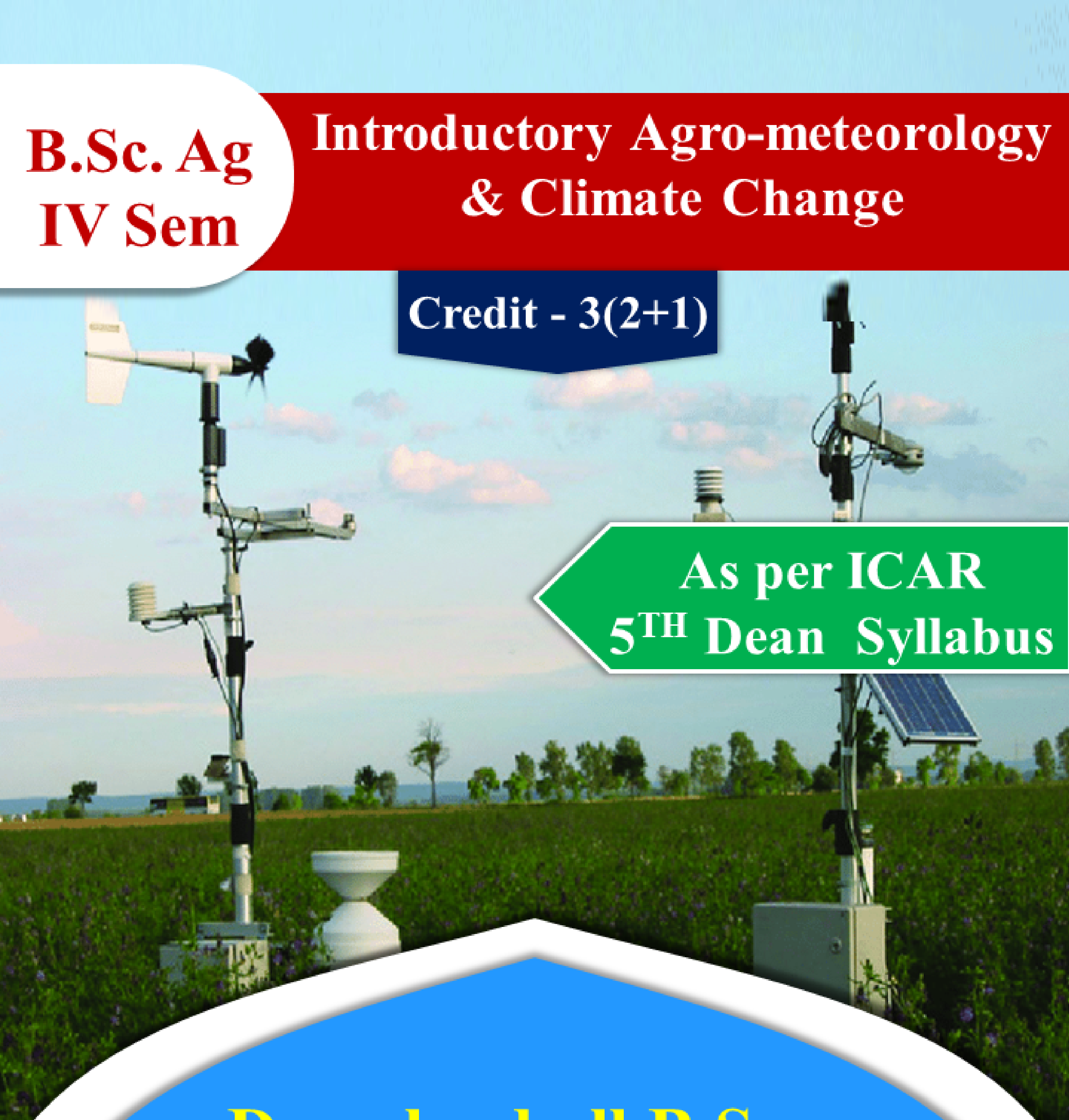

B.Sc. Ag
IV Sem

Introductory Agro-meteorology & Climate Change

Credit - 3(2+1)

As per ICAR
5TH Dean Syllabus

LECTURE NO -16

AGRICULTURAL METEROLOGY – INTRODUCTION - DEFINITIONS OF METEROLOGY, CLIMATOLOGY AND AGRICULTURAL METEROLOGY – SCOPE AND PRACTICAL UTILITY OF AGRICULTURAL METEROLOGY

Agricultural Meteorology-Introduction-Definitions of Meteorology, Climatology and Agricultural Meteorology-Scope and Practical Utility of Agricultural Meteorology

Atmosphere

The earth is elliptical in shape. It has three spheres. They are:

1 Hydrosphere: the water portion.

2 Lithosphere: the solid portion.

3 Atmosphere: the gaseous portion.

The atmosphere is defined as "The colourless, odourless and tasteless physical mixture of gases which surrounds the earth on all sides". It is mobile, compressible and expansible.

Uses of atmosphere for agriculture: The uses of atmosphere are: It

1. Provides oxygen which is useful for respiration in crops.
2. Provides carbon-dioxide to build biomass in photosynthesis.
3. Provides nitrogen which is essential for plant growth.
4. Acts as a medium for transportation of pollen.
5. Protects crop plants on earth from harmful U.V. rays.
6. Maintains warmth to plant life.
7. Provides rain to field crops as it is a source of water vapour, clouds etc.

Agricultural Meteorology

Meteorology

Meteorology is defined as

- "The science of atmosphere".
- "A branch of physics of the earth dealing with physical processes in the atmosphere that produce weather".

Climatology

It is defined as "The science dealing with the factors which determine and control the distribution of climate over the earth's surface". Different factors affecting the climate of a region are:

1. Latitude.
2. Altitude.
3. Land and water.
4. Winds and air masses
5. Low and high pressure belts.
6. Mountain barriers.
7. Ocean currents.
8. Extent of forests, etc.

The above factors are also known as "climatic elements"

Agricultural Meteorology

Agriculture is defined as **"**The art and science of production and processing of plant and animal life for the use of human beings". It is also defined as "A system for harvesting or exploiting the solar radiation".

Agriculture deals with three most complex entities viz., soil, plant and atmosphere and their interactions. Among these three, atmosphere is the most complex entity over the other two. It is defined as

- "The study of those aspects of meteorology that have direct relevance to agriculture". It is also defined as
- "A branch of applied meteorology which investigates the responses of crops to the physical conditions of the environment".
- "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 `Agrometeorology' is the abbreviated form of agricultural meteorology.

Practical Utility / Importance / Economic Benefits / Significance of Study of Agricultural Meteorology:

In a broad manner the study of agricultural meteorology helps in

1. Planning cropping systems / patterns.
2. Selection of sowing dates for optimum crop yields.
3. Cost effective ploughing, harrowing, weeding etc.

1 Reducing losses of applied chemicals and fertilizers.

2 Judicious irrigation to crops.

3 Efficient harvesting of all crops.

4 Reducing or eliminating outbreak of pests and diseases.

5 Efficient management of soils which are formed out of weather action.

6 Managing weather abnormalities like cyclones, heavy rainfall, floods, drought etc. This can be achieved by ;

a Protection : When rain is forecast avoid irrigation. But, when frost is forecast apply irrigation.

b Avoidance : Avoid fertilizer and chemical sprays when rain is forecast.

c Mitigation : Use shelter belts against cold and heat waves.

7 Effective environmental protection.

8 Avoiding or minimising losses due to forest fires.

Scope of agricultural meteorology

In addition to the points mentioned above, the influence of weather on agriculture can be on a wide range of scales in space and time. This is reflected in the scope of agricultural meteorology as detailed below:

1. At the smallest scale, the subject involves the study of microscale processes taking place within the layers of air adjacent to leaves of crops, soil surfaces, etc. The agrometeorologists have to study the struture of leaf canopies which effects the capture of light and how the atmospheric carbon dioxide may be used to determine rates of crop growth.
2. On a broader scale, agrometeorologists have to use the standard weather records to analyse and predict responses of plants.
3. Although the subject implies a primary concern with atmospheric processes the agrometeorologist is also interested in the soil environment because of the large influence which the weather can have on soil temperature and on the availability of water and nutrients to plant roots.
4. The agro meteorologist also be concerned with the study of glass houses and other protected environments designed for improving agricultural production.

LECTURE NO – 17

COMPOSITION AND STRUCTURE OF THE ATMOSPHERE – DEFINITION OF WEATHER AND CLIMATE – ASPECTS INVOLVED IN WEATHER AND CLIMATE

Composition of the atmosphere

There is no definite upper layer to the atmosphere. The decrease of air (density) with altitude (height) is so rapid (Figure 1) that half of the atmosphere lies within 3.5 miles (5.5 kms) from the surface and nearly 3/4th of the atmosphere lies upto 7 miles (11 km).

The atmosphere is a mixture of many gases. In addition, it contains large quantities of solid and liquid particles collectively called "aerosols". The lower part of the atmosphere contains water vapour from 0.02 to 4 per cent by volume. Nitrogen and oxygen make up approximately to 99 per cent and the remaining 1 per cent by other gases (Table 1). Innumerable dust particles are also present in the lower layers of the atmosphere. They are microscopic and play an important role in absorption and scattering of insolation.

Table: 17.1. Principal gases comprising dry air in the lower atmosphere

S. No.	Constituent	Per cent by volume	Per cent by weight
1	Nitrogen	78.08	75.51
2	Oxygen	20.94	23.15
3	Argon	0.93	1.28
4	Carbon-dioxide	0.03	0.046

Physical structure of the atmosphere

On the basis of vertical temperature variation, the atmosphere is divided into different spheres or layers as detailed below:

I Troposphere

1. The word "Tropo" means mixing or turbulence and "Sphere" means region.
2. The average height of this lower most layer of the atmosphere is about 14 kilometers above the mean sea level; at the equator it is 16 kilometers; and 7- 8 kilometers at the poles.
3. Under normal conditions the height of the troposphere changes from place to place and season to season

4. Various types of clouds, thunderstorms, cyclones and anti cyclones occur in this sphere because of the concentration of almost all the water vapour and aerosols in it. So, this layer is called as “Seat of weather phenomena”.
5. The wind velocities increase with height and attain the maximum at the top of this layer.
6. Another striking feature of troposphere is that there is a decrease of temperature with increasing elevation at a mean lapse rate of about 6.5^{o}C per kilometer or 3.6^{o}F per 1,000 feet.
7. Most of the radiation received from the sun is absorbed by the earth's surface. So the troposphere is heated from below.
8. In this layer, about 75 per cent of total gases and most of the moisture and dust particles present.
9. At the top of the troposphere there is a shallow layer separating it from stratosphere which is known as “Tropopause”.
10. The tropopause layer is thin and its height changes according to the latitudes and infact this is a transitional zone and distinctly characterised by no major movement of air.

II Stratosphere

1. This layer exists above the tropopause (around 20 km onwards) and extends to altitudes of about 50-55 kilometers.
2. This layer is called as "Seat of photochemical reactions".
3. In any particular locality, the temperature remains practically constant at around 20 kilometers and is characterised as Isothermal because the air is thin, clear, cold and dry.
4. The temperature of this layer increases with height and also depends upon troposphere because troposphere is higher at equator than at poles.
5. In the upper parts of the stratosphere the temperatures are almost as higher as those near the earth's surface, which is due to the fact that the ultra violet radiation from the sun is absorbed by ozone in this region.
6. Less convection takes place in the stratosphere because it is warm at the top and cold at the bottom.
7. There is also persistence of circulation patterns and high wind speeds.
8. The upper boundary of the stratosphere is called stratopause and above this level there is a steep rise in temperature.

III Mesosphere / Ozonosphere

1. There is a maximum concentration of ozone between 30 and 60 km above the surface of the earth and this layer is known as ozonosphere.
2. A property of ozone is that it absorbs ultra violet rays. Had there been no layer of ozone in the atmosphere, the ultra violet rays would have reached the surface of the earth and no life on it.

3. The temperature of the ozonosphere is high (warm) due to selective absorption of ultra violet radiation by ozone.
4. Because of the preponderance of chemical process this sphere is called as "Chemosphere".
5. In this layer the temperature increases with height at the rate of $5^{o}C$ per each kilometer.
6. According to some leading scientists the ionosphere is supposed to start at a height of 80 kilometers above the earth's surface. The layer between 50 and 80 kilometeris called Mesosphere. In this layer the temperature decreases with height. The upper boundary of this layer is called the mesopause.

IV Ionosphere/Thermosphere

1. Ionosphere layer lies beyond ozonosphere (mesosphere) at a height of about 80 kms. above the earths surface and extends upto 400 kilometers.
2. The atmosphere in ionosphere is partly ionised. Enriched ion zones exist in the form of distinct ionised layers. So, this layer is called as ionosphere.
3. Above the ozonosphere the temperature falls again. According to some climatologists, the layer between 80 and 140 kilometers is known as "Thermosphere".
4. The ionosphere reflects radio waves because of one or multiple reflections of short wave radio beams from the ionised shells. So, long distance radio communication is possible due to this layer.

V Exosphere

1. The outer most layer of the earth's atmosphere is named as exosphere and this layer lies between 400 and 1,000 kilometres.
2. At such a greater height the density of atoms in the atmosphere is extremely low.
3. Hydrogen and Helium gases predominate in this outer most region.
4. At an altitude of about 500 to 600 kilometres the density of the atmosphere becomes so low that collisions between neutral particles become extremely rare.

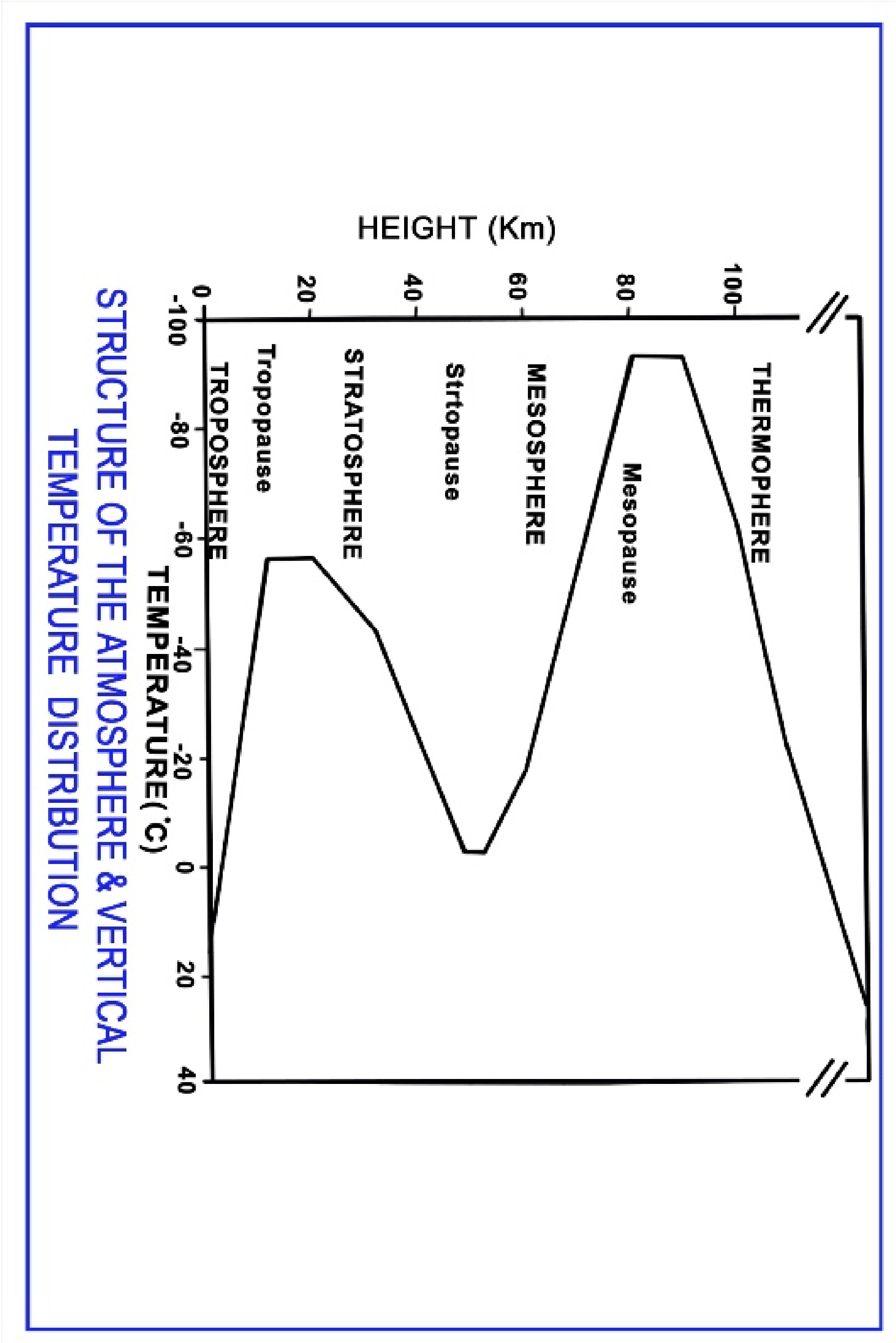

Fig:17.1 Structure of Atmosphere

Weather and climate

Weather: It is defined as “A state or condition of the atmosphere at a given place and at a given instant of time”.

- The daily or short term variations of different conditions of lower air in terms of temperature, pressure, wind, rainfall, etc".
- The aspects involved in weather include small areas and duration, expressed in numerical values etc. The different weather elements are solar radiation, temperature, pressure, wind, humidity, rainfall, evaporation etc. Weather is highly variable. It changes constantly sometimes from hour to hour and at other times from day to day.

  Example: The air temperature of Rajendranagar on 20-01-2000 at 2.30 p.m. is 32°C.

