, streams and river and fall in ground water level.

(3) Agricultural drought:

It occurs when soil moisture and rainfall are inadequate during the growing season to support a healthy crop growth till maturity, causing extreme crop stress and wilt.

There are seven kinds of agricultural drought:

1. **Permanent drought**: This type of drought is common in arid regions. Under such condition rainfall is not sufficient to grow crop in any seasons during year.
2. **Early season drought**: It is due to delayed monsoon which alters optimum time of sowing, growing season of crop, incidence of insect and pest deceases crop productivity
3. **Mid-Season drought:** It is caused by the breaks in the monsoon during crop growing seasons. Drought during vegetative phase results in stunted growth low leaf area development and reduced plant populations.
4. **Late-Season drought:** It is caused due to early withdrawal of rainy season It has impact at reproductive stage leading to force maturity.
5. **Apparent drought:** It is caused due to mismatching of the cropping pattern with rainfall distribution and moisture availability.
6. **Contingent drought:** It is caused due to irregularity of rain fall in any season.
7. **Invisible drought:** This type of drought occurs in humid region when daily rain water is not enough to meet daily water requirement of the crop.

Socio economic drought

It combines the impact of meteorological, hydrological and the agricultural droughts on society in terms of economy in the region.

Agricultural practices to be taken under drought conditions:

1. Drought resistance cultivars of plants / seeds should be preferred for sowing.
2. The use of keeping fallow land as a management technique.
3. Erosion of drought affected soils and adoption of water harvesting technology.
4. Pasture land management or grasses may be grown in drought prone area.
5. Effect of drought on the lives of various insects and pests and on diseases is brought about by reducing moisture content of their natural environment.
6. In general drought is adverse to agriculture, but it brings a measure of compensation in greatly reducing economic loss from some pests and diseases. Powdery mildew often flourishes in dry weather and aphids and birds, which migrate early from drying, grass to alternative sites such as crops and orchard trees, causing greater damage.
7. Some agricultural practices can influence meteorological condition in the plant /soil environment and these may be used to advantage under drought conditions e.g. wind barriers can reduce evapotranspiration in their lee ward side, thus reducing the demand on the store of soil moisture.
8. Elimination of weed and conserve soil moisture for crop use in later stage.

(B) Frost

Frost is said to occur when the surface temperature (of the ground or plant etc.) falls below $0^{o}C$. Frosts are generally expected on clearer nights. The conditions for the formation of frost are clear sky and calm atmosphere without winds.

Influence on crop production:

1. Frost is undesirable and detrimental effects on many of the crops.

2. The crops, which are highly susceptible to frost, are; pigeon pea (tur), potato, tomato and other solanaceous crops, cotton, sugarcane etc.

Symptoms of frost damage

1. The crops turn black and have the similar effect of burning.
2. Fruits may crack and become stony and hard.
3. Leaves may fall down and wilt.

Preventive measures:

1. Susceptible crops should be irrigated as soon as frost is forecasted.

2. Field should be made smoky by burning heaps of waste vegetation.

3. Application of balanced fertilizers makes the plants sturdy and to avoid the frost hazard to some extent.

Heat and Cold waves:

Heat wave

A continuous spell of abnormally hot weather. Heat wave need not be considered till maximum temperature of a station reaches at least 40º C for Plains and at least 30º C for Hilly regions.

a) When normal maximum temperature of a station is less than or equal to 40^{0} C

Heat Wave Departure from normal is 5^{0} C to 6^{0} C .Severe Heat Wave Departure from normal is 7^{0} C or more

b) When normal maximum temperature of a station is more than 40^{0} C

Heat Wave Departure from normal is 4^{0} C to 5^{0} C C.Severe Heat Wave Departure from normal is 6^{0} C or more.

c) When actual maximum temperature remains 45^{0} C or more irrespective of normal maximum temperature, heat wave should be declared.

