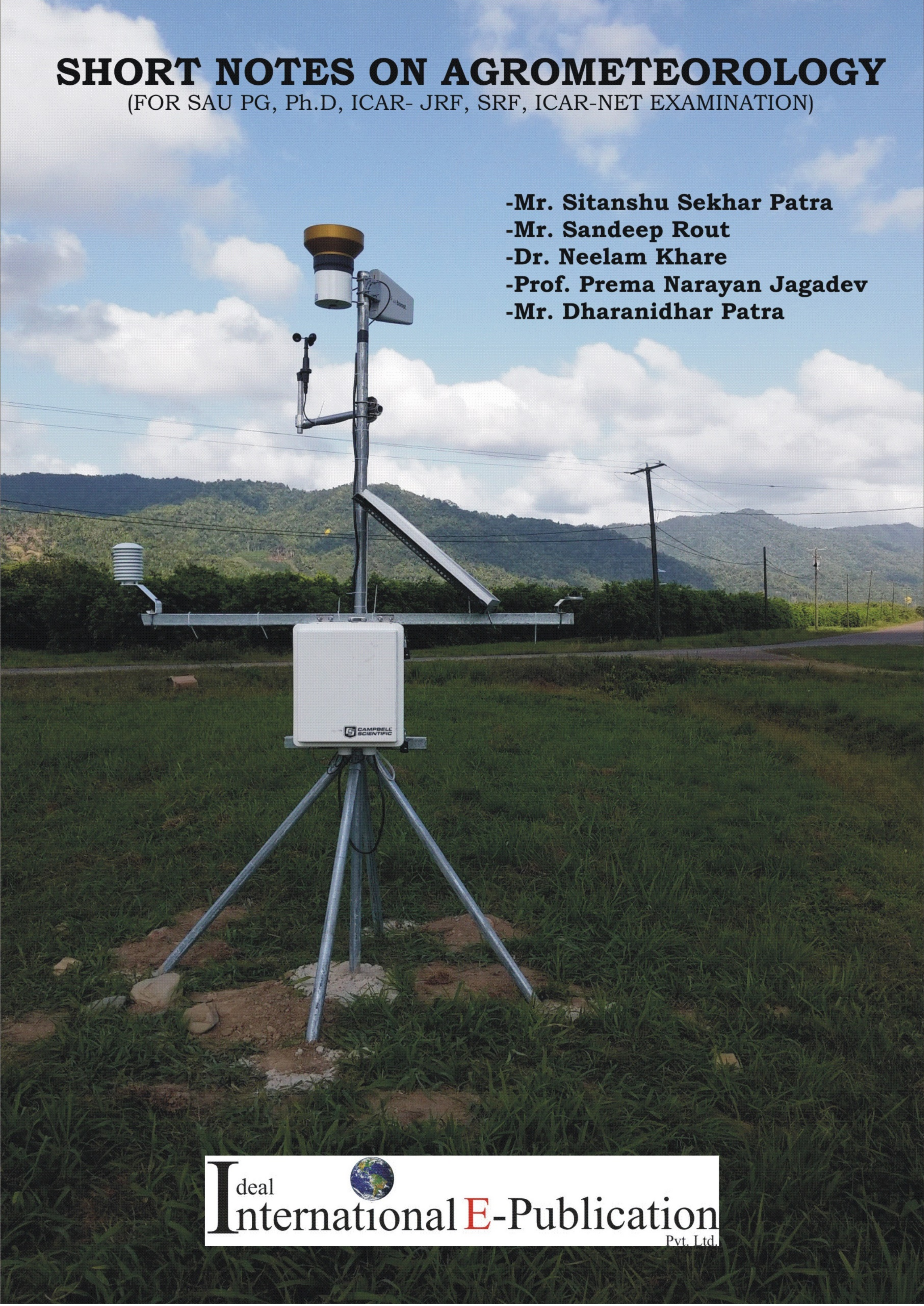
SHORT NOTES ON AGROMETEOROLOGY

(FOR SAU PG, Ph.D, ICAR- JRF, SRF, ICAR-NET EXAMINATION)

-Mr. Sitanshu Sekhar Patra
-Mr. Sandeep Rout
-Dr. Neelam Khare
-Prof. Prema Narayan Jagadev
-Mr. Dharanidhar Patra



Ideal International E-Publication
Pvt. Ltd.