Climate

It is defined as

- "The generalised weather or summation of weather conditions over a given region during comparatively longer period".
- "The sum of all statistical information of weather in a particular area during a specified interval of time usually a season or year or even a decade". The aspects involved are larger areas like a zone, a state; a country is described by normals etc.

  Example: The climatic elements are latitude, longitude, altitude etc. In Andhra Pradesh the winter temperatures range from 15 to 29°C.

Table 17.1 Differences between Weather and Climate.

S. No.	Weather	Climate
1	A typical physical condition of the atmosphere	Generalised condition of the atmosphere which represents and describes the characteristics of a region
2	Changes from place to place even in a small locality	Different in different large regions
3	Changes according to time (every moment)	Change requires longer (years) time
4	Similar numerical values of weather of different places usually have same weather	Similar numerical values of climate of different places usually have different climates
5	Crop growth, development and yield are decided by weather in a given season	Selection of crops suitable for a place is decided based on climate of the region
6	Under aberrant weather conditions planners can adopt a short-term contingent planning	Helps in long-term agricultural planning

LECTURE NO – 18

SOLAR RADIATION - DEFINITION, INTRODUCTION OF ELECTROMAGNETIC SPECTRUM AND FUNCTIONS OF LIGHT, SOLAR CONSTANT, NET RADIATION, BLACKBODY RADIATION, EMISSIVITY, ABSORPTIVITY, REFLECTIVITY, TRANSMISSIVITY, AND ALBEDO

Introduction

Solar radiation is the primary source of energy on earth, and life depends on it. Solar radiation is defined as "The flux of radiant energy from the sun". All matter at a temperature above the absolute zero, imparts energy to the surrounding space. This energy is transformed by green plants in the process of photosynthesis into the potential energy of organic material. In inorganic bodies the rays absorbed are used in heating. The variations of the total radiation flux from one site to another on the surface of the earth are enormous and the distribution of plants and animals responds to this variation.

Solar radiation definition

Heat energy is transmitted by three processes.

1 Radiation

- This is the process of transmission of energy from one body to another without the aid of a material medium (solid, liquid, or gas).

Example: The energy transmission through space from the sun to the earth.

2 Conduction

- This is the process of heat transfer through matter without the actual movement of molecules of the substances or matter. Heat flows from the warmer to cooler part of the body so that the temperature between them are equalised.

  Example: The energy transmission through an iron rod which is made warmer at one end.

3 Convection

- This is the process of transmission of heat through actual movement of molecules of the medium. This is the predominant form of transmission of energy on the earth as all the weather related processes involve this process.

  Example: Boiling of water in a beaker

Of the above three processes of transmission of energy convection is the predominant form of transmission of energy on the earth. All the weather related processes involve this process.

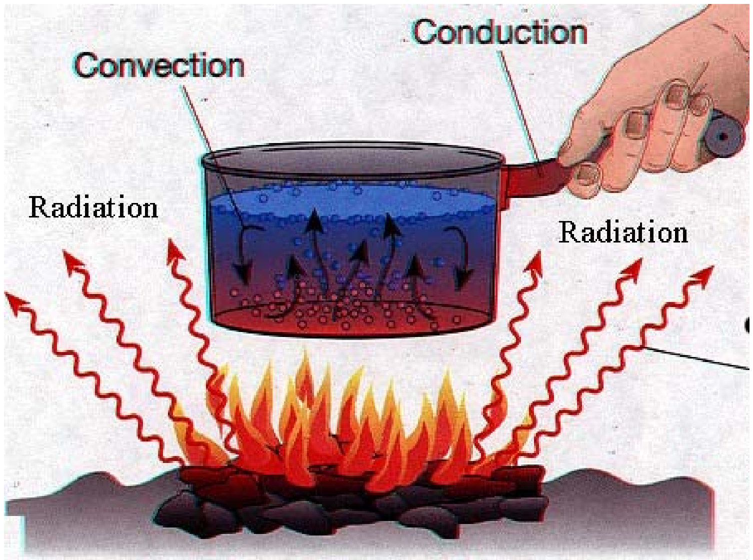

Fig: 18.1 CONDUCTION, CONVECTION AND RADIATION

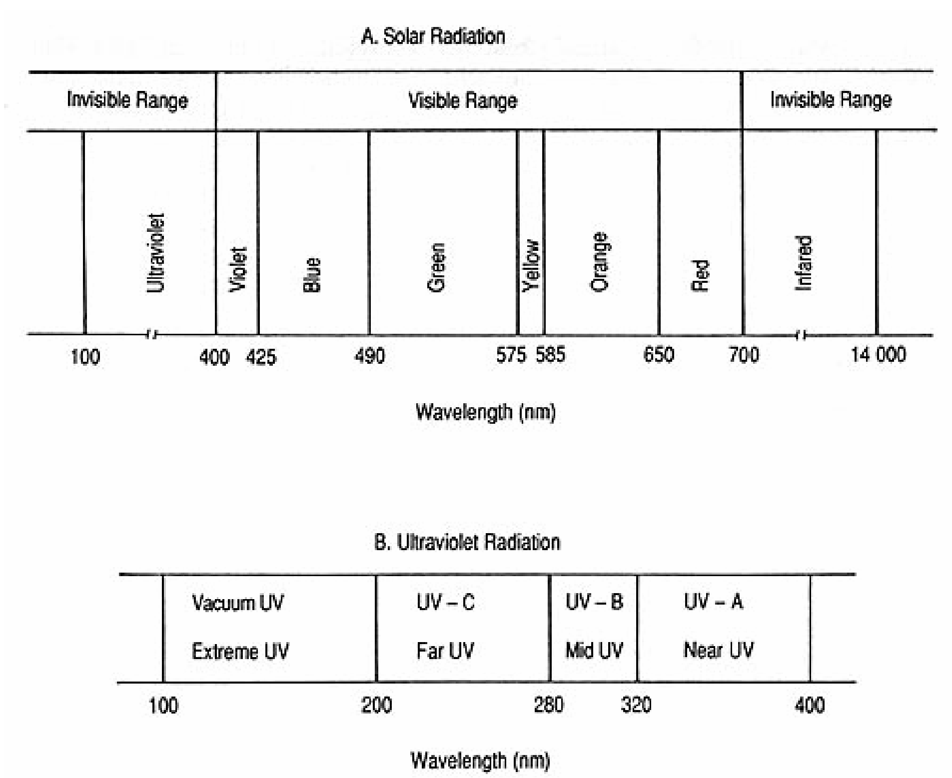

Fig:18.2 SOLAR SPECTRUM

4. Solar Radiation: When the radiation is transmitted from the sun, it is known as solar radiation.

Solar spectrum

Radiant energy is transmitted in the form of electromagnetic waves by the sun. The energy from the sun is spread over a very broad band of wave lengths known as solar spectrum. It is also known as electromagnetic spectrum. The spectrum does not constitute only one band, but a combination of different waves which are characterised individually.

Example: U.V. rays, light part, Near I.R., Far I.R. Radio weaves, micro waves, radar waves, etc.

Table: 18.1. Energy content of different bands in solar spectrum.

S. No.	Spectrum	Wave length in microns	Percentage of energy
1.	Gamma r-rays frays & x-rays	0.005 - 0.20	9%
2.	U.V. rays	0.2 - 0.4	
3.	Violet	0.4 - 0.43	
4.	Blue	0.43 - 0.49	
5.	Green	0.49 - 0.53	
6.	Yellow	0.53 - 0.58	41 %
7.	Orange	0.58 - 0.66	
8.	Red	0.63 - 0.70	
9.	Infrared rays	> 0.70	50%

Different bands of solar spectrum are:

1. The shorter wave lengths of the spectrum are known as U.V. rays. These are chemically very active. Unless these are filtered in the atmosphere, there is a danger for life on the earth. This band ranges between 0.005 to 0.4 microns.
2. The part of the spectrum which is visible known as `light'. It is the part of the spectrum which is essential for all the plant processes and ranges from 0.4 to 0.7 microns.
3. The third part of the solar spectrum (last band) is known infra red band. This is essential for thermal energy of the plant (the source of heat to the plant). This band is less than 0.7 microns.

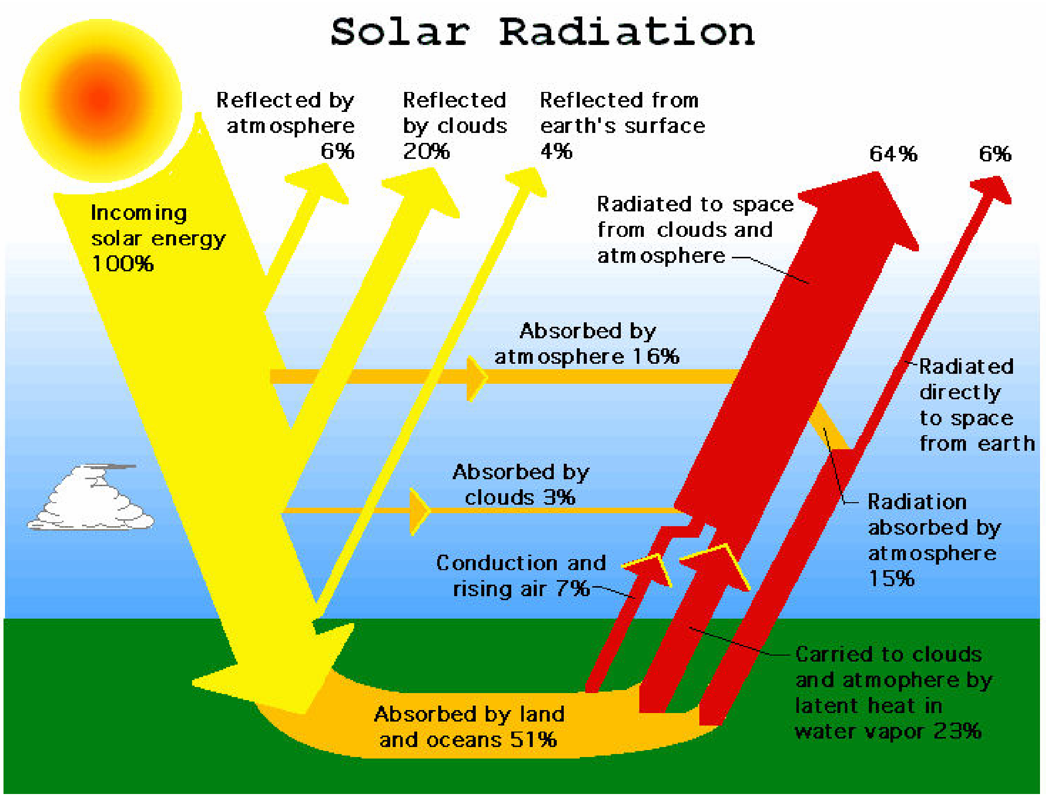

Fig:18.3 Solar Radiation

Functions of light: The functions of light are:

1. All the plant parts are directly or indirectly influenced by light
2. Light of correct intensity, quality and duration is essential to normal plant development
3. Poor light availability causes abnormalities and disorders in plants
4. Light is indispensable to photosynthesis
5. Light governs the distribution of photosynthates among different organs of plants
6. Effects tiller production
7. Effects stability, strength and length of culms
8. Effects dry matter production
9. Effects the size of the leaves
10. Effects the root development
11. Effects the flowering and fruiting
12. Effects the dormancy of the seed

Solar constant: It is the energy falling in one minute on a surface of 1 cm^2 at the outer boundary layer of the atmosphere, held normal to the sunlight at the mean distance of the earth from the sun. The units are $cal/cm^2/min$. "cal/cm^2 "is also known as "Langley". The estimated value of this constant is from 1.94 to 2.0 largely/min. The average value is 2 LY/mn.

It depends on:

1. Output of solar radiation.
2. Distance between the earth and the sun.
3. Transparency of the atmosphere.
4. Duration of the sunlight period
5. The angle at which the sun's rays strike the earth.

Net radiation

The difference between the incoming radiation from the sun and the out going radiation from the earth is known as net radiation. The net radiation values become -ve after late evening hours to early morning hours. It is a conservative term and plays an importance role in the energy processes of the crops.

Black body: It is an ideal hypothetical body which absorbs all the electromagnetic radiation falling on it. It neither reflects nor transmits any radiation striking it. However, when heated it emits all the possible wavelengths of solar radiation and becomes a perfect radiator. So, an ideal black body is a perfect absorber and a perfect radiator.

Black body radiation: The radiation radiated by an ideal black body is known as black body radiation.

Emittance: It is the ratio of the emitted radiation of a given surface at a specified wavelength to the emittance of an ideal black body at the same wavelength and temperature.

For other than a black body the value of emittance is always less than one and for black body the emittance value is one.

Absorptivity: For an object this is the ratio of the electromagnetic radiant power absorbed to the total amount incident upon the same object.

Like emissivity the values are less than one for other than a black body and one for a black body.

Reflectivity: The ratio of the monochromatic beam of electromagnetic radiation reflected by a body to that incident upon it. The units of expression are by %.

Transmissivity: This is the ratio of transmitted to the incident radiation on a surface preferably a crop canopy.

Albedo: It is defined as the ratio between reflected radiation to the incident radiation on a crop field, snow, leaves etc. For white bodies the albedo values are high. For fresh snow cover the albedo values range between 75 and 95; for cropped fields - it is 12-13; dark cultivated soil 7-10; human skin 15-25, etc. Albedo determines how much of the heat that reaches the ground in the form of radiation will remain available for use.

LECTURE NO – 19

PHYSIOLOGICAL RESPONSE OF DIFFERENT BANDS OF INCIDENT RADIATION – FACTORS AFFECTING DISTRIBUTION OF SOLAR RADIATION WITH IN PLANT CANOPY

Factors affecting the distribution of solar radiation within the plant canopy

Type of plants

a) The leaves cereal crops like paddy, wheat etc., have a transmissivity in the range of 5 to 10 per cent.

b) The broad leaves of ever green plants have lower value of 2 to 8 per cent, where as aquatic plants have the transmissibility of 4 to 8 per cent.

c) Transmissivity changes with age of a leaf: the transmissivity of young leaves is more as compared to old leaves.

1. Age of the leaves

The transmissivity of young leaves is more as compared to old leaves

2. Chlorophyll content:

As the chlorophyll content increases the values of transmissibility decreases.

3. Arrangement of leaves

a) The relative light interception by horizontal and erect foliage is 1 : 0.44

b) When the leaf area index is one (i) the light transmissibility of more upright leaves is 74 as against 50 per cent for horizontal leaves

4. Angle of leaves

a) In full sunlight, the optimum inclination for efficient light use is 81^o.

b) At full sunlight, a leaf placed at the optimum inclination is 4-5 times as efficient in using light as a horizontal leaf.

c) The ideal arrangement of leaves (shall be) is that the lowest 13 per cent of the leaves lay at angles between 0^o and 30^o to the horizontal, that the adjoining 37 per cent of the leaves lay at 30^o to 60^o and the upper 50 per cent of the leaves lay at 60^o to 90^o.

5. Plant density

In case of sparse crop stands not only the per cent of light transmissivity is more but it is also variable with the time of the day. It is minimum at noon and maximum during morning and evening hours. In dense crop canopies the light transmissivity is less.

6. Plant height

When the plant height increases the transmissivity of light by the canopy decreases.

7. Angle of the sun

a The highest radiation penetration occurs at noon

b. Relatively high radiation penetration also occurs both in the morning as well as before sunset due to high proportion of diffuse light.

The Dutch Committee on plant irradiation has divided the solar spectrum into the following eight bands. This was done on the basis of the physiological response of plants to the incident radiation.

Table: 19.1 Physiological responses of plants to different bands of incident Radiation.

S. No.	Band No	Spectral region (microns)	Character of absorption	Physiological effect
1.	1st	Infrared >1.000	By water in tissues	Converted into heat; this has no specific effects on photochemical and biochemical processes.
2.	2nd	1.000 to 0.700	slight	Stimulator elongation in plants
3.	3rd	0.700 to 0.610	Very strong by chlorophylls	Large effect on photosynthesis and photoperisodism
4.	4th	0.610 to 0.510	Somewhat less	Small effect on photosynthesis; small morphogenic effect
5.	5th	0.510 to 0.400	Very strong by chlorophylls and carotenoids	Large effect on photosynthesis; large morphogenic effect
5.	5th	0.510 to 0.400	Very strong by chlorophylls and carotenoids	Large effect on photosynthesis; large morphogenic effect
6.	6th	0.400 to 0.315	By chlorophyus and protoplasm	Small effect on photosynthesis. Produces fluorescence in plants
7.	7th	0.315 to 0.280	By protoplasm	Significant germicidal action; Large morphogenic effect; stimulating some biosynthesis; large effect on physiological processes
8.	8th	< 2.80	By protoplasm	Large germicidal effects. Lethal in large doses

LECTURE NO – 20

AIR TEMPERATURE – INTRODUCTION -TEMPERATURE AND HEAT DEFINITIONS – ISOTHERMS - HORIZONTAL AND VERTICAL TEMPERATURE VARIATIONS IN THE ATMOSPHERE - CARDINAL TEMPERATURES - IMPORTANCE OF AIT TEMPERATURE

TEMPERATURE AND HEAT DEFINITIONS:

Temperature is defined as "The measure of speed per molecule of all the molecules of a body" where as heat is "The energy arising from random motion of all the molecules of a body".

The temperature of a body is the condition which determines its ability to transfer heat to other bodies or to receive heat from them. In a system of two bodies the one which looses heat to the other is said to be at a higher temperature.

Heat measures total molecular energy. Temperature measures average energy of individual molecules. Temperature is that characteristic of a body which determines the direction of heat flow by conduction.