Cold wave

A rapid fall in temperature within 24 hours to a level requiring substantially increased protection to agriculture, industry, commerce, and social activities.

a) When normal minimum temperature is equal to 10°C or more**.**

Cold Wave Departure from normal is -5°C to -6°C.Severe Cold Wave Departure from normal is -7°C or less

b) When normal minimum temperature is less than 10°C.

Cold Wave Departure from normal is -4°C to -5°C.Severe Cold Wave Departure from normal is -6°C or less.

Cold Wave should be declared irrespective of normal minimum temperature of the station. However, this criteria is not applicable for those stations whose normal minimum temperature is below 0°C.

Hot day

In the northern plains of the country, dust in suspension occurs in many years for several days, bringing minimum temperature much higher than normal and keeping the maximum temperature around or slightly above normal. Sometimes increase in humidity also adds to this discomfort. Nights do not get cooled and become uncomfortable. To cover this situation, hot day concept has been introduced as given below:

Whenever, the maximum temperature remains 40^0C or more and minimum temperature is 5^0 C or more above normal.

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CHAPTER-9

AGRICULTURE AND WEATHER RELATION

Importance/ Influence of weather and climate on agriculture and crop production

Crops are influenced by the environment in which they are grown.

Environment

External elements — internal elements

Climate effects are unstable, Unpredictable, uncontrollable — Physiology of crops effects are stable and slow.

- **Climate** regulates and determines the **suitability of crops** for a region whereas; **weather** decides the **growth, development and yield of crops** grown in that region.
- The effect of weather and climate is very complex, because the climatic elements operate simultaneously in the nature.
- The excess or deficiency of climatic elements exerts a negative influence on plant growth and development.
- It is difficult to point out a single value of climatic elements for the maximum growth and production of crops.

Influence of weather variables on plant growth: -

The most important weather abnormalities/variables which have <u>negative</u> <u>influence</u> on crop production are: -

1. Excessive and untimely rains
2. Scanty rains
3. Heat and cold waves
4. Dust storms, thunder storms, hail storms
5. High winds
6. Frost
7. Flood etc.

Weather variables which have both positive and negative influence on crop production are:-

1. Solar radiation
2. Temperature
3. Humidity
4. Wind
5. Rainfall and water
6. Snow
7. Soil temperature

(1) Solar radiation

The radiation from sun is the main source of energy for the life on earth. All the three segments of the solar spectrum are significant for plant life:

(A) Ultraviolet Radiation /rays

Cosmic rays**,** X-rays and Gamma rays are chemically very active has detrimental effect on loving organisms. However, the atmosphere acts as a regulator for this type of radiation and a very small amount of higher wave length normally tolerable by the plant which reaches the surface of earth. Wavelengths of UV range from 0.005 to 0.4 um (microns).

(B) Infrared radiation

It has thermal effects upon the plants. It supplies the necessary thermal energy to the plant environment in presence of water vapour. In presence of water vapour this radiation does not cause any harm to the plants. The Short wave radiation in higher than visible wave length segment from 0.7 to 50 um is known as infrared radiation.

(C) Visible radiation or Light

- This is the middle part of the solar spectrum in the wavelength between 0.4 and 0.7 um. This is sensitive to human eye and the most important for plant life.
- All the plant processes directly or indirectly are influenced by visible radiation/ light.
- It influences the orientation of the shoots.
- The light of correct **intensity, quality** and **duration** is essential for plant growth and development.

(a) Light intensity

- It is indispensable/ essential to photosynthesis.
- It governs the distribution of photosynthates among the different plant organs.
- It affect the production of tillers, stability, strength and length of stalks / stems, total weight of plant structure or yield, and the size of the leaves an the roots.

(b) Duration of light

- It has profound effect on the content of **soluble carbohydrate.**
- It accelerates the flowering of **cryophytes (c**old loving plants) and delays that of **non - cryophytes** (heat loving plants).

- It suppresses the growth of the shoot and leaves. But favours the growth of roots, tubers and fruits.
- It increases the rate of photosynthesis.