SHORT NOTES ON AGROMETEOROLOGY

(FOR SAU PG, Ph.D, ICAR- JRF, SRF, ICAR-NET EXAMINATION)

Mr. Sitanshu Sekhar Patra

Mr. Sandeep Rout

Dr. Neelam Khare

Prof. Prema Narayan Jagadev

Mr. Dharanidhar Patra

2017

Ideal International E – Publication Pvt. Ltd.

www.isca.co.in

Ideal International E-Publication Pvt. Ltd.

427, Palhar Nagar, RAPTC, VIP-Road, Indore-452005 (MP) INDIA
Phone: +91-731-2616100, Mobile: +91-80570-83382
E-mail: **contact@isca.co.in**, Website: **www.isca.co.in**

Title:	SHORT NOTES ON AGROMETEOROLOGY
Author(s):	Mr. Sitanshu Sekhar Patra Mr. Sandeep Rout Dr. Neelam Khare Prof. Prema Narayan Jagadev Mr. Dharanidhar Patra
Edition:	First
Volume:	I

ISBN:978-93-86675-12-5

CONTENTS

CHAPTER.1

GENERAL METEOROLOGY

EARTH ATMOSPHERE

- Atmosphere is a perfect gas obeying perfect gas laws.
- Mobility, capacity for expansion and compression are the principle property of the atmosphere.
- The age of the atmosphere is 400 million years.
- The height of the earth atmosphere is 400 km.
- The mean sea level pressure is 1013.25 mb (mb= Millibar, 1mb=1 hectopascal)

OZONOSPHERE

The lower part of stratosphere between 15-35 km is concentrated with ozone (O_3) and is called ozonosphere. The highest density is as about 22-25 km height. Ozone absorbs ultraviolet (UV) radiation and protects biological life from harmful radiation. Therefore, ozonosphere is called as UMBRELLA of the earth.

The average ozone concentration in earth's atmosphere being only about 0.6 ppm. The thickness of this layer varies seasonally & geographically.

- The ozone layer was discovered in 1913 by the French physicists Charles Fabry & Henri Buisson.
- The ozone layer absorbs 97-99% of the sun's medium frequency ultraviolet light (from 200 nm to 315 nm wave length).
- The ozone layer can be depleted by free radical catalysts, including nitric oxide (NO), Nitrous oxide (N_2O), Hydroxyl (OH), CFCs, BFCs etc. (BFCs=Bromo fluorocarbons)
- In 2009, nitrous oxide (N_2O) was the largest ozone depleting substance (ODS) emitted through human activities.

CHLORO FLUORO CARBON (CFC)

Release from industries combines with ozone depleting ozone amount or content in the stratosphere. This is also called ozone hole, this result in increasing global temperature & change in global climate.

- Many CFCs have been widely used as refrigerants, propellants and solvents. The manufacture of such compounds has been phased out and replaced with products such as R-410A as they contribute to ozone depletion.
- This compound is also a greenhouse gas, with a much higher potential to enhance the greenhouse effect than CO_2.

GAS LAWS

The air is conceded as ideal gas & therefore obeys gas laws as follow.

1) BOYLE'S LAW-

At constant temperature, the density (d) of a gas varies directly with pressure (P).

Which means,

$d \propto P$

or

$P=kd$, Where, $k=$ Constant

& also, $P \propto 1/V$ or $PV=k$, (P=Pressure of the gas, V= Volume of the gas)

2) CHARLES LAW (also known as the law of volumes)-

At constant pressure, the volume (V) changes in proportion to change in temperature (t).

$V \propto t$

ATMOSPHERE

Atmosphere is a deep blanket of gases which envelope the earth. Air is a mechanical mixture of gases and cannot be felt except when it moves as a wind. Total mass of the atmosphere has been calculated at about 56×10^{14} t, without the atmosphere there could be no clouds, winds, rain or no weather. Air protects the earth from the full force of the sun during daytime and prevents loss of too much of heat at night. Therefore, without atmosphere life could not exist.