AIR TEMPERATURE

Temperature Distribution

1. Each day the earth receives energy in the form of incoming solar radiation from the sun.
2. This shortwave solar radiation ranges mostly from ultra-violet (0.2 µm wavelength) to the near infrared (3.0 microns wavelength), but reaches its maximum at around 0.5 microns wavelength (Blue-green visible light).
3. This insolation is absorbed by the earth's surface and is converted to heat (long wave radiation)
4. The earth's (terrestrial) longwave radiation reaches its peak intensity at 10 microns wavelength (thermal infrared) and is responsible for heating the lower atmosphere.

Horizontal temperature distribution

Sun rays make different angles at the same place at different times. Also different angles at the same time at different places as the axis of the earth makes an angle of 23-50 with the vertical. Due to the variation in angle of sums rays distribution of solar heat on earth decreases both ways from equator to polar. This is known as horizontal distribution of air temperature.

On maps, the horizontal distribution of temperature is shown by isotherms. The isotherms are imaginary lines drawn the connecting points that have equal temperature.

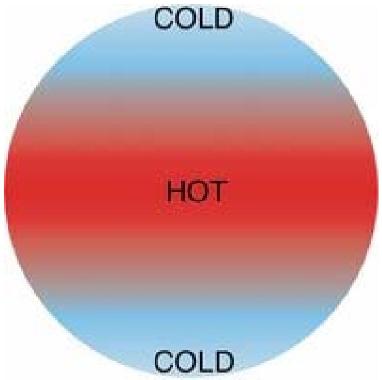

Fig: 20.1 TEMPERATURE AT DIFFERENT PARTS OF GLOBE.

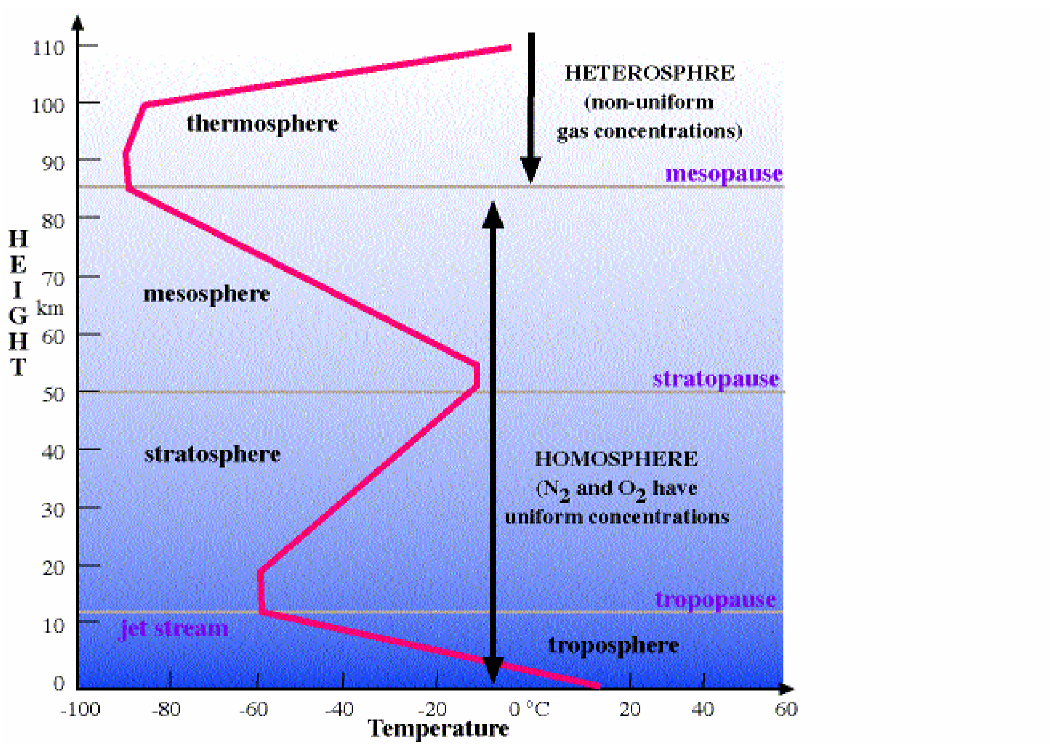

Fig: 20.2 TEMPERATURE CHANGES WITH ALTITUDE

Factors influencing horizontal distribution of temperature:

1. Latitude

The effectiveness of insolation in heating the earth's surface is largely determined by the latitude. So, there is a general decrease in temperatures from the equator to poles, which is a classical example of horizontal temperature distribution.

2. Ocean currents

Transport of ocean water in the form of currents carries heat from one part of the earth to another which results in horizontal distribution of sea-surface temperature.

3. **Mountain barrier**: Mountain ranges tend to guide the movement of cold air masses resulting in horizontal temperature variation. Ex: Himalayas protect India from polar air.

4. Topography and relief

In the northern hemisphere north facing slopes generally receive less insolation than south facing slopes and temperatures are normally lower.

Vertical distribution of temperature: The decrease of air temperature with altitude is known as vertical temperature distribution.

Ex: Permanent snow caps in high mountains.

Vertical temperature distribution

The vertical distribution of temperature is due to adiabatic lapse rate

1. An adiabatic process is one in which the system being considered does not exchange heat with its environment.
2. The most common atmospheric adiabatic phenomena are those involving the change of air temperature due to change of pressure.
3. If an air mass has its pressure decreased, it will expand and do mechanical work on the surrounding air.
4. If no heat is taken from the surroundings, the energy required to do work is taken from the heat energy of the air mass, resulting in a temperature decrease.
5. When pressure is increased, the work done in the air mass appears as heat, causing its temperature to rise.
6. The rates of adiabatic heating and cooling in the atmosphere are described as lapse rates and are expressed as the change of temperature with height.
7. The adiabatic lapse rate for dry air is very nearly $1^{o}C$ per 100 m.
8. If condensation occurs in the air parcel, latent heat is released, thereby modifying the rate of temperature change.
9. This is known as wet adiabatic lapse rate

10. However, the average adiabatic lapse rate is 6.5^{o}C per kilometre height and it is assumed as 0.5^{o}c per 100 m.
11. Large scale atmospheric motions are approximately adiabatic and clouds and snow or rain associated with them are primarily adiabatic phenomena in that they result from cooling air associated with decreasing pressure of upward air motion.
12. Simpler adiabatic phenomena on a smaller scale. A common example is that of rising "bubbles" of air on a warm day, leading to cumulus cloud forms.
13. The growth of such cumulus clouds into thunder clouds is more complex but still largely adiabatic phenomena.

Periodic temperature variation

The air temperature changes continuously during a day or a year.

Mean daily cycle of air temperature

1. From sun rise insolation is supplied and the air temperature continuously rises.
2. Maximum air temperature occurs between 1 p.m. and 4 p.m. and minimum temperature occurs just before sun rise.
3. Maximum insolation is received around noon (12 noon) but maximum temperature is recorded from 1 p.m. to 4 p.m. and this delay is known as thermal lag or thermal inertia.

Mean annual cycle of temperature

1. The annual temperature changes from one location to other due to many factors.
2. In the northern hemisphere winter minimum occurs in January and summer maximum in July and vise-versa in southern hemisphere.
3. When loss of longwave radiation exceeds the shortwave radiations received than the temperature falls and under reverse of this situations the temperature increases in a cycle.
4. Cardinal temperatures
5. There are three points of temperature which influence the growth of crop plants. These are termed as "cardinal points" and the synonymous term is `cardinal temperature'.
    1. A minimum temperature below which growth ceases (minimum cardinal temperature).
    2. An optimum temperature at which the plant growth proceeds with greatest rapidly (optimum cardinal temperature).
    3. A maximum temperature above which plant growth ceases (maximum cardinal temperature).

Table: 20.1. Cardinal temperature for different crops.

S. No.	Crop	Min. Cardinal temp. °C	Opt. Cardinal temp'	Max. Cardinal temp°C
1.	Wheat and Barley	0-5	25-31	31-37
2.	Sorghum	15-18	31-36	40-42

Importance of air temperature on crop plants

1. Temperature influences distribution of crop plants and vegetation (In Western Himalayas the temperature falls as altitude increases and this change is responsible for the change of vegetation at different altitudes.
2. The growth and development of crop plants are chiefly influenced by air temperature.
3. Affects leaf production, expansion and flowering.
4. Physical and chemical processes within the plants are governed by air temperature
5. The diffusion rate of gases and liquids changes with temperature
6. Solubility of different substances is dependent on temperature
7. Influences biochemical reactions in crops (double or triple with each 10°C rise)
8. Equilibrium of various systems and compounds in a function of temperature
9. Temperature effects the stability of enzymatic systems in the plants.

LECTURE - 21

LOW AIR TEMPERATURE AND PLANT INJURY - HIGH AIR EMPERATURE AND PLA NT INJURY – SOIL TEMPERATURE - FACTORS AEEECTING SOIL TEMPERATURE

Air temperature and plant injury

Low air temperature and plant injury: On exposure of crop plants to low temperature the following effects are observed. The primary effect of low air temperature below their optimum temperature is the reduction of rates of growth and metabolic processes.

1. Suffocation

- a Small plants may suffer from deficient oxygen when covered with densely packed snow.
- b Certain toxic substances accumulate in roots and crowns because of low diffusion of carbon dioxide

2. Physiological drought

- a In middle latitudes drought occurs under cool temperature conditions. This is due to excessive transpiration and absence of absorption of moisture from the soil, when the soil is in extremely low temperature conditions.
- b The internal water content of crop plants is depleted which may result in death of leaves.

3. Heaving

- a The injury to a plant is caused by lifting upward from the normal position causing the root to stretch or break at a time when the plant is growing.
- b Sometimes the roots are pushed completely above the soil surface.
- c It is difficult for the roots to become firmly established again and the plants may die because of this mechanical damage and desiccation.

4. Chilling

- a Due to this injury some crop plants are killed and others recover under favourable conditions later on.
- b This injury is common in temperate climates where delayed growth and sterility are common symptoms.
- c Moderate wind speeds when the air temperature ranges from 0 to 10^{o}C, tends to cause very rapid fall in the activity of metabolic processes, especially respiration in crop plants. Which is known as “chilling injury”. This results in severe damage and death within a few hours or days.
- d Chilling in the affected plants causes a phase change (“liquid” to “solid”) in membrane lipids resulting in inactivation of membrane bound enzymes.
- e Sometimes chilling results yellowing of plants.

5. Freezing

1 Freezing damage is caused by the formation of ice crystals in the intracellular spaces and extracellular spaces.

2 Ice within the cells cause injury by mechanical damage and plant parts or entire plant may be killed or damaged.

3 If extracellular ice persists, the gradient of water vapour pressure between the apoplast and the cells causes water to migrate out of the cells and into the apoplast, where it freezes, thereby increasing the amount of ice, in the plant tissue.

4 This results not only in mechanical damage to the tissue, but also brings about dehydration of cell contents and lead to death of the cell.

II High air temperature and plant injury

1 High air temperature results in the desiccation of the crop plants also.

2 The injury caused because of short period fluctuation (within a day highest in noon and lowest at early morning) in air temperature is known as sunclad.

3 The scorching of stem near the soil surface known as stem girdle is another injury at high air temperatures.

4 Plant tissues escape from high heat by emission of long wave radiation, convection of heat, and transpiration.

5 However, transpiration is the most effective process in many natural situations.

6 High plant temperatures (> 40^oC) are almost invariably due to the cessation of transpirational cooling, caused by stomatal closure.

7 Exposure of crop plants to temperatures over 45^oC for just 30 minutes can cause severe damage to the leaves of plants.

8 The effect of high temperature are the disruption of cell metabolism (possibly by protein denaturation), production of toxic substances, and damage to cellular membranes.

Cardinal temperatures

There are three points of temperature which influence the growth of crop

Factors affecting soil temperature

Heat at ground surface is propagated downward in the form of waves. The amplitude decreases with depth Figures ___ and ___ show different factors that effects soil temperature.

Both meteorological and soil factors contribute in bringing about changes of soil temperature.

I Meteorological factors

1. Solar radiation

a The amount of solar radiation available at any given location and point of time is directly proportional to soil temperature

b Even though a part of total net radiation available is utilised in evapotranspiration and heating the air by reradiation (latent heat and sensible heat fluxes) a relatively substantial amount of solar radiation is utilized in heating up of soil (ground heat flux) depending up on nature of surface.

c Radiation from the sky contributes a large amount of heat to the soil in areas where the sun's rays have to penetrate the earth's atmosphere very obliquely.

2. Wind

Air convection or wind is necessary to heat up the soil by conduction from the atmosphere.

Example: The mountain and valley winds influence the soil temperature.

3. Evaporation and condensation

a The greater the rate of evaporation the more the soil is cooled. This is the reason for coolness of moist. Soil in windy conditions.

b On the other hand whenever water vapour from the atmosphere or from other soil depths condenses in the soil it heats up noticeable. Freezing of water generates heat.

4. Rain fall (precipitation)

Depending on its temperature precipitation can either cool or warm the soil.

II. Soil factors

1. Aspect and slope

a In the middle and high latitudes of the northern hemisphere the southern slopes receive more insolation per unit area than the northern exposure (Fig. ___).

b The southwest slope are usually warmer than the south east slope. The reason is that the direct beam of sunshine on the southeast slope occurs shortly after prolonged cooling at night, but the evaporation of dew in the morning also requires energy.

2. Soil texture

a Because of lower heat capacity, poor thermal conductivity sandy soils warmup more rapidly than clay soils. The energy received by it is concentrated mainly in a thin layer resulting in extraordinary rise in temperature.

b Radiational cooling at night is greater in light soils than in heavy soils.

In the top layer, sand has the greatest temperature range, followed by loam and clay.

c The decrease of range with depth is more rapid in light soils than heavy soils when they are dry but slower when they are wet.

d Soils with rough surface absorbs more solar radiation than one with a smooth surface.

3. Tillage and tilth

a By loosening the top soil and creating a mulch, tillage reduces the heat flow between the surface and subsoil.

b Since, the soil mulch has a greater exposed.

c Surface than the undisturbed soil and no capillary connection with moist layers below, the cultivated soil dries up quickly by evaporation, but the moisture in the subsoil underneath the dry mulch is conserved.

d The diurnal temperature wave of the cultivated soil has a much larger amplitude than that of uncultivated.

e The air 2-3 cm above the tilled soil is often hotter (10^oC or above) than that over an untilled soil.

f At night loosened ground is colder and more liable to frost than the uncultivated soil.

4. Organic matter

a The addition of organic matter to a soil reduces the heat capacity and thermal conductivity. But, the water holding capacity increases

b The absorptivity of the soil increases because of the dark colour of the organic matter.

c At night, the rapid flow of heat from sub soil by radiation is reduced with the addition of organic matter because of its low thermal conductivity.

d The darker the colour, the smaller the fraction of reflected the incoming radiation.

e Dark soils and moist soils reflect less than light coloured and dry soils.

5. Soil moisture

a Moisture has an effect on heat capacity and heat conductivity.

b Moisture at the soil surface cools the soil through evaporation.

c Therefore, a moist soil will not heat up as much as a dry one.

d Moist soil is more uniform in temperature throughout its depth as it is a better conductor of heat than dry soil.

LECTURE NO – 22

DEFINITIONS OF ATMOSPHERIC PRESSURE - CYCLONES AND ANTICYCLONES - BASIC PRESSURE PATTERNS – WIND - EFFECTS OF WIND ON CROPS - MOUNTAIN AND VALLEY WINDS - LAND AND SEA BREEZES

PRESSURE

Pressure

Technically pressure is defined as "Force per unit area".

Atmospheric pressure

Atmospheric pressure is defined as "The pressure exerted by a column of air with a cross sectional area of a given unit i.e., a square inch or a square centimeter extending from the earth surface to the upper most boundary of the atmosphere".

Standard atmospheric pressure

The atmospheric pressure varies continuously over a relatively small range and the average of these fluctuations is very close to a value adopted for certain standard conditions defined as "Standard atmosphere". At a temperature of 15^{o}C and at 45^{o} latitude the standard normal pressure is *1013.2 millibars which is equivalent to 29.92 inches (or) 760 mm of mircury at the sea level, which is considered as standard atmospheric pressure.

Basic atmospheric pressure patterns

These are various smaller pressure systems closely identified with daily weather changes. These are seen on daily weather maps.

1. Low pressure systems or cyclones

- ♦ When the isobars are circular or elliptical in shape, and the pressure is lowest at the centre, such a pressure system is called "low" or "depression" or "cyclone".
- ♦ A line of low pressure is called a "Trough" when the isobars are not joined at the ends.
- ♦ The word "cyclone" is derived from a Greek word "cyclos" meaning the coils of a snake.
- ♦ In India cyclones occur during the monsoon seasons especially in north-east monsoon.
- ♦ The gales accompanying a cyclone give rise to confused seas, torrential rains and usually approach the coast at 300 to 500 kilometers per hour.

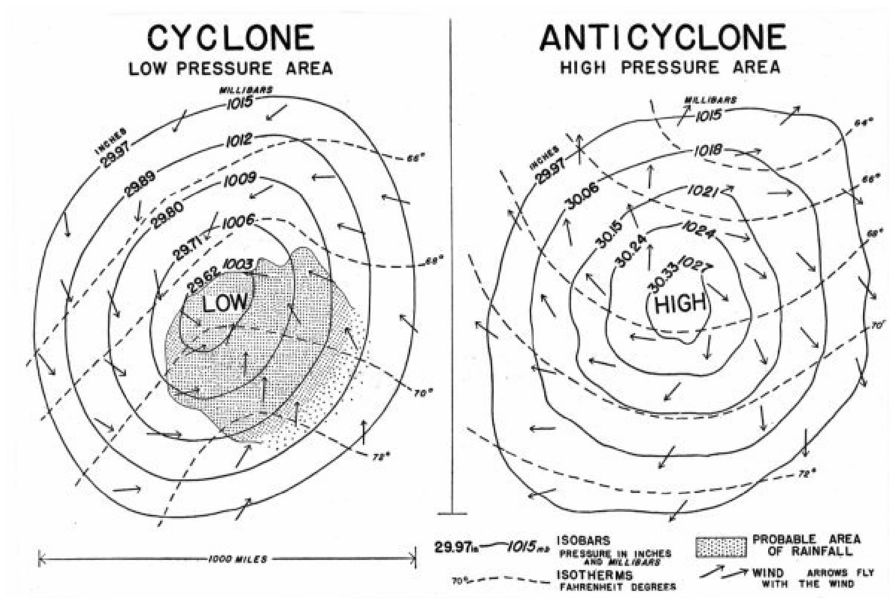

Fig:22.1 Cyclone and Anticyclone

A single severe cyclone can perish hundreds of human lives, animal populations, and submerge thousands of hectares of standing crop.