(c) Quality of light (wavelength composition)

- It effects germination, flowering and elongation.
- Germination is inhibited when they are exposed to green, blue and other short wavelength colours and then again in infrared part.
- Red light induces germination of seeds.
- Red light inhibit flowering in long day plants.
- Far red light promotes stem elongation, but red light suppresses the elongation.

Plant responses to solar radiation: - Split up of solar energy in the spectrum.

S.N	Region	Wave length (µm)		% Energy
1	Ultraviolet radiation	Comic, Gamma ray	0.1-0.2	10%
		X-ray	0.2-0.3	
		U.V.	0.3-0.4	
2	Visible radiation	Blue	0.4-0.5	40%
		Green	0.5-0.6	
		Red	0.6-0.7	
3	Far-red rays	-	0.7-0.9	18%
4	Infrared rays	-	0.9-4.0	32%

Solar spectrum has been divided into 8 divisions on the basis of the physiological response of plants to the incident radiation:

Band	Wave length (micron)	Response
I	>1.0 micron	This radiation is transformed into heat Interference in biochemical process.
II	1.0 to 0.7	Specific **elongation** effects.
III	0.7 to 0.6 (Red region)	**Strongest** photosynthesis and photoperiodic activity.
IV	0.61 to 0.51 (Green region)	**Low** photosynthetic activity and weak formative activity.
V	0.51 to 0.40 (Blue-violet)	**Strong** photogenic and formative activities.
VI	0.40 to 0.30	Produce florescence in plants **Strong** photographic emulsions
VII	0.30 to 0.28	Germicidal action

VIII	< 0.28	Injurious to eye Killing effect on plants.

(2) Air Temperature

Temperature is the intensity aspect of **thermal** energy (heat energy). It is also the index of the availability of **heat energy**. It is a component of net radiation transformed in to the **sensible heat**.

i. All the physical and chemical processes within the plants are governed by air temperature.

ii. Stability of enzyme system is affected by temperature range of 0 to 60°C.

iii. Solubility of different substances is dependent up on temperature.

iv. Crop plants can grow within a narrow range of 10 to 40◦C.

v. However, each crop and its species have its own upper and lower critical temperature value.

Cardinal range of temperature

Temperature range is more important than the mean temperature for plant growth studies. Three temperatures of vital activity have been recognized as minimum for the growth of plants is known as cardinal temperature.

i. Minimum Cardinal Temperature: It is a temperature range below which no growth occurs

ii. Optimum Cardinal Temperature: It is a temperature range maximum plant growth occurs.

iii. Maximum Cardinal Temperature: It is a temperature range above plant growth stops.

Crops	Minimum	Optimum	Maximum
Cool season	0-5	25-31	31-37
Hot season	15-18	31-37	44-50

Effect of High maximum temperature

- Increases the saturation deficit of plants.
- Accelerates the photosynthesis and ripening of fruits and crops.
- Devernalise the cryophytes.
- Affects plant metabolism.
- High maximum temperature with high humidity favours development of plant diseases.

Effect of High minimum temperature

- High minimum temperature increases respiration.
- Its favours growth of shoots and leaves but inhibits the growth of roots and fruits.
- Governs the distribution of photosynthates among plant organ.
- It accelerates the development of non-cryophytes.

- Affects the plant metabolism.

Effect of Low minimum or Frost

- Interferes with respiration and metabolism of plants.
- Tender leaves and flowers are very sensitive to low temperature.
- Rapidly growing plants are easily killed by low temperatures or frosts.
- **Heaving**: The term heaving refers to one of the damages caused by low temperature on plants. During winter in northern states the plants are either lifted upwards or their roots stretch or break or sometimes the roots are pushed above the soil due to low temperature.

3) Relative humidity

- Regulates the intensity and quality of solar radiation and rate of transpiration.
- Some plants directly utilize the water vapour from the atmosphere.
- **High** humidity reduces the saturation deficit.
- **High** humidity favours plant diseases and pests.
- Increases the growth of shoots and leaves at the expense of fruits, bulbs and stolons.
- Low humidity **increases** the saturation deficit and accelerates transpiration.