COMPOSITION & DIVISION OF THE ATMOSPHERE-

The earth has three realms, lithosphere (solids), hydrosphere (water) and atmosphere (gases). The gaseous cover extends over earth's surface to a height of about 9,600 km and envelops it.

MAJOR CONSTITUENTS-

CONSTITUENTS	BY VOLUME (%)	BY WEIGHT (%)
Nitrogen	78.09	75.53
Oxygen	20.95	23.13
Argon	0.93	1.28
Carbon dioxide	0.03	0.05

Water vapour -1%

In addition to these gases, very minor amounts of neon, helium, krypton, xenon, methane, hydrogen, nitrous oxide, carbon monoxide, ozone, ammonia, nitrogen dioxide, sulphur dioxide, hydrogen sulphide comprise the remaining parts.

Concentration of ozone (O_3) is mainly between 20 and 35 km.

IMPORTANCE OF MAJOR CONSTITUENTS-

NITROGEN-

- It is one of the major constituent for sustenance of plant life.
- Microorganisms present in soil fixes the atmospheric nitrogen into the soil and provide the crop the nitrogen percentage.
- Nitrogen is associated with the reduction of O_2 concentration in the atmosphere there by making atmosphere favorable for living organisms.
- Atomic nitrogen in the upper atmosphere is involved in photochemical reactions.

OXYGEN-

- It is essential for life on earth and for natural combustion.
- It takes part in photochemical reactions to produce ozone.
- It has no influence on weather phenomena.

CARBON DIOXIDE-

- Vital contribution in photosynthesis & respiration in plants.
- It is a good absorber of heat and works like an insulating blanket to regulate the air temperature near the surface.

- Increase in concentration of CO_2 increases the atmospheric temperature.
- Increase in CO_2 in the atmosphere warms large scale climate change.

OZONE-

It is most efficient absorber of ultraviolet radiation and protects all forms of life from excessive of these deadly rays and makes life possible on earth.

WATER VAPOUR-

- About 90% of water vapour is present within 6 km above the earth’s surface.
- It controls temperature of atmosphere.
- Water vapour is the source of water for clouds and rain.
- The rate of evaporation and transpiration and thereby crop water requirements are controlled by atmospheric water vapour content.

SOLIDS-

- Dust particles in air absorb some incoming solar energy.
- Hygroscopic dust particles act as nuclei for condensation and help in the formation of clouds and fog.
- Blue colour of sky is due to scattering of visible solar spectrum by gas molecules & dust particles (Rayleigh scattering).

DIVISION OF THE ATMOSPHERE-

Based on composition, the atmosphere is broadly divided into two spheres- Homosphere, the zone of homogenous composition of gases and Heterosphere, the zone of variable composition.

Homosphere further subdivided into four layers-

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

The transition zone between two spheres is called pause such as:-

1. Tropopause (Transition zone between troposphere and stratosphere)
2. Stratopause (Transition zone between stratosphere and mesosphere)
3. Mesopause (Transition zone between mesosphere and thermosphere)

TROPOSPHERE-

- This layer is nearest layer to the earth's surface extending to around 16 to 17 km. The extension of this layer is not same at all latitudes. It is about 17 km at the equator, 12.5 km at 45^0 latitudes and 4.5 km over polar region.
- This layer contains almost all the water and dust and represent all the atmospheric phenomena such as clouds, rain, snow, fog, lightning, thunder storms, cyclone etc. No visible weather phenomenon occurs above this layer.
- It contains approximately 75% of the atmosphere's mass and 99% of the total mass of water vapor and aerosols.
- In this layer, the temperature decreases at 6.5 ^{0}C km^{-1} which is known as lapse rate.
- In the troposphere, instead of decrease in temperature with altitude, sudden raise in temperature is seen at certain points which is known as temperature inversion, for example lapse rate changes abruptly at 14 km.
- Wind speed increases with height and convection current is present.

STRATOSPHERE-

- It is up to 50 km but at equator it is up to 50 km and at poles it is about 70 km.
- There are no convection currents. (Convection currents- These are the forms of small to high speed wind.)
- It consists of ozone.
- Bacterial life survives in the stratosphere making it the part of biosphere.