- The diameter of a cyclone ranges from a few hundreds to 2000 kilometers.
- Floods are the results of the cyclones.
- The devastation could be attributed to the absence of – Timely warning – Lack of awareness among the people – Inadequate preparedness – Poor response and participation.
- Cyclones are recurring feature in India.

2. High pressure systems or anticyclones

When isobars are circular, elliptical in shape and the pressure is highest at the centre such a pressure system is called “High” or “Anticyclone”. When the isobars are elliptical rather than circular the system is called as a “Ridge” or “Wedge”.

Table: 22.1. Differences between cyclones and anticyclones

S. No.	Cyclones	Anticyclones
1.	Lowest pressure at the centre and it increases towards the outer rim gradually.	Highest pressure at the centre and it decreases towards the outer rim gradually.
2.	Relative humidity increases towards centre and bring cloudy weather.	Relative humidity decreases and clouds are dissipated giving fair weather.
3.	Variety of clouds lies at different heights.	Little clouds with cool dry air are usually associated.
4.	Highest rainfall occurs at the front side.	Rainfall is almost negligible.
5.	Wind velocity increases from outer rim to the centre.	Wind velocities ask much lesser than cyclones (Wind spirally rushes outward from the centre to periphere).
6.	Move in anticlock wise in northern hemisphere and clock wise in southern hemisphere	Move in clock wise in northern hemisphere and anti clock wise in southern hemisphere.

WIND

Air in horizontal motion is known as “Wind”. Winds are named by the direction they come from. Windward refers to the direction a wind comes from and leeward is the direction towards which it flows. The wind which flows more frequently from one direction than any other is called as “Prevailing wind”.

Importance of wind crop plants

1 Transports heat in either sensible or latent form, from lower to higher latitudes,
2 Provides the moisture (to the land masses) which is necessary for precipitation
3 Moderate turbulence promotes the consumption of carbon – dioxide by photosynthesis.
4 Wind prevents frost by disrupting a temperature inversion
5 Wind dispersal of pollen and seeds is natural and necessary for certain agricultural crops, natural vegetation, etc.
6 Action of wind on soil

   Wind causes soil erosion in two ways

   a Strong wind flows loose and course soil particles (sand) and dust for long distances. In some areas all the soil is blown by this way, and no cultivation is possible in such areas.
   b In dry countries and sea shores, strong wind is seen to eat up a cliff or a hard rock. When strong wind armed with millions of small particles of sand flows against a cliff or a hard rock, it gradually eats it up. The action is strongest near the ground so that the rock is undercut and eventually falls over.

Mountain and valley winds

1 The daily up-valley winds and nightly down-valley winds are commonly found in mountainous regions.
2 During day time the slopes of mountains heat up rapidly because of intensive insolation.
3 But, the free atmosphere at the same elevation over the low lands is not heated to the same extent.
4 This results in warm air moving up along the slope. This up slope breeze is called as the "Valley breeze" or "Valley winds".
5 However, at night the temperature difference between mountain slopes and free atmosphere at the same elevation is reversed.
6 Nocturnal radiation brings about a more rapid cooling of mountain slopes as a result of which the cool air drains into the valley below.
7 This, down-slope wind is called the "Mountain breeze" or "Mountain wind".

Table: 22.2. Differences between mountain and valley winds

S. No.	Mountain winds	Valley winds
1	Blows from mountain up slope to base.	Blows from valley base to up slope.
2	Occur during night time.	Occur during day time.
3	Cooling of air close to slope takes place.	Over heating of air adjacent to slope takes place.
4	Adiabatic heating decreases this phenomenon.	Adiabatic cooling decreases this phenomenon.
5	Also known as "Katabalic winds".	Also known as "Anabatic winds".

Land and sea breezes

1 These winds are defined as "The complete cycle of diurnal local winds occurring on sea coasts due to differences in surface temperature of land and sea".

2 There is a complete diurnal reversal of wind direction of these coastal winds.

3 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 (monsoon by seasonal variation).

5 During the day time, more so in summer land is heated more than the adjacent body of water.

6 As a result, warmed air over the land expands producing an area of low pressure.

7 The cooler air over the water starts moving across the coast line from sea to land. This is the "Sea breeze" or "On shore breeze".

8 However, at night because of nocturnal radiation, land is colder than adjacent sea and the pressure gradient is directed from land to sea. There is a gentle flow from land to sea. This "Off-shore" wind is called "Land breeze".

Table: 22.3. Differences between land and sea breezes

S. No.	Land breeze	Sea breeze
1	Occurs in night time.	Occurs in day time.
2	Flows from land.	Flows from sea.
3	Do not have more moisture than sea breeze.	Have more moisture than land breeze.
4	Occurrence depends on topography of land to little extent.	Occurrence depends on topography of coast to a greater extent.
5	Produces cooler winters and warmer summers.	Modifies weather on hot summer afternoons.
6	Weaker than the sea breeze.	Stronger than land breeze.

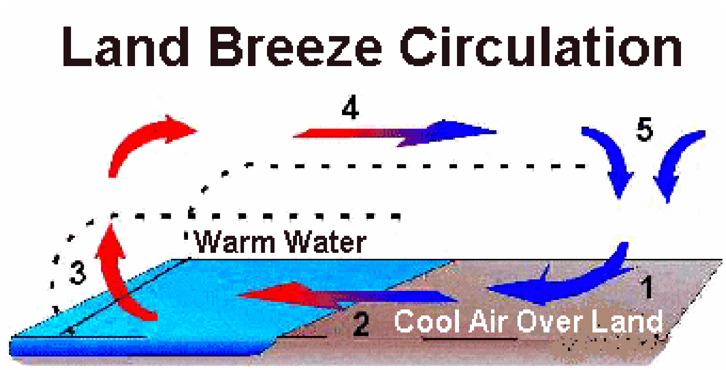

Fig: 22.2 Land Breeze Circulation

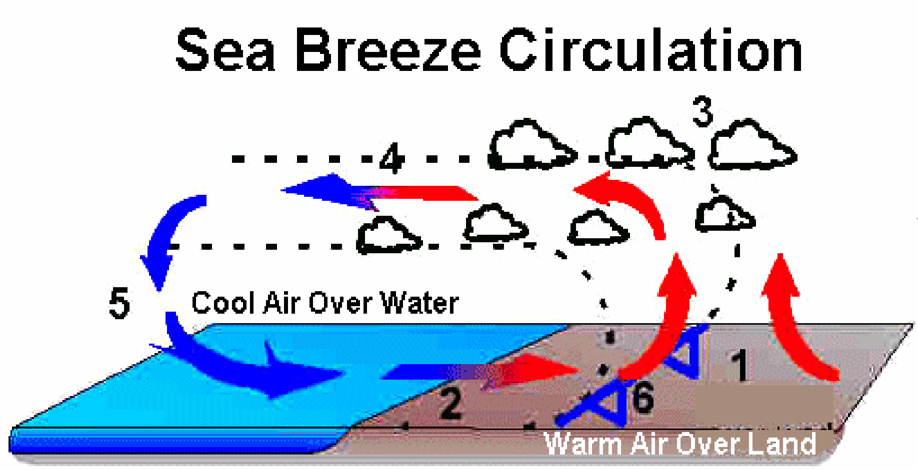

Fig:22.3 Sea Breeze Circulation

LECTURE NO – 23

ATMOSPHERIC HUMIDITY AND ITS EXPRESSION – SATURATION - EFFECTS OF HUMIDITY ON CROPS

HUMIDITY

Expression or Measures of humidity

A. Mass and volume based measures

Specific humidity

It is defined as the ratio of the mass of water vapour in a sample of moist air to the total mass of the sample. It is expressed as kg of water vapour in a kg of moist air.

Absolute humidity

It is the ratio of the mass of water vapour to the volume of moist air in which it is contained. Absolute humidity is expressed as kg m^{-1}.

Mixing ratio

It is the ratio of the mass of water vapour contained in a simple of moist air to the mass of dry air. It is expressed as kg water vapour per kg dry air.

B. Saturation based measure

Relative humidity

It is expressed as the ratio of actual vapour pressure to the saturated pressure expressed in terms of percentage. It is most common measure of atmospheric humidity.

Vapour pressure deficit

It is another measure of moisture in the atmosphere. It is the difference between the saturated vapour pressure and actual vapour pressure.

Dew point

It is defined as the temperature to which a given parcel of air must be cooled at constant pressure and constant water vapour content in order to become saturationed.

Effects of humidity on crops

Humidity is an important factor in crop production and it is not an independent factor but closely related to rainfall and temperature. It plays significant role in weather and climate. The dampness of air is called humidity.

a. Humidity is the invisible vapour content of the air and is of great importance in determining the vegetation of a region.

b. it affects the internal water potential of plants.

c. Humidity is a major determinant of potential evapotranspiration. So, it determines the water requirement of crops.

d. It influences certain physiological phenomena including transpiration.

e. Change in relative humidity can produce various morphological and anatomical changes in the plants. For example, orchids grow abundantly in humid forests as epiphytes depend for their moisture supply on the atmosphere by developing certain morphological and anatomical characteristics that are not found in other plants (hydroscopic aerial roots).

f. Xerophytes in desert region where relative humidity is low show certain adaptations to conserve water.

g. High relative humidity can prolong the survival of crops under moisture stress.

h. Relative humidity plays a significant role in the outbreak of disease and pest epidermics. High humidity promoters the growth of some saprophytic and parasitic fungi and bacteria which cause various plant diseases.

i. Very high or very low relative humidity is not conductive for higher yields.

LECTURE NO – 24

EVAPORATION AND TRANSPIRATION – DEFINITIONS - FACTORS AFFECTING RATE OF EVAPORATION AND TRANSPIRATION

Evaporation

The sun is the source of energy that activates the hydrologic cycle i.e. the heat required for evaporation is supplied by the sun. The moisture in the atmosphere is supplied by evaporation.

Evaporation is defined as "A physical process in which liquid water is converted into its vapour".

In this process molecules of water having sufficient kinetic energy to overcome the attractive forces tending to hold them within the body of liquid water are projected through the water surfaces.

Factors affecting the evaporation

Evaporation losses from a fully exposed water surface are essentially the functions of several factors.

I Environmental factors

1 Water temperature: With an increase of temperature the kinetic energy, of water molecules increases and surface tension decreases. So, the rate of evaporation increases with a rise in temperature. The maximum amount of water vapour that can exist in any given space is a function of temperature.

2. Wind*:* The velocity of wind is directly proportional to evaporation from a fully exposed surface and vice versa. The reason is that the dry wind replaces the moist air near the water. The process of evaporation takes place continuously when there is a supply of energy to provide latent heat of evaporation (approximately 540 calories per gram of water evaporated at $100^{o}C$).

3 Relative humidity: A mechanism to remove the vapour so that the vapour pressure of the water vapour in the moist layer adjacent to the liquid surface is less than the saturated vapour pressure of the liquid i.e., a vertical gradient of vapour pressure exists above the surface.

When the air above water is dry or has low relative humidity, the evaporation will be greater than when air has high relative humidity over the water.

4 Pressure: The evaporation is more at low pressure and vice versa.

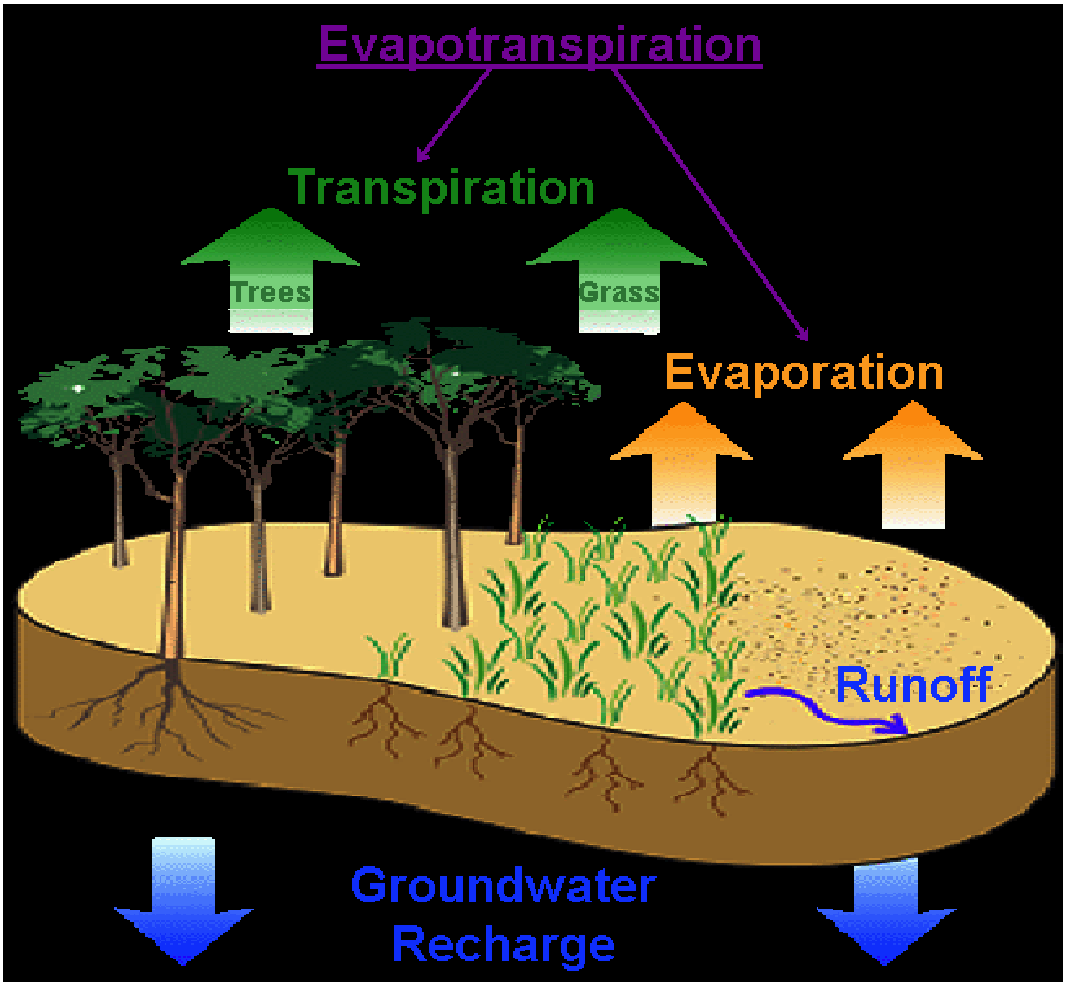

Fig:24.1 Evapotranspiration

II Water factors

1. Composition of water

The dissolved salts and other impurities decreases the rate of evaporation. Evaporation is inversely proportional to the salinity of water. The rate of evaporation from the surface of the sea is less than that of fresh water in rivers. Under equivalent conditions ocean water evaporates 5 per cent less than fresh water in rivers.

2. Area of evaporation

If two volumes of water are equal in two containers, evaporation will be greater for the one having the larger exposed surface.

Transpiration

Transpiration is defined as "The loss of water from living parts of the plant". There are 3 kinds of transpiration.

Factors affecting the transpiration

I Environmental Factors

1 **Light**: Light plays predominant role in transpiration both directly and indirectly. The direct effect of light is on the opening and closing of stomata. Bright light is the main stimulus which causes stomata to open. It is because of this reason that all plants show a daily periodicity of transpiration rate. The indirect effect of light is that the increasing light intensity raises the temperature of leaf cells. This increases the rate at which liquid water is transformed into vapour.

2 **Atmosphere humidity**: The rate of transpiration is almost inversely proportional to atmospheric humidity. The rate of transpiration is greatly reduced when the atmosphere is very humid. However, as the air becomes dry, the rate of transpiration also increases proportionately. These effects occur in accordance with the low of simple diffusion.

3 **Air temperature**: Increase in the temperature results in opening of stomata. Temperature has significant effect on the permeability of the wall of the guard cells and therefore greatly effects the osmatic phenomenon. This phenomenon is responsible for the movement of guard cells.

4 **Wind velocity**: The velocity of wind affects the rate of transpiration to a greater extent. Fast moving wind and air currents bring fresh and dry masses of air in contact with leaf surfaces. So, higher the wind speed higher the transpiration.

II Plant Factors

Some plants adopt physiological modifications to check the excess transpiration. Some other plants modify their structure for this purpose, thereby withstand drought. Such characters greatly effect the transpiration.

1 **Plant height:** The water need of a crop varies with its height. In general, the rate of transpiration of a tall crop will be more (around 50 %) than when the crop is cut or clipped to half.

2 **Leaf characteristics:** In some plants like *cacti* and other desert plants leaves are altogether absent and their function taken up by the stem itself. In case of *Pines, Firs* etc., the leaf size is very much reduced. In such cases reduction in leaf area brings about reduction in transpiration. Some graminaceae family plants (maize), flower plants, etc., roll up or turn the edges of their leaves when exposed to bright sun and fast breeze. This causes reduction in the transpiration.