(4) Rainfall and water

- **Water** is raw material for photosynthesis and universal solvent. It dissolves all plant nutrients in the soil. The solutes enter the plant through this medium. Its presence in the plants is essential for the normal functioning of plant cells and to maintain their turgidity. It increases the chemical activity of the compounds in the plants.
- **Rainfall** is the main natural source of water supply for the earth as a whole. It is the most important factor affecting crop production and distribution.
- It provides water for evaporation and transpiration.
- It interferes with farming operations like preparation of land, sowing, interculturing, harvesting, threshing, spraying etc.
- Excess rains cause soil erosion and reduce soil fertility and cause floods in rivers.
- Deficiency of rains cause drought and reduce yield.
- Favours plant diseases and pests.

(5) Snow

- It can be beneficial or injurious to plants.
- It causes physical and physiological damage to plants.
- Heavy snowfall breaks-off the leaves and stems.
- In cold climate some trees prefer some amount of snowfall.
- It causes damage to plants by suffocation, accumulation of toxic materials and oxygen deficiency in plants.

(6) Hail

- It affects the crop plants suddenly and nothing can be done to prevent it.
- Cereal and vegetable crops are more seriously damaged.

(7) Wind

- It influences the configuration and distribution of plants in a region.
- It increases photosynthesis, transpiration and intake of carbon dioxide.
- The normal form and position of the shoots are deformed due to constant wind pressure.
- Hot winds accelerate drying up of the plants/ soil.
- Hot and dry winds cause lodging of plants (maize, wheat, rice and sugarcane).
- A strong wind breaks the branches, stems and shed fruits from the plants.
- Helps in transportation of cold and heat waves, clouds, fogs and changes the water, light and temperature conditions.

(8) Soil temperature: It particularly influences

- The germination of seeds.
- The functional activity of the root system.
- The incidence of plant disease.
- It affects the rate of plant growth and vegetative growth.
- High soil temperature may kill the plants living tissues of many temperate plants.
- Low soil temperature reduces the intake of nutrients. At about 1◦C or less, soil moisture intake by plants stop.
- The soil temperature during the day is more important than the night time temperature, because it is necessary to maintain a favourable internal crop water balance.
- Soil temperature is more important than air temperature for potato, corn, groundnut and other tuber crops.

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CHAPTER-10

WEATHER FORECASTING

Weather Forecasting in India

Introduction:

The advance information regarding forthcoming weather is called weather forecast.

Weather forecasting is a most complicated technique. To solve the complex equations related to weather forecasting the use is made of very fast Super computers. Now-a-days our country has a Super Computer at New Delhi for this purpose.

Weather forecasting requires a number of surface and upper air observations for visual representation of all the meteorological observations on the weather map. In all, directly or indirectly, weather makes a contribution of approximately ¾ of the annual losses in the farm production (H.S. Mavi, 1986).

Weather forecasting is most useful to (1) Farmers, (2) Fishermen, (3) Aviation (Civil & IAF), (4) Ships (Commercial & Navy), (5) Railway and Road transports, (6) Electricity & Communication Department.

Observational Network

In India, there exists one Head Quarter (New Delhi), One Central Observatory (Pune), Five Regional Meteorological Centers (RMC), Fourteen State Meteorological Centers (SMC) and number of Sub Meteorological Observatories. All these stations are also connected with a good communication system to each other and to SMC, RMC and Sub-meteorological observatories to HQ, New Delhi. These observatories are also classified according to various types of meteorological observations.

RMC	**SMC**
1. New Delhi	: Srinagar, Chandigarh, Lucknow
2. Chennai	: Banglore, Trivandrum, Hyderabad
3. Mumbai	: Pune, Ahmedabad
4. Calcutta	: Bhubaneshwar, Guwhati, Patna
5. Nagpur	: Bhopal, Nagpur

Observation to be recorded: Weather forecasting requires a number of surface and upper air observations for visual representation of all the meteorological observations on the weather map.