MESOSPHERE-

- It is extended up to about 80 km (Generally 95-120 km) from earth's surface. Maximum chemical activities take place in this sphere and hence it is also called as chemosphere.
- The upper boundary of mesosphere is called as mesopause whose temperature is -143^{0}C.
- It is warmer layer due to selective absorption of UV rays by ozone. Temperature increases with height at about 5^{0}C km^{-1} and reaches its maximum as 77^{0}C at about 40-50 km (As lower boundary mesosphere is 50 km above of earth surface) and then falls to as low as -100^{0}C.
- It contains electrically charged particles (ions) which reflect radio waves back to earth surface and enable us to have wireless communication.

THERMOSPHERE-

- It extends upwards from 80 km (generally above 125 km to 600 km) and lies above mesosphere and below exosphere.
- Temperature increases rapidly (around 1000^0C) at 350 km with height due to absorption of ultraviolet radiation.
- It lower portion consists of atomic oxygen and nitrogen.

EARTH

It does not have its own source of illumination that's why it is called as a planet. Its structure is oblate ellipsoid. It is about 150 million km away from the sun. Its axis has an inclination (tilt) of 23.5^0 from the vertical. The earth has two types of motions.

1) ROTATION-

It rotates west to east upon its axis. It completes one rotation in 24hrs. The time period of earth rotation determines the length of a day. During this time, all the places of the sphere turned alternately towards and away from the sun. Though they go from a period of light and period of darkness and they are moved twice by the circle of illumination (circle of illumination- The imaginary circular line that divides the earth's surface in to illuminated and dark hemispheres). The rotational speed is variable according to latitude. The rotational speed is maximum at equator. The rotation not only causes days and night but also determines direction of winds ocean currents.

2) REVOLUTION-

The rotating earth revolves on elliptical orbit around the sun. Time taken to complete one revolution around the sun is called a year. The earth complete one revolution in 365.25 days. The .25 days is why every four years February has 29 days.

An imaginary plane passed through the sun and extended outward through all points in the earth's orbit is called plane of the elliptic. The axis of the earth rotation inclined about 66.5^0 from the plane of the elliptic, with the plane of elliptic this inclination remains constant throughout the path of orbit due to parallelism of axis and revolution, there are larger seasonal changes due to distribution of solar radiation on the earth.

SEASONS ON THE EARTH

1. EQUINOXES-

When the sun rays are over head or vertical end of equator (0^0 Latitude), this situation comes twice in a year during earth revolution.

When sun rays on the equator then the day and night duration is same throughout the globe. They are not exactly equal, however, due to the angular size of the sun and atmospheric refraction. To avoid this ambiguity, the word *equilux* is sometimes (but rarely) used to mean a day in which the durations of light and darkness are equal.

A. Vernal Equinox-The point at which sun crosses from south to North Pole on the equator is called vernal equinox (21st march). The March equinox or Northward equinox is the equinox on the Earth when the subsolar point appears to leave the southern hemisphere and cross the celestial equator, heading northward as seen from Earth. In the Northern Hemisphere the March equinox is known as the vernal equinox, and in the Southern Hemisphere as the autumnal equinox.

B. Autumnal Equinox-The opposite of vernal equinox (North to south) (23rd Sept.)

Day is usually defined as the period when sunlight reaches the ground in the absence of local obstacles. On the day of the equinox, the center of the Sun spends a roughly equal amount of time above and below the horizon at every location on the Earth, so night and day are about the same length. In reality, the day is longer than the night at an equinox. There are two reasons for this: First, from the Earth, the Sun appears as a disc rather than a point of light, so when the centre of the Sun is below the horizon, its upper edge is visible. Sunrise, which begins daytime, occurs when the top of the Sun's disk rises above the eastern horizon. At that instant, the disk's centre is still below the horizon. Second, Earth's atmosphere refracts sunlight. As a result, an observer sees daylight before the top of the Sun's disk rises above the horizon. Even when the upper limb of the Sun is 0.4 degrees below the horizon, its rays curve over the horizon to the ground.