3 **Availability of water to the plant*:*** If there is little water in the soil, the tendency for dehydration of leaf causes stomatal closure and a consequent fall in transpiration. This situation occurs during a) periods of drought b) when the soil is frozen and c) at a temperature so low that water is not absorbed by roots.

LECTURE-25

RAINFALL - IMPORTANCE OF RAINFALL (WATER) ON CROPS -TYPES OF RAINFALL - MONSOON DEFINITION - ORIGIN AND DISTRIBUTION OF SOUTHWEST MOONSOON

Importance of rainfall (water) on crop plants

One centimetre of rain over an area of one hectare or 100 m^3 (100,000 litres) contains 4,339 grams of oxygen at 20^{o}C. This is equivalent to 3,000 litres of pure oxygen at atmospheric pressure. Consequently, a rain usually has a much more invigorating effect on a crop than does irrigation. Rain water has extraordinary qualities.

1 Water has high solvent power and this plays an important role in crop plants as the plants get their nourishment from soil only in solution form.

2 Water plays an important role in life processes of crop plants (in the exchange of gases).

3 The heat capacity of water is high and its high thermal stability helps in regulation of the temperature of crop plants.

4 Water has highest heat conduction capacity and due to this the heat produced by the activity of a cell is conducted immediately by water and distributed evenly to all plant parts.

5 The viscosity of water is higher than that of many solvents and this property helps in protecting the crop plants and trees against mechanical disturbances.

6 Water is driest at 4^{o}C. The freezing point of fresh water being 0^{o}C and that of sea water about – 2.5^{o}C, the ice can float on the surface and plant life in deeper parts of sea is made possible.

7 The transparency of water facilitates the passage of light to great depths and this helps for the survival of aquatic plants.

8 The high surface tension that water has helps in movement of water into and through the plant parts.

9 Rainfall influences the distribution of crop plants in particular and vegetation in general, as the nature of vegetation of a particular place depends on the amount of rainfall (the vegetation of a desert where rainfall is less differs a lot from the vegetation of a rainforest).

Types of rainfall

There are mainly 3 types of rainfall which are as follows:

1. Convectional rains

1 The air near the ground becomes hot and light due to heating. Then it starts upward movement. This process is known as convection (This differs slightly from `Convection' defined in Chapter (2).

2 As the air moves upward it cools at about 10^{o}C per kelometer i.e., at dry adiabatic lapse rate.

3 As it becomes saturated, relative humidity reaches to 100 per cent and dew point is reached where the condensation begins. This level (height) is known as condensation level.

4 Above this level, air cools at about 4^{o}C per kilometre slightly less than i.e., saturated adiabatic lapse rate. First, cloud is formed.

5 Then, the further condensation results into precipitation. These rains are known as convectional rains and mostly occurs in the tropics.

2. Orographic rains

1 When moist air coming from the sea or ocean strikes mountain it can not move horizontally. It has to over come the mountations.

2 When this air rises upward, cools down, cloud is formed and condensation starts giving precipitation.

3 These rains are known as orographic rains.

4 These are also known as `relief rains" as the rains also occurs when the air from sea or ocean strike or pass over relief barriers.

5 Due to these processes rains with high intensity are possible on the windward side of the mountain.

3. Cyclonic and frontal rains

1 The rains received from cyclones are known as `cyclonic rains' (Chapter 6).

2 When two opposing air currents with different temperatures meet, vertical lifting takes place.

3 This convection gives rise to condensation and precipitation which is known as frontal precipitation.

The size of the rain drop reaching the ground depends upon the following points.

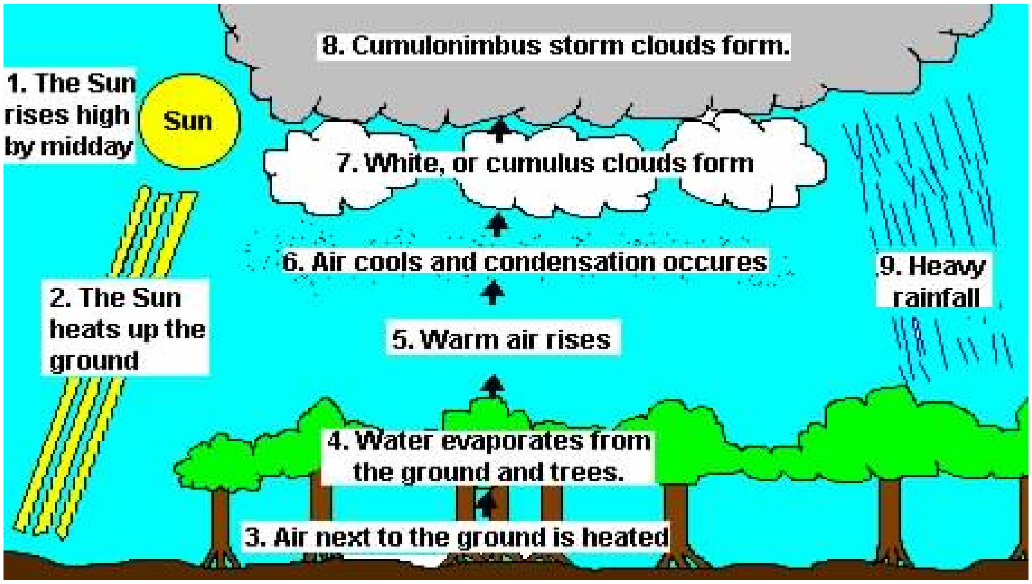

Fig:25.1 CONVECTIONAL RAIN FALL

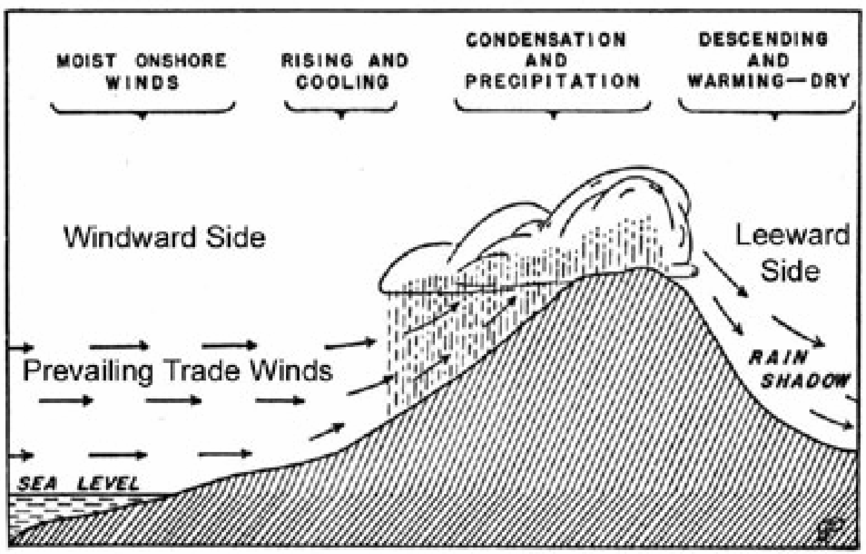

Fig:25.2 OROGRAPHIC RAINFALL

Monsoons

The term monsoon is derived from an Arabic word "Mausim" means "Season". There are different concepts to explain Indian monsoons. Of them the "Thermal concept" proposed by Halley in 1636 is of more practical relevance than other concepts like aerological, Flohins etc. The two types of distinguished monsoons over India are

a. South-West monsoon (SW), 2. North-East monsoon (NE)

1. South-West monsoon (SW)

1 In summer the land mass of India heats quickly and develops a strong low pressure centre, particularly over north-west India during April and it exists upto September.

2 As the pressure over the adjacent oceans is high, a sea to land pressure gradient is established.

3 Therefore, the surface air flow is from the high pressure areas over the oceans towards the low pressure areas over the heated land.

4 Eventhough India should have North east monsoon winds throughout the year due to its position in NE trade wind zone the SW winds predominate because of the low pressure through lesing along Ganges and upper India.

5 The air that is attracted into the centres of low pressure from over the oceans is "Warm and moist".

6 This monsoon is active from June to September.

7 The rainfall received is 80 to 90 per cent of the total annual rainfall of India covering all parts.

8 This monsoon enters Kerala on June and by 15 July reaches the northern most parts of the country (Fig...).

9 There are two branches of the South West Monsoon.

a. The Arabian Sea branch: This branch crosses Western ghats.

b. The Bay of Bengal branch: This branch crosses Gangetic plains.

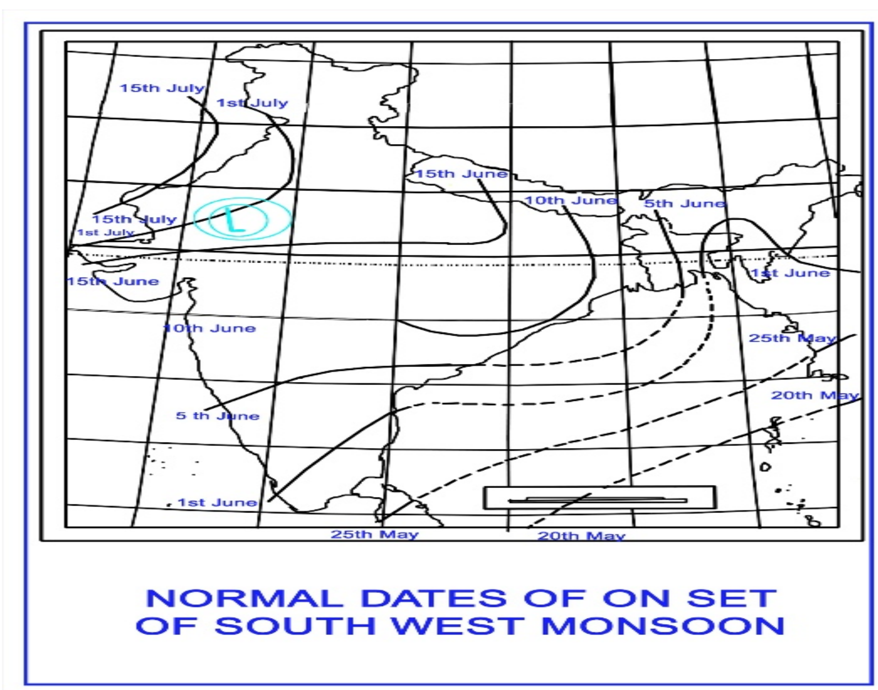

Fig:25.3 Onset of SW- Monsoon

LECTURE - 26

ORIGIN AND DISTRIBUTION OF NORTH-EAST MONSOON –ECONOMIC IMPORTANCE AND INFLUENCE OF MONSOON RAINS ON FARM OPERATIONS

North-East monsoon

1. A complete reversal of the South west monsoon winds takes place during winter.
2. In this season the land mass over India cools more rapidly than the surrounding oceans.
3. So, a strong high pressure centre develops over the continent.
4. On the other hand, the pressure over the adjacent oceans is relatively lower.
5. As a consequence, the pressure gradient is directed from land to sea and winds flow in North-East direction.
6. Therefore, there is an outflow of air from the continental land mass to the adjacent oceans.
7. The air flow brings "Cold dry" air towards low latitudes.
8. This monsoon is active from October to mid December.
9. The rainfall received is 10 to 20 per cent of the total annual rainfall of India covering parts of Andhra Pradesh (Nellore, Chittoor) and Tamil Nadu.
10. The driving mechanisms of monsoon
    - Differential heating of land and ocean masses causes a pressure gradient and wind is driven accordingly.
    - Jwist to wind by rotation of earth.
    - Moist process determines strength, vigour, location etc.
11. The path of monsoon air is distributed by diverse features like
    - Earth's rotation
    - Mountain barriers

- The retarding effect of friction as winds blow over land.

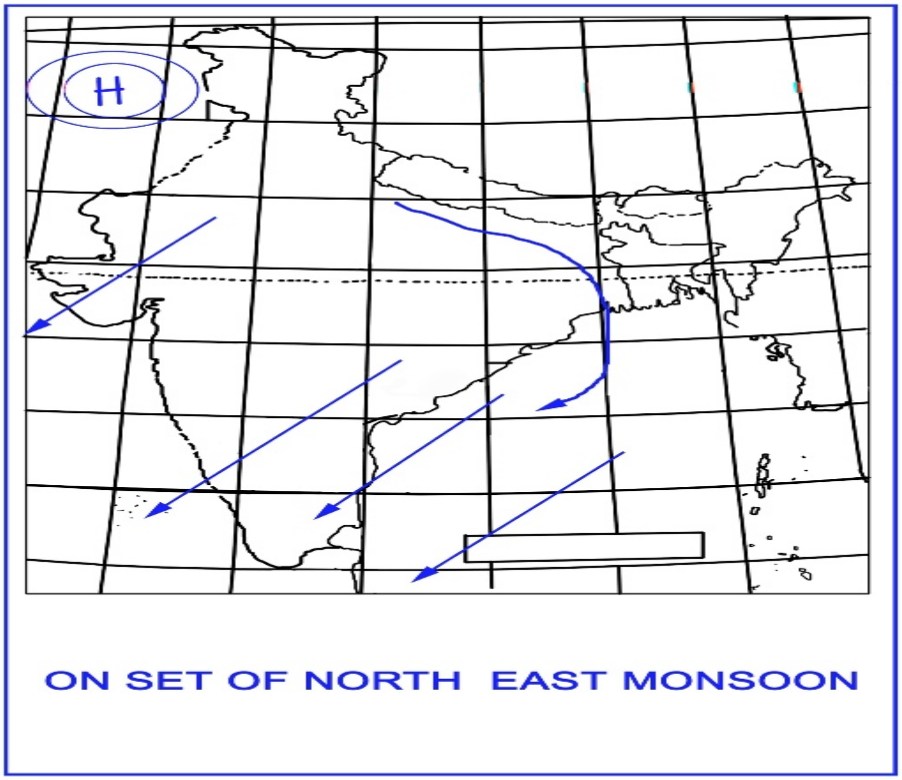

Fig: 26.1 Onset of NE-Monsoon

Withdrawn of monsoon

1. **The monsoon withdraws** from northern India around mid September.
2. **The monsoon withdraws** from extreme South of Indian Peninsula by December.

Break and Active in monsoon

1 A period of lean rainfall occurs when "Trough" shifts towards foot hills of Himalayas which is known as break in the monsoon over Indian sub-continent.

2 When the "Trough" shifts south of its normal position, monsoon becomes active over India.

Economic importance and influence of monsoon rains on farm operations

1 Nearly 54 per cent of population of the world depends on monsoon for their income.

2 Monsoon rains are considered as life giving rains. Rice or paddy which is a major food crop depends on only rainfall for its yield. If rainfall is not uniformly distributed, it results in huge loss of rice crop in particular and all other crops in general.

3 Heavy rain during harvesting causes lodging of crop and seed germination. If rainfall does not occur immediately after sowing, it results in germination failure.

4 As in the case of other weather elements the amount and distribution of rainfall influence the crop yield considerably.

Example: Paddy and sugarcane require high amount of water as compared to groundnut and castor.

1 Timely and evenly distributed rainfall during the crop growth is more beneficial than heavy rainfall occurring at once.

2 Rainfall of 20 mm is necessary to wet the soil upto a depth of 15 cm which rainfall helps in decomposition of organic matter and also influences the fertility status of the soil by way of leaching of nutrients.

3 Many farm operations such as seed bed preparation, sowing, intercultivation etc. depend on rainfall.

LECTURE - 27

CLOUDS - CLOUD FORMATION – CLOUD CLASSIFICATION AND CHARACTISTICS -WORLD METEOROLOGICAL ORGANISATION (WMO)

Clouds

Definition

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

Cloud formation

1 When air rises due to increase in temperature the pressure being less it expands and cools until temperature is equalised. If the cooling proceeds further till the saturation point, the water vapour condenses and cloud is formed.

2 Clouds are also formed

- When a current of warm air strikes the one that is cooler.
- When moist air from sea blows over a cold land.

Basic types of clouds

Cirrus (Ci): Cirrus means `curl' which is recognised by its veil like fibrous or feathery form. This is the highest type of cloud, ranging from approximately 7 to 12 kilometers (20-35 thousand feet) in altitude, in tropics and sub-tropics.

Cumulus (Cu): Cumulus means heap or globular mass. This cloud is wooly and bunchy with rounded top and flat base. This is seen in summer months as it is formed due to convection. The height varies depending upon humidity of the atmospheric air.

Stratus (St): This cloud looks like a sheet. This is lowest in height from the ground.

Nimbus (Nb): This looks dark and ragged. Precipitation occurs from this cloud as the prefix "nimbus" means associated with precipitation and `alto' means above normal height. Combination of different primary clouds is referred with these clouds.