Surface Observation:

1. Pressure	Barometer, Barograph
2. Temperature	Thermometers, Thermograph
3. Humidity	Psychrometer, Hygrometers, Hygrographs
4. Cloudiness	Nephoscope, Ceilliometer
5. Visibility	Visibility meter
6. Wind direction	Wind vane
7. Wind speed	Anemometer, Anemograph
8. Precipitation	Ordinary Rain gauge, Self recording Rain gauge
9. Sunshine	Campbell & stock Sunshine Recorder

Upper air observations:

(i) Wind direction and speed: Pilot balloons, radio rawin, and wind finding radar

(ii) Temperature, Pressure & Humidity: Radio Sonde, Pilot Balloon

Types of weather forecast

(1) Short Range Forecast

(2) Medium Range Forecast

(3) Extended Range Forecast

(4) Long Range Forecast

(5) Local Forecast

(1) Short Range Forecast

Short-range forecasts are usually prepared by synoptic or numerical method. These are issued for next 24 hours and extend up to next 72 hours. Short-range forecasts are issued for pressure, pressure tendency, wind, temperature, and upper wind data after preparing weather maps. These weather maps are the indicators of bad weather (such as cyclonic storm, hail storm, dust storm, western disturbance, etc.) and fair weather (clear sky). Short-range forecasts also cover the information like showers, fog, thunderstorm, lighting, cold wave, hot wave, gale warning and Sunny weather period with space and time.

Examples of specific language used in forecasting rainfall is,

1. Heavy to very heavy rain is likely to occur over South Gujarat region during next 24 hours. 2. Wide spread rain over South Gujarat region.

3. Fairly wide spread rain over Saurashtra.
4. Scattered rain over North Gujarat region.
5. Isolated rain over Kutch.
It is formatted in such a way that they assist the farmer in:

To determine the depth at which seed should be grown to achieve an optimal rate of emergence.

1. To determine whether to sow a crop or not
2. To decide whether to irrigate the crop or not
3. To decide whether to harvest some crops or not
4. Ensuring maximum efficiency of spray programme and herbicides.

(2) Medium Range Forecasting:

Medium Range Forecasts are generally prepared by synoptic and sometimes by numerical methods. These forecasts are valid for the period of next 3-7 days. The weather information of forth coming weather changes is given at least three days in advance. The forecast period can be extended up to about a week ahead. This forecast is much more useful to agriculture, because agriculture is an industry where the work depends very much on the weather. At present, farmers make great use of medium range weather forecasts for planning of their daily crop management practices.

MRWF is useful to the farmers in the following ways

i. To decide the future use of water
ii. Avoiding spraying when diseases and pests are below threshold level
iii. To make efficient and economic use of their labour and equipment and management of water for irrigation
iv. Change of temperature up to 5 days.
v. It is now-a-days issued with the use of super computer for numerical analysis of weather
vi. Sowing & harvesting of crops
vii. Programming spray schedule
viii. Animal feed requirements
ix. Protection of crops from frost

(3) Extended Range Forecast:

This is the forecast range lies between long range (seasonal) and medium range. Thus, it starts generally from days 10 (however, beyond days 7 in tropics) up to one month.

(4) Long Range Forecasting:

LRWF attempts to give a generalized weather picture for intervals up to 30 days and can be extended for three months or a season also. It gives statistical statements of certain weather elements like temperature and precipitation. LRWF gives the information on trends and changes in general circulation which are related to forth coming weather like thunder storm, hailstorm, cyclonic, storm, western disturbance etc.

Long term forecasting involves prediction of weather conditions over the entire crop growth period or season. Statistical methods are generally used for this type of forecasting. These forecasts are used for planning purposes only.