WMO cloud classification

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

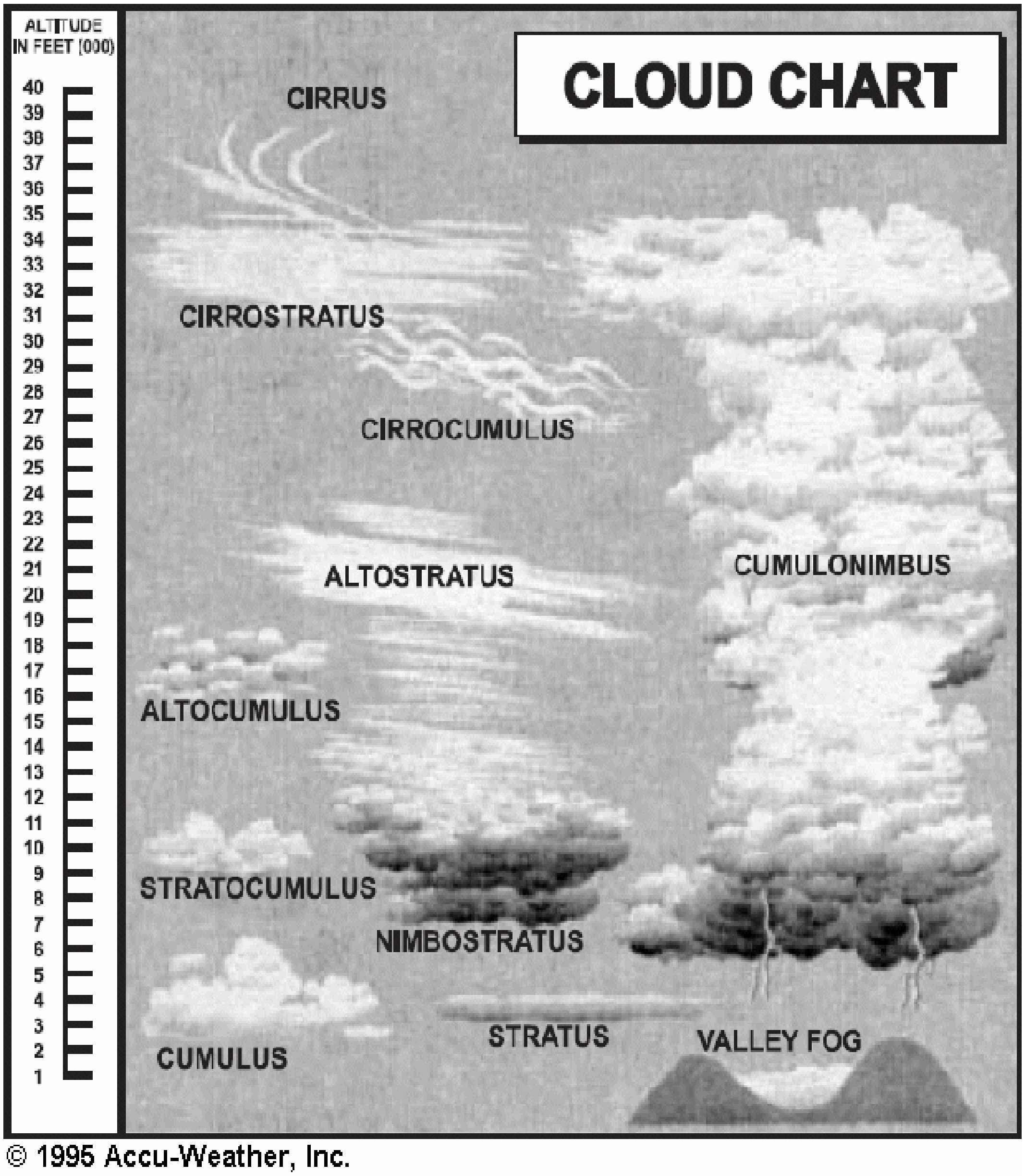

Fig: 27.1 Cloud Classification

Family A The clouds in this category are high. The mean lower level is 7 kilometers and the mean upper level is 12 kilometers in tropics and sub-tropics. In this family there are 3 sub-categories.

(1) Cirrus (Ci)

- In these clouds ice crystals are present.
- Looks like wispy and feathery. Delicate, desist, white fibrous, silky appearance.
- Suns rays pass through these clouds and sunshines without shadow.
- Does not produce precipitation

2) Cirrocumulus (Cc)

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

3) Cirrostratus (Cs)

- Like the above two clouds ice crystals are present in these clouds also
- Looks like whitish veil and covers the entire sky with milky white appearance.
- Produces “halo”

Family `B’ The clouds in this category are middle clouds. The mean lower level is 3 kilometers and the mean upper level is 7 kilometers in tropics and sub-tropics. In this family there are 2 sub categories as detailed below :

1) Altocumulus (Ac)

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

2) Alto-stratus (As)

- In these clouds water and ice are present separately.
- Looks like fibrous veil or sheet and grey or bluish in colour.
- Produces coronos and cast shadows.
- Rain occurs in middle and high latitudes

Family `C' The clouds in this category are lower clouds. The height of these clouds extends from ground to upper level of 3 kilometers in tropics and sub-tropics. In this family like high clouds there are 3 sub-categorises as stated below:

1. Strato cumulus (Sc)

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

2) Stratus (St)

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

3) Nimbostratus (Ns)

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

Family `D': These are the clouds formed due to vertical development i.e., due to convection. The mean low level is 0.5 and means upper level goes upto 16 kilometers.

In this family two sub-categories are present as stated below.

1) Cumulus (Cu)

- These clouds are composed of water with white majestic appearance with flat base.
- Irregualr dome shaped and looks like Cauliflower with wool pack and dark appearance below due to shadow.
- These clouds usually develop into cumulo-nimbus clouds with flat base.

2) Cumulonimbus (Cb)

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

LECTURE - 28

DROUGHT – DEFINITION -TYPES OF DROUGHT - EFFECT OF DROUGHT ON CROPS - MANAGEMENT OF DROUGHT

Drought

1 **Drought is explained by the following ways**.

a. The condition under which crops fail to mature because of insufficient supply of water through rains.

b. The situation in which the amount of water required for transpiration and evaporation by crop plants in a defined area exceeds the amount of available moisture in the soil.

c. A situation of no precipitation in a rainy season for more than 15 days continuously.

2 **The other causes contributing to the drought condition are:**

a. Defective tillage of soil.

b. Failure to store rain water.

c. Lack of technology with the user to retain the soil moisture.

d. High seed rate and thick plant population.

3 **The effects of drought are:**

a. Depletion of soil moisture and reduction in ground water table.

b. Reduction of output and turnover in industry, agriculture and thereby total economy of the nation.

Classification of Drought

Droughts are broadly divided into 3 categories.

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

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

Agricultural drought: This is a situation which is a result of inadequate rainfall. Because of this, the soil moisture falls short to meet the demands of the crop during its growth. Since the soil moisture available to a crop is insufficient, it affects growth and finally results in the reduction of yield.

Some scientists consider the above classification only as a part of the total classification. The classification based on `medium' and also `temporal' are in vogue, in addition to the information mentioned above.

Droughts and their Influence on Crop Plants

The influence of drought can be observed not only on phenology but also on phenophases of crop plants.

1 From seedling to ripening stage the water influence the crops particularly in case of cereals after the leaves are emerged from coleoptile. The influence of drought is more pronounced at the time of maturity.

2 During flowering stage, any little stress of moisture by virtue of drought substantially reduces the size of inflorescence thereby affecting the final yield.

3 In the same way fertilization and grain filling are also markedly influenced and the final yield is substantially reduced.

4 When soil moisture stress increases, it limits water supply to all the plant parts, which result in wilting.

5 If drought occurs at the time of grain filling, it results in the decrease of yield considerably.

6 Cell division and enlargement are very sensitive to drought stress. During moisture drought stress cell enlargement is affected and is the primary cause of stunted growth plant is under field conditions.

7 Drought also affects nutrient absorption, carbohydrate and protein metabolism and translocation of ions and metabolites.

8 Protein breakdown injures the drought stressed plant due to the accumulation of toxic products of protein breakdown such as ammonia, rather than due to a protein deficiency.

9 Abscission of leaves, fruits and seeds can be induced by plant water deficit during droughts.

10 Plant respiration is drastically reduced.

Drought Control and Management Practices at the Time of Drought

1 Modification of microclimate by use of shelter-belts and artificial barriers to reduce evapotranspiration and wind movement.

2 Maintaining optimum plant population.

3 Best possible seed-bed preparation to hold and absorb maximum moisture and better weed management.

4 Tillage practices to minimise runoff and evapotranspiration.

5 Crops that evade or endure periods of drought shall be sown.

6 Drought tolerant crops for which row spacing can be increased without affecting the final yield can be identified and practiced.

7 The dates of sowing shall be adjusted such that the reproductive stage of the crop shall not pass through the drought, in addition to other stages for critical crop growth.

8 Effective control of pests and diseases and use of recommended doses of fertilizers.

9 Correcting nutrient deficiencies and use of recommended doses of fertilizers.

10 Application of antitranspirants and use of mulches will reduce evapotranspiration.

11 Application of irrigation at appropriate stages of crop growth.

12 Weed control by keeping the land fallow has an added effect in conserving the moisture.

13 Ploughing of range lands with heavy disks or similar equipment to make a more rapid and complete infiltration.

14 Shaping of land so that the water stays where it falls or runoff from a slope to irrigate a level bench below the slope.

LECTURE - 29

PRECIPITATION AND CONDENSATION – DEFINITION - DIFFERENT FORMS OF PRECIPITATION AND CONDENSATIONS - CLOUD SEEDING (ARTICIFICIAL RAIN MAKING)

Precipitation

For general use the terms precipitation and rainfall are used as synonyms with each other. Precipitation is defined as "Earthward falling of water drops 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 vapour is suspended in the air in different forms. But, in the precipitation an appreciable deposit either in solid or liquid form takes place on the earth surface. There are some common forms and different types in precipitation.

Table: 29.1. Different forms and types of precipitation

S. No.	Form	Type
1	Liquid	Rain, Drizzle, Shower
2	Solid	Snow, Hail
3	Mixed	Sleet, Glaze

I Liquid forms

1 Rain: It is defined as "Precipitation of drops of liquid water". The cloud consists of minute droplets of water and when these droplets combine and form large drops and can not remain suspended in the air they fall down as rain. These droplets are formed by rapid condensation. The size of rain drop is more than 0.5 mm in diameter. The imaginary lines drown on a map connecting the points of equal rainfall are known as "Isohytes".

2 Drizzle: It is more or less uniform precipitation of very small and minute rain drops. These drops can be carried away even by light winds. The diameter of drizzle drop less than 0.5 mm. It falls from low lying nimbostratus cloud. Fog merges to form drizzle.

3 Shower: It is the precipitation lasting for a short time with relatively clear intervals.

II Solid forms

1 Snow: It is defined as "Precipitation of water in solid form of small or large ice crystals". It occurs only when the condensing medium has a temperature well below

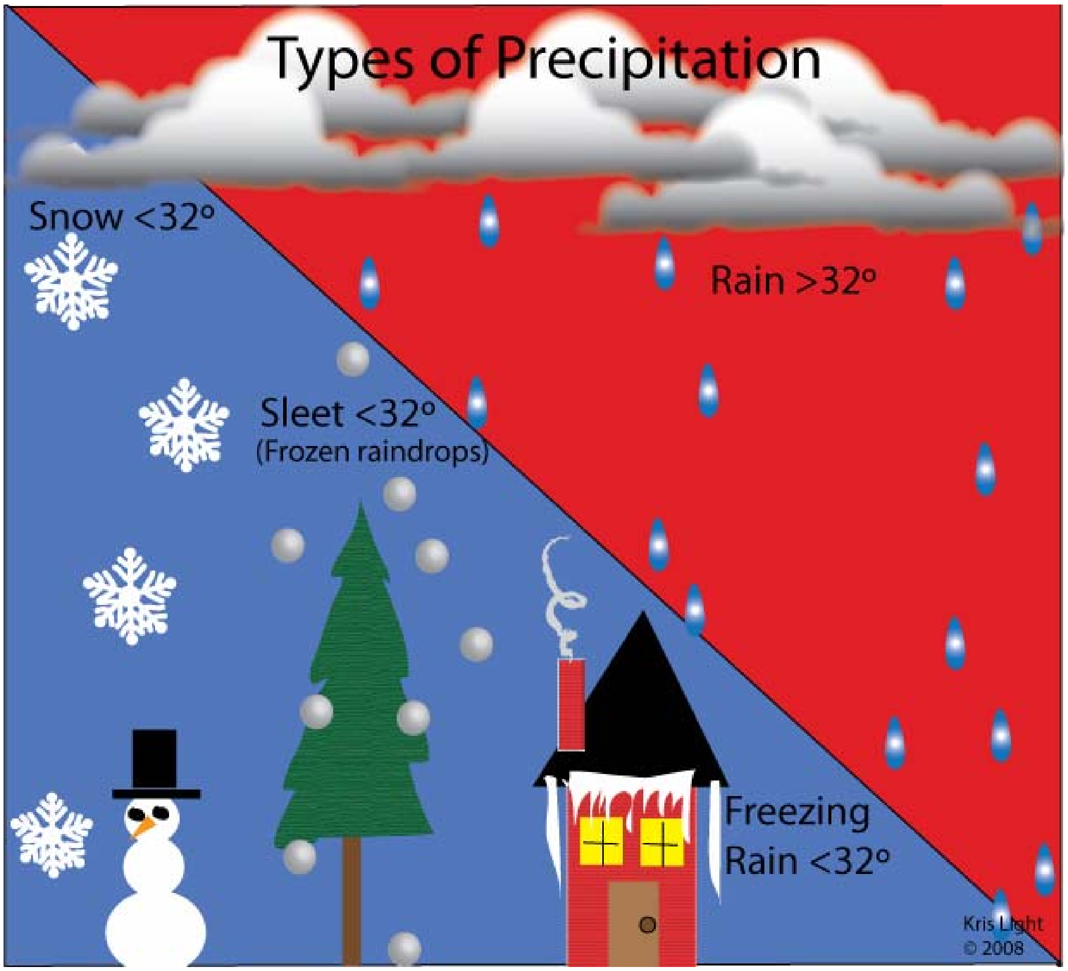

Fig: 29.1 Different Forms of Precipitation freezing (O^{O}C) temperature. It is also seen in the form of flakes which are aggregates of many crystals, formed due to sublimation of water vapour at sub-freezing temperatures.

2 Hail: It is a precipitation of solid ice. A strong convective column on a warm sunny day may cause the formation of pellets of spherical shape with concentric layers of ice, which is known as hail. Hail falls from cumulo-nimbus clouds and is often associated with thunder and storm. The size of hail ranges from peanut to cricket ball. The rainfall associated with the hailstorms is called as "Hail Storm".

III Mixed

1 Sleet: It is the simultaneous precipitation of the mixture of rain and snow. Occasionally half frozen drops also fall, as sleet forms when rain drops are frozen as they fall through a layer of cold air.

2 Glaze: Freezing rain is known as glaze. This is formed at sub freezing temperatures when rain falls on objects or on ground. It looks like a sheet or coat.

Condensation

- Condensation is defined as "The process in which the water vapour is converted into its liquid".
- This process is inverse of evaporation process. In condensation 600 calories of heat is released by each gram of water which was taken in the evaporation process.
- Thus the evaporation of water produces cooling effect and condensation gives warming effect.
- The visible forms of condensed moisture in the atmosphere are known as "Hydrometeors".

Conditions for condensation: The following three conditions must be fulfilled for the condensation occurrence of in the atmosphere.

a) Presence of sufficient water vapour

- An adequate amount of water vapour is necessary to bring about saturation of air.
- Dew point shall be reached through this water vapour to begin condensation.

b) Presence of condensation nuclei

- Sodium chloride injected into the atmosphere by sea-spray; Sulphur dioxide, nitrous oxide etc., released from industries as combustion products; dust present in the atmosphere act as nuclei of condensation.
- Water vapour can only deposit and condense on them as these are hygroscopic in nature (affinity to water).
- As these particles are microscopic or sub-microscopic in size (0.1 to 1 micron) these are called either hygroscopic nuclei or condensation nuclei.
- In the absence of hygroscopic nuclei condensation can not trigger even if air is supersaturated and its temperature being below freezing level.

c) Cooling of air

Cooling of air upto and below dew point is necessary for saturation of atmospheric air with water vapour.

Forms of condensation

Dew

The deposition of water vapour in the form of tiny droplets on the colder bodies by condensation is known as dew.

The temperature at which water vapour condenses is known as dew point temperature.

When the objects on the surface of the earth get cooled in the night below dew temperature the water vapour is condensed on these surfaces.

Dew forms when condensation takes place above freezing point.

These surfaces should be good radiators and bad conductors of heat (Plant leaves; window glasses, pieces of paper etc.

The conditions for the formation of dew are:

a. Clear sky
b. Absence of wind

With particularly favourable conditions, dew deposition may commence before sunset and continued till after sunrise. Deposition trends to be reduced under very calm conditions (wind speed range of 1-3 m/sec). Dew is an important secondary source of moisture for crops during the non-rainy season and plays vital role in plant growth. Dew occurrences benefit the plants in many ways.

Significance of dew

1 The dew deposited on the leaf surface in the morning delays the rise in leaf temperature and thus reduces the rate of evapotranspiration.
2 Dew provides water for direct plant use. The amount of dew deposition varies from 0.25 to 0.40 mm per night in semi-arid tropics (Usually, from September to April dew amounts are measured in these areas).
3 Under suitable conditions, in semi-arid areas, it may exceed even 25-30 mm per annum.

2 Frost

When the temperature of atmospheric air falls below $O^{o}C$ before the dew point 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 injurious to agricultural and horticultural crops.

a Hoar frost

The white and opaque deposition in the form of ice crystals having the shapes of feathers, needles etc.

b Gleazed frost

This is caused by rains which are freezed on falling to the ground. This is transparent.

3. Fog

"Low cloud" near the ground surface. Extremely small water droplets suspended in the atmosphere reducing the horizontal visibility is known as `Fog'. Fog reduces the visibility. The conditions for the formation of fag are

- ♦ Calm wind
- ♦ Atleast upto 75 % relative humidity

Fog is also called as "Cloud on and near the ground". There is no particular form, shape or structure to fog. The following are types of fog.

- **Radiation fog**

This results from rapid loss of night time radiation either from the ground or lower air. This radiation produces cooling.

- **Inversion fog**: This is another type of radiation fog. This results from condensation of water vapour in a mass of warm moist air lying over a layer of cold air and near the ground.

These two fogs occur during night or cold morning. They disappear due to desaturation of air with vapours after the rise of sun in the morning.

- **Advection fog**

This fog occurs when warm moist air rides in over a cold surface of either land or water. These fogs occur at any time of the day.

4 Smog: The combined effect of smoke and fog droplets which reduce visibility is called "Smog". Some solid particles like dust, smoke from fires and industry restricts the visibility further when these are added to smog which is known as `Haze'. On some occassions toxic materials present in fog, smog and haze and these are harmful. All these processes cause difficulty in rail, road, aviation and shipping traffics.

5 Rime: This is "Freezing fog" and is formed when wet fog has super cooled droplets immediately freeze on striking objects having temperatures below freezing point. White ice is formed on windward freezing point (telegraph post).

6 Mist: Mist is less dense fog. The suspended water droplets in the atmosphere in the atmosphere restrict the visibility between 1100 to 2200 yards or number 4 on the coded scale (IMD). The obscurity is known as mist. The relative humidity is 75 per cent when mist occurs. Mist disappears with rising sun.

LECTURE - 30

WEATHER DISASTERS MANAGEMENT – RAINFALL, HEAT AND COLD WAVES, WINDSTORMS, THUNDER STORMS AND DUST STORMS, TORNADOS, DEFECTIVE INSOLATION

Weather Disaster Management

1 Crops depend upon certain optimum weather conditions for their potential production, although other variables such as fertilizers, insecticides., etc interact to certain extent in an agricultural system

2 Daily, seasonal and long term variations in any or all the climatic elements alter the efficiency of plant growth thereby the crop production.

3 The deviation of climatic factors considerably from their normal values is referred as "Adverse weather" or "Adverse climate" depending on duration of such impact.

4 The following are the adverse weather conditions and the possible management strategies.

1. Rainfall

Rainfall is the major source of water which is essential for plant growth and development. However, rainfall is considered under it is a. Excess rainfall b. Scanty rainfall and c Untimely. The total amount of rainfall in a season is not the criteria. But, its well distribution over a large area is desirable. Heavy rains with short frequencies will result in floods. If 125 mm of rain is received in two and half hours it is called as heavy rain.

a Excess rainfall

1 Even though water in all its forms plays a fundamental role in the growth and production of all crops excessive amounts of water in the soil alter various chemical and biophysical processes.

2 Free movement of oxygen is blocked and compounds toxic to the roots are formed, due to drainage problem.

3 Soils with high rate of percolation are unsuitable for cultivation as plant nutrients can be removed rapidly.

4 Heavy rains directly damage plants on impact or interfere with flowering and pollination.

5 Top soil layers are packed or hardened which delays or prevents emergence of tender seedlings.

6 Snow and freezing rain are threats to winter plants. The sheer weight of ice and snow may be sufficient to break limbs on trees and shurbs.

7 A thick ice cover on the ground tends to produce suffocation of crop plants such as winter wheat.

8 Under excess rainfall conditions floods occur. In areas drained by large river systems.

9 Floods submerge crops; silt up fields; tank bunds and river embankments are washed off.

Management of excess rainfall (floods)

1 By constructing multipurpose projects such as irrigation and electric systems.

2 Planned afforestration.

3 Keeping the field drains open

4 By growing flood obstructing crop

b Scanty rainfall

This is a synonym with "Inadequate rainfall" or `Drought'. The influence of drought can be observed not only on phenology but also on phenophases of crop plants (chapter 8).

1 Water limitation from seedling emergence to maturity in all the cereals is very damaging.

2 Water stress/drought during flowering reduces the size of inflorescence, affect fertilization, grain filling and reduce final yield.

3 Plants show wilting symptoms

4 Cell division and enlargement are very sensitive to drought stress, which results in stunted growth.

5 Drought effect nutrient absorption, carbohydrate and protein metabolism and translocation of ions and metabolites.

6 Abscission of leaves, fruits and seeds can be induced by plant water deficit during droughts.

7 Plant respiration is drastically reduced.

Management of drought / scanty rain

1 Application of sufficient irrigation water negates the condition of insufficient or scanty rain.

2 Discover amount of water needed at various stages and adjust the sowing dates.

3 Conserve water by suitable management of fallow and cropped field’s viz., breaking up the surface to reduce runoff, removal of weeds, digging pits of small size which collects runoff water, etc.

c Untimely rains

This refers to rainfall received too early or too late in the season with the result that normal agricultural operations are upset (chapter 8).

1 Too early rains do not permit proper preparation of seedbed due to heavy rains.

2 Too late rains delay sowings and pest attack cause collosal losses.

3 Wet spells during flowering and harvesting results in poor fertilization and subsequent loss in yield.

Management of untimely rains

1 Farmers shall be advised to follow the weather forecasting by IMD for proper management of their crops through crop-weather advisories.

2 Contingency crop plans shall be made available to the needy farmers.

2. Temperature

Temperature is essential for all plant physiological processes, gaseous exchange between plant and environment, stability of plant enzymatic reactions etc (chapter 3). However, both cold and heat waves and abnormal soil temperatures are adverse to crop growth and development.

(a) Cold Waves

During winter (December - February), temperature decreases generally over the Indian subcontinent. It is lower in northern-India and higher in southern- India. This fall in temperature may cause damage to the crops. If the temperature drops on freezing or below, a frost may occur which causes severe damage to the crops/crop plants. Threat of frost is danger to crops.

1. Forst is a form of condensation that forms on cold objects when the dew point is below freezing (chapter 8).
2. Frosts are of two types.
    a. Advection or air mass frost: Which results when the temperature at the surface in an airmass is below freezing?
    b. Radiation frost: Which occurs on clear nights with a temperature inversion?
3. There is a special case of frost caused by loss of heat by evaporation. This occurs when cold rain showers wet the leaves and are then followed by dry wind.

Advection Frost

The usual effects of Advection frost are:

1 The injury and death caused by frost is due to the formation of ice crystals in and outside the plant cells.

2 During dormancy, plants can withstand lower temperatures upto -20^{O}C.

3 Once growth has commenced temperatures of few degrees below freezing point may be fatal.

4 The cell sap gets frozen below 0^{O}C, as also between cells.

5 Extra cellular ice formation occurs followed by withdrawal of water from the cell.

6 The protoplasm may become dehydrated and brittle, resulting in mechanical damage, or the cell may contract and damage the protoplasm.

Management of advection frost

For production of most field crops, the only satisfactory solution to the problem of advection freezing is to avoid it as far as possible by planting after the damage is past and by selecting varieties which will mature before the beginning of the hazard.

Radiation frost

The damage due to radiation frost differs from the above freeze damage in degree and its spotly occurrence.

1 This radiation frost damage is critical during critical stages of growth.

2 Young seedlings may be killed.

3 Flowering stage is most prone.

4 Crops like potato, tomato and melons are vulnerable right upto maturity.

5 For most field crops and orchard crops flowering stage is most critical for frost damage.

6 Forsty nights followed by warm sunny days produce a sunclad on orchard fruits, considerably reducing their production.

Management of radiation frost

The management of radiation frost can be grouped into a) Passive and b) Active

a. Passive methods

- Clean cultivation.
- Maintenance of soil moisture.
- Wrapping plants with insulating material and enclosing the basal part of the plant.
- Proper site selection.
- Choice of growing season.
- Breeding of cold resistant varieties.

The above methods can be followed even for advection frost also. These passive methods do not involve any modification of environment.

b. Active methods

The active methods of frost protection are many, like use of

- Heaters.
- Wind machines.
- Sprinkling water.
- Following weather forecasst for better management of crops.

B. Heat Waves

These are very harmful during summer. These are experienced over Deccan and Central parts of India during March to May. The harmful effects include shedding of fruits, plants drying of water resources.

1 Loss of water by evaporation from irrigation channels.

2 Transpiration increases from plants beyond recouping levels

3 Plants tend to wilt and die owing to rapid desiccation.

4 Hot winds cause shrivelling effect at milk stage of all agricultural crops.

Management of heat waves

Adoption of specific agronomic practices like, shelterbelts, choice of varieties etc.

3. Wind

Wind has its most important effects on crop production indirectly through the transport of moisture and heat. Vegetative growth at `Zero' wind, as experienced in glass houses or under low glass cover is luxurient. But, there is typically a reduction in vegetative growth as the wind increases to small values, viz., 1 or 2 metres per second.

Beneficial effects of winds

1 Moderate turbulence promotes the consumption of carbon-dioxide by photosynthesis.

2 Prevent frost by disrupting a temperature inversion.

3 Wind dispersal of pollen and seeds is natural and necessary for certain agricultural crops and natural vegetation also.

Harmful effects of winds

1 At sustained high speeds (12-15 metres per second) at plant height, plants assume a low, dwarf like form, whilest the intermittent high wind speeds experienced in gales, hurricanes etc., results in gross physical damage to bushes and trees.

2 At higher wind speeds, the shape of the orchard tree alters giving rise to the characteristic wind shaping of trees in exposed positions.

3 Leaves become smaller and thicker.

4 Breakage occurs and bushes and trees subjected to natural (seasonal) pruning.

5 Direct mechanical effects are the breaking of plant structures, lodging of cereal crops, or shattering of seed from panicles.

Management of High Winds

It can be done by using wind breaks and shelter belts.

Fig; 30.1 SHELTER BELT

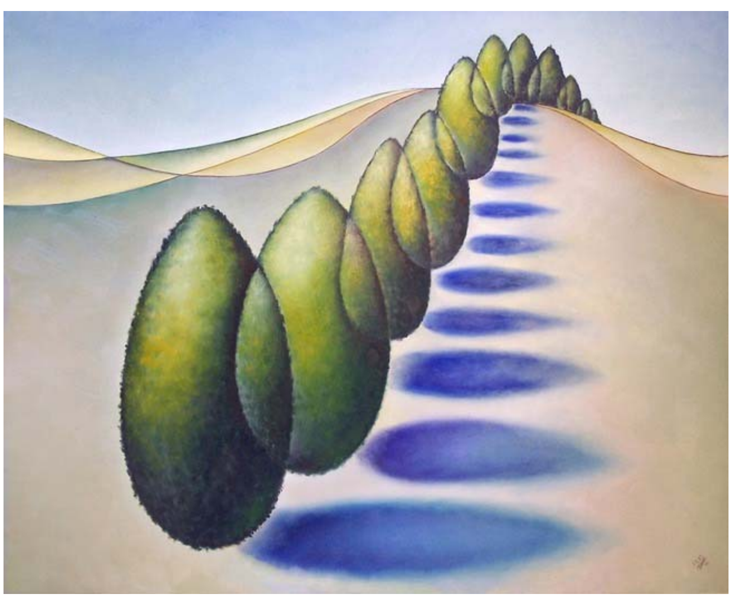

Fig: 30.2 WIND BREAK

1 The effects of wind on evaporation can be avoided by using proper method of irrigation.

2 The damaging effect of wind can be reduced over a limited area by the use of shelter belts (rows of trees planted for wind protection) and wind breaks (any structure that reduce the wind speed).

4. Thunderstorms, dust storms and hail storms

These storms are known as local severe storms. As many as 44,000 thunder storms occur daily on earth.

1 These are formed in a situation where a great deal of the energy for their genesis and development comes from the release of the latent heat of condensation in rising humid air.

2 These local storms cause severe damage to the standing crop by causing mechanical injury to the plants.

3 In dust storms, the dust is rised by the wind covers small plants, which may cause stomata closure and suffocation.

4 Hails cause direct damage to crops by lodging, shattering of seeds etc., depending on their intensity.

Management of storms

1 Prevention of hails by hail suppression techniques.

2 Following forecasts of weather and protecting crops.

3 Spraying of salt on harvested paddy, to prevent the germination / sprouting of harvested produce.

5. Excessive or defective insolation

Excessive solar radiation results in rise of soil and air temperatures. Defective insolation with consistantly cloudy weather on one hand and consistantly bright and high intensity sunshine on the otherhand causes enormous damage to crop plants.

1 Cloudy weather retard growth, affect pollination and cause disease and pest incidence.

2 High solar radiation intensity cause pollen burst or flower drop.

Management

Since, these are very rare, the location specific solutions like

1 Proper site selection.

2 Allowing air drainage.

3 Adequate water supply.

4 Pruning of orchard trees.

5 Spray of chemicals and plant harmones.

6 Covering plants with "hot caps" (covering plants with some standard and recommended material) may prove beneficial.

6. Tornado

This is a violent, destructive storm of small horizontal dimensions. A cumulonimbus cloud forms into a funnel shape with an vortex extending from the base of the storm to the surface. The Whirl-wind encireles a small dimension of about 500 metres. These are capable of causing severe structural and other damages. The violent winds associated with this abnormality are strong upward air currents. The tornados occurring on water are known as "Water spouts".

Management

1 Warning in advance

2 Precautions to protect the agricultural produce like transportation to safety places etc.

3 Quick removal of debris immediately after damage.

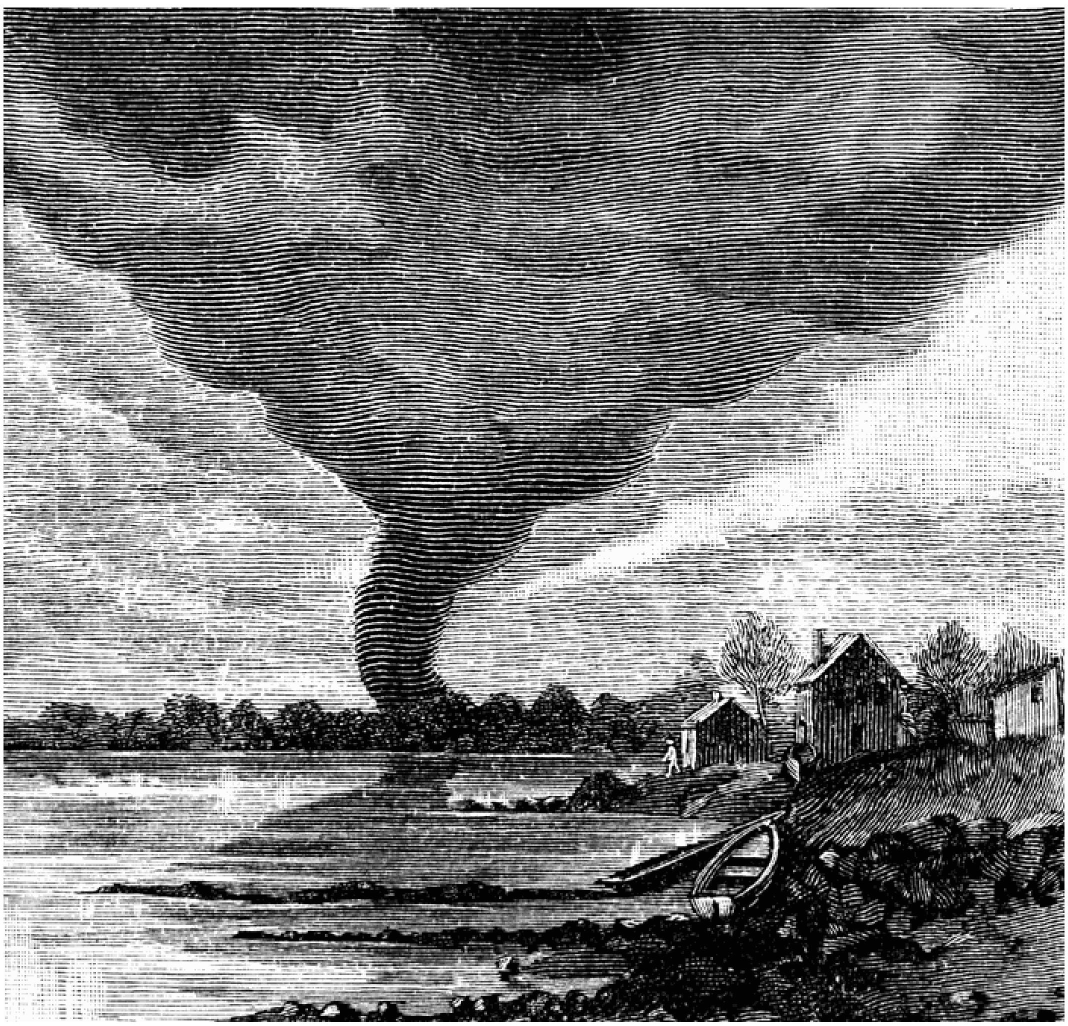

Fig:30.3 TORNADO

LECTURE – 31

WEATHER FORECASTING - APPLICATIONS AND UTILITY FOR AGRICULTURE - SYNOPTIC CHARTS, REPORTS AND SYMBOLS

Synoptic Reports

For better crop management under adverse weather conditions synoptic climatology play an important role.

The term synoptic climatology is applied to investigations of regional weather and circulation types. It is also used to refer to any climatological analysis which makes some reference to synoptic weather phenomena. This field is concerned with obtaining an insight into local or regional climates by examining the relationship of weather elements individually or collectively to atmospheric circulation processes.

Synoptic climatology is defined as "The description and analysis of the totality of weather at a single place or over a small area, in terms of the properties and motion of the atmosphere over and around the place or area".

There are essentially two stages to a synoptic climatological study.

1. The determination of categories of atmospheric circulation type.
2. The assessment of weather elements in relation to these categories.

Besides agricultural meteorological observatories, synoptic weather stations also record weather data such as rainfall, temperature, radiation, low level wind, evaporation etc. The surface observatories collect information on various weather elements and based on these recordings daily forecasts, warnings and weather reports are prepared by 5 regional forecasting centres at Chennai, Nagpur, Mumbai, Delhi and Kolkata. The weather bulletins are being broadcast in regional languages through All India Radio and Television.

Synoptic report Observed weather conditions are marked in brief coded form as a synopsis of the conditions. Such a brief report on weather conditions is known as "Synoptic report".

Synoptic chart/weather map The regular observatories record weather elements at scheduled time and send these readings through a telegram to the main observatory at Pune. They reach Pune within an hour of observation and they are charted on outline map of India, using the international code of signals and abbreviations. These are called "Synoptic charts or weather maps".