LRWF is most beneficial to mankind for further planning of work

i. To decide weather to grow marginal crops or not
ii. Aiding in the management of scarce water resources
iii. Determining timings of cropping schedules
iv. Planning timely measures against diseases and pests
v. Choosing varieties most likely to thrive in the expected pattern of weather.
vi. Determining national policy with regard to the support or development of marginal areas
vii. Determining the choice of crops to be grown

(5) Local Weather Forecast:

i. LRWF are issued for a shorter period and for a limited area
ii. LRWF valid for next 24 hours and are issued for local weather information on strong wind speed, thunderstorm. Fog etc.
iii. Local forecast are issued by meteorological office located at Aerodrome sites.
iv. They also serve the purpose of crops and farmers to take different agricultural practices

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CHAPTER-11

CLIMATE CHANGE

- **Climate variability** – The way climate fluctuates yearly above or below a long-term average value.
- **Climate change** – Long-term continuous change (increase or decrease) to average weather conditions **or** the range of weather.
- **Climatological normal** – 30-year average of a weather variable.
- **Global Warming –** It means an increase in the average temperature of the earth's atmosphere near its surface - either from natural or human causes - that may result in a change in global climate patterns.

Why Study Climate Variability?

We use these averages and ranges to make important societal decisions. For example, climatologal normals of precipitation and historical records of storm events are used to calculate probabilities of future rain events. Engineers can then use these data to design community storm water drainage systems.

These data also serve as a baseline against which to compare current weather and climate data. Without a baseline we have no way to understand how current observations fit into the bigger picture.

What Causes Climate Variability?

Common drivers of climate variability include El Niño and La Niña events, which are shifts of warm, tropical Pacific Ocean currents that can dramatically affect Michigan's winters. El Niños give us milder, less snowy winters (such as the winter of 2009-2010), while La Niñas give us colder, snowier winters (such as the winter of 2007-2008). Other drivers of climate variability include volcanic eruptions and sunspots. Sometimes climate varies in ways that are random or not fully explainable.

Climate Change

If climate variability is year-to-year variation, what is climate change? Climate change is a long-term continuous change (increase or decrease) to **average** weather conditions (e.g. average temperature) OR the **range** of weather (e.g. more frequent and severe extreme storms). Both can also happen simultaneously. Long-term means at least many decades. Climate change is slow and gradual, and unlike year-to-year variability, is very difficult to perceive without scientific records.

How do scientists detect climate change? They look for long-term continuous changes (trends) in climatological averages and normals and the variety around these averages. Climate in the Great Lakes region is generally highly variable in the short term, which makes it difficult to tease apart natural variability from long-term change. However, looking at data since the late 1800s reveals some significant shifts in temperature, total precipitation, and extreme events in recent decades in the Great Lakes region. Scientists use this evidence to conclude that climate is indeed changing.

Climate change occurs because of changes to Earth's environment, like changes in its orbit around the sun or human modification of the atmosphere. There is nothing inherently wrong with climate change. It has happened in the past and will happen again. The current concern stems from the rate of change – how quickly changes are happening. Scientists have found that the current rate of temperature increase is higher than any previously seen in the last 800,000 years. Evidence strongly indicates that human-driven changes in the atmosphere are contributing to the unprecedented rate of temperature increase.

Using historical weather data from a weather station in South Haven, Michigan, a coastal community on the Lake Michigan shoreline, we can graphically illustrate the climate change and variability concepts using a real life example:

Introduction:

Agriculture is a complex system. The agricultural production is driven by the agronomic, natural and climatic resources. It is very well known that agriculture is inherently sensitive to climatic conditions and is among the sectors most vulnerable to weather (and climate) at the time when crop is grown. Any major change in climate can lead to increased climatic risks to agricultural production and food security. Of the total annual crop losses in world agriculture, climatic (and weather) related events such as droughts, flash floods, uneven distribution of rains, frost, hail and severe storms reduce agriculture production by as much as 40%. These affect food production and food security particularly of the developing nations.