In synoptic charts different weather phenomena and atmospheric characters are marked with different symbols as mentioned below:

Table: 31.1. Character of symbols used in synoptic charts

S. No.	Symbols	Weather element / character / phenomenon
1.	Narrow black lines	Isobars
2.	Numbers at ends of isobars	Pressure values in millibars.
3.	Shading	Precipitation
4.	Arrows	Wind direction
5.	Feathers in the arrows	Wind velocity
6.	Small circles with shading	Amount of clouds

In addition to the above, different symbols are used for recording weather phenomena, in relevant columns of the pocket register and the monthly meteorological register by the observer. A few are mentioned in the Figure 9.1.

The duties of the observer: The routine duties of the observer include:

1. To make regular and careful observations and to note the general character of the weather and record in the pocket register.
2. To prepare and dispatch the weather telegram as per the instructions to the different forecasting centres, immediately after the observations are taken.
3. To send heavy rainfall telegrams to the various offices on warning list.
4. To prepare and post monthly meteorological and pocket registers for each month to the controlling meteorological office.
5. To keep the instruments clean and maintain them properly.

After the observer sends the data as per the standard procedure it should be decoded and the weather observations for each station must be plotted at the appropriate location in a systematic manner following the international station model. Only weather maps in first class forecasting centres approach the completeness of this model. Printed maps and maps used for plotting usually have an appropriately numbered circle corresponding to each reporting land station and observations are plotted about this location in the appropriate position regardless of the number of observations shown. The weather pattern affecting a locality is an integral part of the much larger hemispheric weather pattern and it is necessary plot a map over a large area. Even if observations are not to be plotted, it is necessary to know the plotting scheme in order to read and interpret weather charts already plotted.

Weather Forecasting

The weather elements which influence the agricultural operations and crop production can be forecast upto different spans of time. Weather forecast is defined as "prediction of weather for the next few days to follow".

Utility of weather forecasts

In India the total annual pre harvest losses of various crops range from 10 to 100 per cent. Similarly, the post harvest losses average upto 10 per cent. When an accurate weather forecast is given for the needs of agriculture it contributes immensely to the monetary benefits of the farmers.

- Short term adjustments in daily and weekly agricultural operations.

  If heavy rain occurs immediately after sowing of seeds the seeds are washed away. If a hail storm occurs during harvesting it causes shedding of grains and fruits. If warned in time the farmer would hurry up some of the operations or postpone them suitably adjusting the cropping operations to weather conditions.

- Minimising input losses resulting from adverse weather (seeds, chemicals, fertilizers, diesel or electric power used for irrigation etc).

  The critical periods for normal growth of the crop can be adjusted for healthy growth and development of crop.

- Markedly improve the yields of crops both qualitatively and quantitatively.

  The yield of the crop is determined by weather conditions to a greater extent, seeds, chemicals fertilizers etc. If weather is predicted in advance the amount spent on irrigation, electricity, labour can be reduced substantially. Nearly, 50 per cent of farmers will definitely be benefited if warnings are given well in advance to them.

  If farmer knows when the monsoon rains are likely to commence and how the rainfall could be from time to time in the season he would be able to plan his agricultural operations like preparation of seed bed, manuring, intercultivation including drying and threshing of the produce.

Prime requirements for weather forecasting

1. A good data set
2. A good method which can be used to forecast.

Weather data used in forecasting

The following weather elements are measured routinely.

1. Pressure, temperature, wind (speed and direction) humidity.
2. Rainfall, cloud (type and amount), visibility pressure change, present and past weather, maximum and minimum temperatures etc.

Types of observations

The main observations used in different weather forecasting types are as follows:

1. Surface observations
2. Upper air observations
3. Aircraft observations
4. Radar observations

Different types of weather forecast. There are three types of weather forecast (Table 9.2).

Table: 31.2. Types of weather forecast and their validity

S.No.	Type of forecast	Validity period	Main users	Predictions
1.	Short range a Now casting b Very short range	Upto 72 hours 0-2 hours 0-12 hours	Farmers, marine agencies, General public etc.	Rainfall distribution, heavy rainfall, heat and cold wave conditions, thunder storms etc.
2.	Medium range	Beyond 3 days and upto 10 days	Farmers	Occurrence of rainfall, temperature intensity etc.
3.	Long range	Beyond 10 days; a few weeks to a month; season	Planners	This forecast is provided for Indian monsoon rainfall. The out looks are usually expressed in the form of expected deviation from normal conditions.

Methods used in weather prediction

Three methods are used for accurate weather prediction.

1 Synoptic method

This is a subjective technique. In this method weather charts are analysed and the analogous situations happened in the past are matched with present situation. This method is useful for present situation. This method is useful also for short range forecast. The success of the forecast depends on the skill and experience of the fore-caster.

2 Statistical methods

In this method correlations and regressions are calculated using weather elements. This method is useful for long range weather forecast.

3 Numerical methods

This is basically an objective technique. Several equations are solved numerically using high speed and large memory computers. This method is useful for short and medium range forecasts.

Agromet advisories

1 The IMD has established Agromet Advisory Service Units (AASUs) at the meteorological offices of the state head quarters. These AASUs issue biweekly agromet advisories to the states. First, the condition of the crops in the state and then advisory on the farming operations, based on the past weather / likely future weather realised is provided. The rainfall forecasts valid for the next two days and the out look valid for two subsequent days is also given Assistance for the agricultural related aspects is taken from the state agricultural universities and agricultural departments.

2 The agromet advisories are sent to the "Farm Radio" division of All India Radio stations through land line telegrams and are broadcast in the farm radio programmes of respective states. A separate pictorial presentation of spatial rainfall distribution over the state is sent to Doordarshan for telecasting in the respective states.

3 The advisories are also sent through faxe to the Agromet Directorate of IMD, Pune on the same day, where all the advisories sent by the various AASUs are assembled and then a consolidated report is prepared. This report is faxed from IMD Pune to IMD Delhi on subsequent day and is used for ministerial/secretarial briefing.

LECTURE – 32

REMOTE SENSING – DEFINITION – INTRODUCTION - APPLICATIONS IN AGRICULTURE

Remote Sensing

The word "Remote sensing" was coined by Fischer in 1960 AD. Remote sensing is defined as "Collection and interpretation of information about a target without being in physical contact with it". According to Lilesand and Kiefer, remote sensing is "The science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation".

Basic concepts of remote sensing

There are two basic interactions between electromagnetic energy and earth surface feature. These interactions are considered as basic concepts of remote sensing.

1. The propositions of energy reflected, absorbed and transmitted will vary for different earth features, depending on their material type and condition. These differences permit to distinguish different features on an image.
2. Even within a given feature type, the proportion of reflected, absorbed and transmitted energy will vary at different wavelengths.

Approaches for information

Mainly, there are two approaches to obtain information.

1 Visual interpretation.

2 Digital image processing.

3 Satellites and sensors

Platforms used in remote sensing

Taking aerial photographs by camera, tracking any object or phenomenon by radar, seeing the object by our eyes or producing satellite images are the examples of remote sensing. Basically, there are three plat forms, used in remote sensing.

1 Ground based remote sensing

If the fat form having sensors is at the ground it is known as ground based remote sensing.

2 Air borne remote sensing

If the platform is upto 100 kilometres height with smaller coverage capability like the aircrafts, balloons or rockets it is called as air borne remote sensing.

A remote sensor can detect variation in reflectance between objects depending upon four interrelated factors.

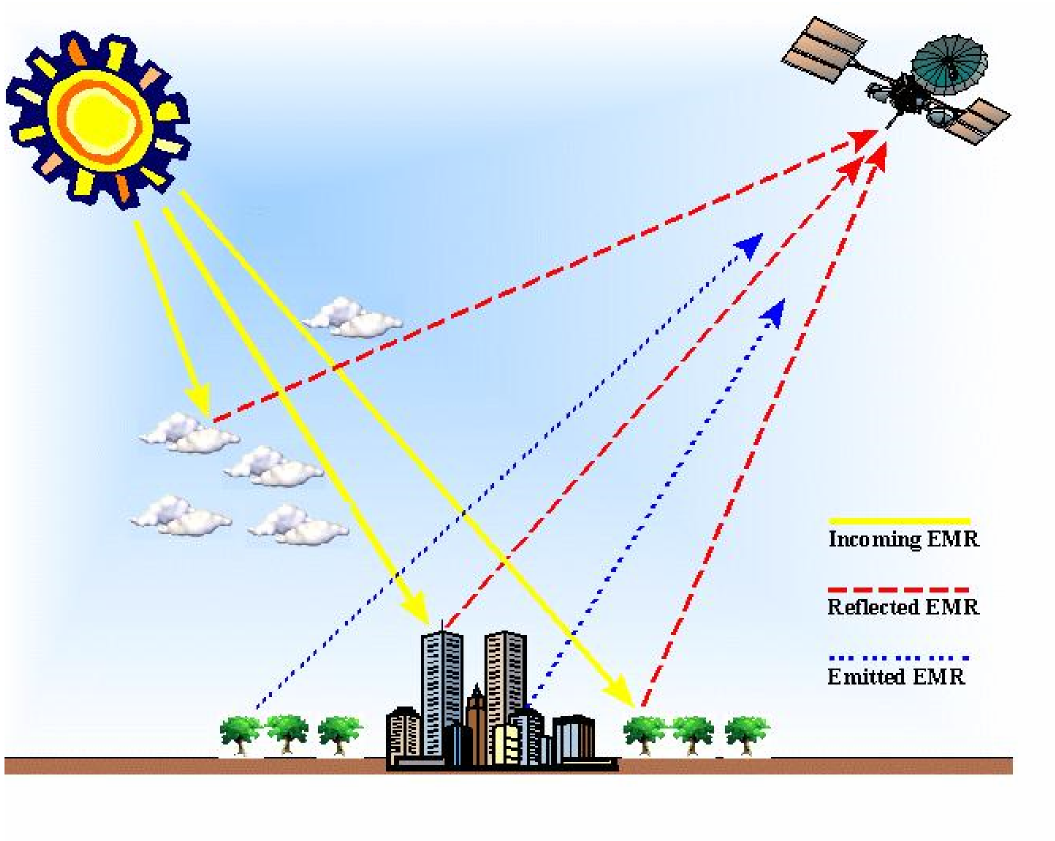

Fig: 32.1 REMOTE SENSING

a The radiometric resolution of the sensor

b The amount of atmospheric scatter

c The surface roughnes of the objects

d The spectral variability of reflectance within the scene.

3 Space borne remote sensing

If the platform is in the space having capability of global coverage it is called space borne remote sensing.

Multispectral scanning

The generalised processes and elements involved in electromagenetic remote sensing of earth resources are

a Data acquisition and

b Data analysis

Sensors are used to record variations in the way earth surface features reflect and emit electromagnetic energy. Multispectral scanners use sensors with very narrow fields of view to scan an area of interest systematically and an image is built up as the scan progress. Each sensor forms an image that represents the reflectance of the scan in its particular wavelength of the scene in its particular waveband. The Indian Remote Sensing Satellite System provide images with 36.25 m and 72.5 m ground resolution in the bands 0.45 – 0.52 microm; 0.52 – 0.59 microm; 0.62 – 0.68 microm and 0.77 – 0.86 microm.

Spectral reflectance for vegetation, soil and water

In the field of agriculture the scientists are interested in spectral signatures (characteristics) of vegetation, soil and water.

These are useful to describe the nature of energy – matter interaction when the energy is in a) visible b) near infrared and c) middle infrared wavelength bands.

Visible and adjacent infrared spectrum provides useful information for the study of plant communities. Within this range spectral characteristics of soil, water and vegetation differ significantly for different spectral bands.

1. Vegetation

- In visible region chlorophyll absorption bands are approximately central at 0-45 to 0.65 pm.
- Internal structure of leaf is different for different vegetations and this difference gets noticed in near infrared to mid-infrared spectral reflectance.
- Crop discrimination gets improved with the measurements in 1.55 to 1.75 and 2.05 to 2.35 pm bands which are sensitive to crop moisture content or leaf air space volume

2. Soil

Soil shows gradual increase in reflectance as the wavelength of optical spectrum increases.

3. Water

- Water bodies show fairly good response to shortwave radiation.
- It also shows absorption in infrared bands.

Applications of remote sensing in agriculture

Remote sensing is an effective tool in assessing the damages to crops and their management.

1. Monitoring in season agricultural operations

   All the farm operations like sowing intercultivation; harvesting etc. is being monitored effectively by the remote sensing.

2. Crop identification

   By using LISS II or III sensors crop identification on regional scale is possible.

3. Crop acerage estimation

   By using stratified sampling methodology crop acerage estimation is done to the high level precision.

4. Crop yield estimation

   Crop yields are estimated by analysing satellite based vegetation indices which are transformations of reflectance in the near infrared portions of electromagnetic spectrum.

5. Monitoring of crop phenology and stresses.

   The crop condition is affected by several factors like deficiency of nutrients, acidic and salinity problems of soil, nutrient deficiencies, adverse weather conditions etc. All these can be detected by remote sensing.

6. Damage assessment and command area management

   The damages due to floods, cyclones, water logged areas in command area can detected and managed effectively by using techniques like Multi-Temporal Remote sensing etc.

7. Water availability and soil moisture estimation

   The surface and sub surface water availability for irrigation and the amount of moisture stored in the upper few centimetres of soil can be found to a greater accuracy.

8. Land degradation and watershed management

   The remote sensing technology is highly useful in identifying and delineating degraded lands. Also, it facilitates in delineation of watershed areas.

9. Drought detection and management

   Assessing the drought realistically and ways to manage the adverse effects is possible through remote sensing.

10. Desertification

    Remote sensing provides information to identify the important indicators of desertification. Based on this action can be taken by the planners at different levels.

11. Monitoring in season agricultural operations

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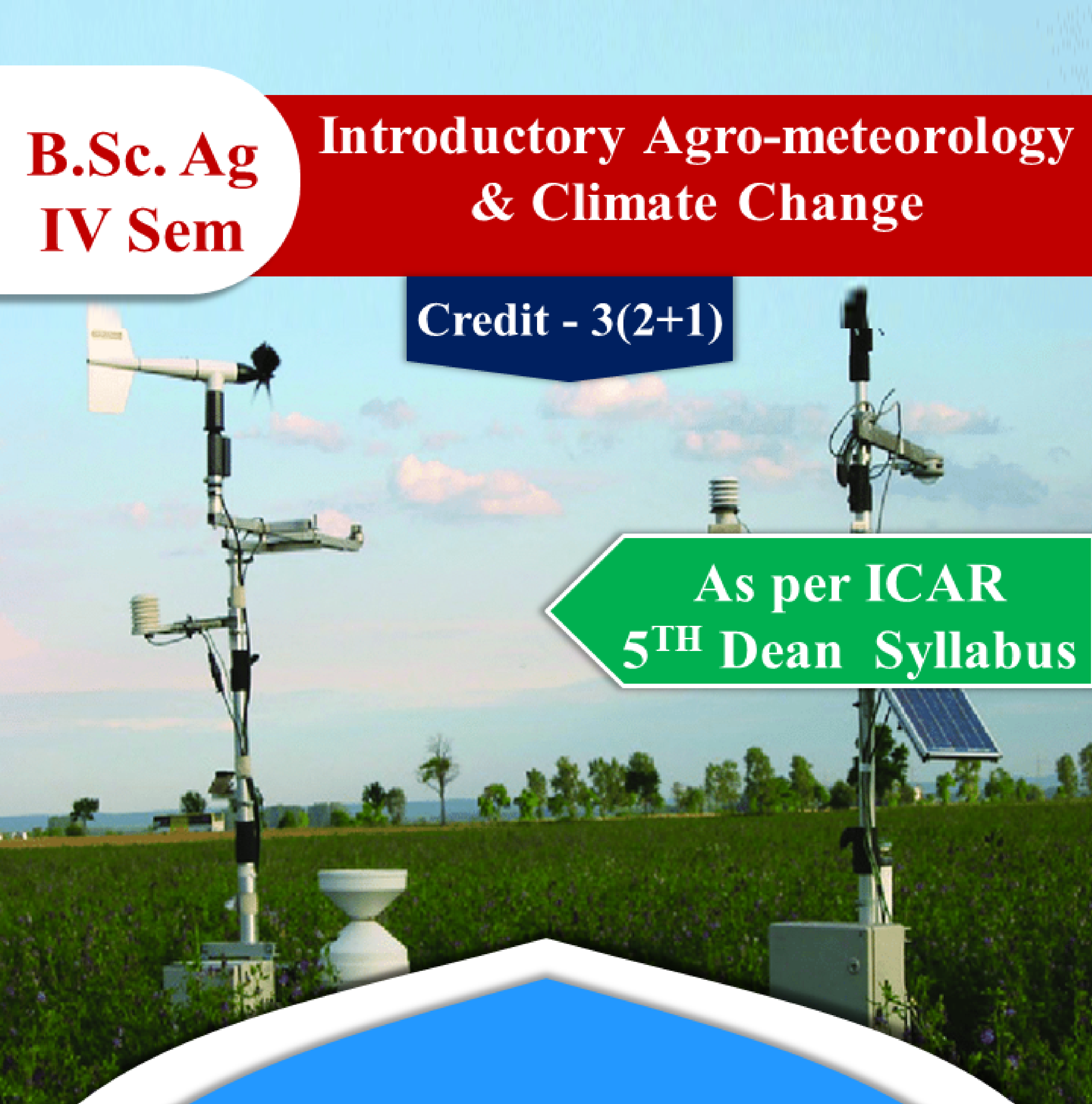

B.Sc. Ag
IV Sem

Introductory Agro-meteorology & Climate Change

Credit - 3(2+1)

As per ICAR
5TH Dean Syllabus