In India it has been estimated that about 28% of its land is vulnerable to droughts, 12% to floods and 8% to cyclones. It has been reported that in the year 1918, which was ranked as the worst drought year of the last century in India, about 69% of the total land area of the country was affected by drought. Millions of people, particularly in the Eastern India died due to famine. Thus food production is important for maintaining the societal fabric and its food security.

Mankind, particularly after the wide spread adoption of industrial revolution, has exploited the natural resources (land, air, water, forests, biodiversity) more that the system could sustain. This has resulted in climate change due to (1) industry-led environmental pollution, (2) depletion of green cover particularly forests, (3) melting of glaciers, (4) global-warming led by an increase of air-warming gases in the atmosphere, and (5) increased soil erosion.

Climate Change in the UN-led Inter-Governmental Panel on Climate Change (IPCC) refers to any change in the climate over time, either due to natural climatic variability or as a result of anthropogenic (human) activity. The UN Framework Convention on Climate Change (UNFCC), on the other hand states that climate change refers to a change of climate that is directly attributed to human activity that alters the composition of the global atmosphere and that is in addition to natural climatic variability observed over comparable time-periods.

Causes of Climate Change

- Changed environment for crop production
- Changed environment for forests
- Changed environment for biota and fauna
- Changed environment for human living
- Changed land-water-ecology interactions
- Changed quality of land and water and related global changes/ecosystem services

The climate of the earth is dynamic and has been always changing throughout the history through a series (related or unrelated events) of natural cycle/s. The world's worry now is that the observed climate changes are occurring at a faster rate due to anthropogenic reasons and the biological driven ecosystems are not able to 'include' the change or cope with it.

Why Climate Change Occurs

1. Due to geo-ecological events:

- Earth quakes
- Tsunami's [Sea surface temperature]
- Global warming/cooling [ENSO/La Nina]
- Long terms changes in the earth's climate

2. Due to land-use changes

- Increased cropped area/intensity of cultivation
- Deforestation
- Water-storage/dams
- Changed river courses/incursion of sea water
- Increased use of ground water/irrigation
- Less than 30% forests of the total land area of an area/country
- More than 30% area cropped compared to total geographical area
- Mono-cropping
- Unbalanced use of biocides and chemicals
- Decreased recharge of ground water

High Manifestations OR impacts of Climate Change

- Increased environmental temperatures
- More variable weather
- Lowering of ground water
- Contaminated soils and ground water
- Acid – rain
- Higher soil erosion/land degradation
- Variable crop yields
- Decreased factor productivity
- More water deficits – frequent droughts
- Higher frequency of floods

- Lower/decreased soil quality
- Human unrest, increased migration
- Livelihood insecurity
- Food and water insecurity
- Decreased quality of life

How to cope with Climate Change:

The goal of effective ways to cope with climate change events is to adopt agricultural management technologies and policy changes between hazard events such that the crop/animal production risk associated with the next event is reduced (or contained) through the adoption of well-formulated land use plans and mitigation actions that have been adopted by the stake holders.

What can be done

- Increase crop diversity by inter-cropping and appropriate cropping systems/rotations/land use;
- Adopt land/water conservation agriculture methods suited to varied agro-climates;
- Balanced use of biocides/chemicals;
- Increase forested area to 33% of the total geographical area;
- Increase carbon fixation in the soil by growing deep-rooted crops so as to decrease carbon foot - print;
- Use water judiciously : more crop/unit of water;
- Use less fossil fuels;
- Use more solar/wind sources of energy;
- Educate farmers on the dangers of climate change;
- Disseminate meteorological/climate data/information on a large – scale;
- Suggest weather-based changes in cropping systems/land uses to sustain agricultural production;
- Encourage farmer groups to establish small weather observatories in their villages;
- Adopt use of soil-health cards widely for making fertilizer use decisions;
- Employ crop-weather models dynamically to advise farmers on improved animal/crop management for sustainable agriculture in a Decision Support System's framework.

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