On equinoxes circle of illumination passes through both poles and duration of day and night remain equal throughout the globe. At equinoxes, maximum solar radiation receives at equator and minimum or less towards poles.

SOLSTICE-

The time during revolution of the earth at which it reaches its maximum declination, when days and nights are unequal is called solstice.

1. Summer solistice-21stJune (when day is longest & night is shortest)
2. Winter solstice -22nd December (when night is longest and day is shortest)

During summer solstice, the sun rays are vertical at tropic of cancer & northern hemisphere is getting comparatively lighter at longer base compare to southern hemisphere.

During winter solstice, the sun rays are over head at tropic of Capricorn as southern hemisphere has longer days and shorter night during winter solstice.

The farthest distance between sun & earth during earth revolution is 152 million km and nearest is 147 million km.

SOLAR RADIATION-

The solar energy that reaches the earth surface in the form of electromagnetic wave is called solar radiation. It is also called as shortwave radiation. 99% of incoming solar radiation lies within the wave length range of 0.15 to 4 µm.

$1\mu=10^{-6}$ m.

RADIATION FLUX-

It is the amount of energy radiated, transmitted and absorbed per unit time. Its unit is Watt (joule/sec).

RADIANT FLUX DENSITY-

It may be defined as radiant flux per unit area. Its unit is Watt/m^2.

IRRADIANCE-

It is the radiation intensity incident on the surface.

EMITTANCE-

It is the radiant flux density emitted by a surface.

ISOHEL-

It is an imaginary line joining the places having equal duration of sunshine hours.

SOLAR CONSTANT-

It may be defined as the radiation energy per unit time, per unit area on surface which is held perpendicular to the sunrays at outer limit of atmosphere at mean distance between sun and earth. The mean value of solar constant is 1.98 cal/cm^2/minute or 1398 Watt /m^2.

1.98 cal/cm^2/minute=2 Langley/ minute

The average distance between sun and earth is 150 million km.

Solar constant is not a true constant, it varies with the latitude, season of a year, sun spot activities.

SOLAR RADIATION SPECTRUM-

Radiation originates from the visible surface of the sun is called photosphere. A wave length determined by its surface temperature of about 6000^0 kelvin.

The range of wavelength of solar radiation is called as solar radiation spectrum. It may also be defined as spread of solar energy over a broadband of wave length. Solar spectrum is a part of electromagnetic spectrum of radiant energy that also includes X-rays, gamma-rays and longer radio waves. It comprises mainly U.V, Visible and infrared wave length.

Further solar radiation can be divided mainly into three parts-

A. ULTRA VIOLET (U.V Radiation)-

The radiation having wave length range of 0.15 to 0.4 µm is called ultraviolet radiation. It constitutes about 9% of the total solar radiation and divided into three parts-

i. U.V$_A$:-

This radiation has the longest wave length (0.32 to 0.4µm) of the ultraviolet radiations. It can cause some damage to living cells. It is transmitted to the earth surface and not absorbed in stratosphere.

ii. U.V_B:-

The wave length range (0.28 to 0.32 µm) of U.V radiation is called as U.V_B .It is absorbed in stratosphere by ozone.

iii. U.V_C:-

It has shortest wave length (0.15 to 0.28 um) of UV radiation. It is lethal and kills the living cells.

B. VISIBLE RADIATION-

The radiation which lies in wave length ranges 0.4 to 0.7 µm of solar spectrum is known as visible radiation. These radiations are visible to human eye and constitute 41% of total solar radiation. This part of solar radiation is most important for photosynthesis process in green vegetation. Therefore, it is called as PAR (Photosynthetically Active Radiation).

C. INFRARED-

The radiation lies between 0.7 to 4 µm were length. This part of radiation constitutes 50% of total solar radiation. These radiations are not important for crop plant. These are simply absorbed by plants and transmitted into heat.

ALBEDO-

It may be defined as ratio of solar radiation reflected by a surface to the total amount of radiation incident on it. It is usually express in % (percent). It is also called as reflection coefficient. Albedo can be express by α (alpha).

$$\text{Albedo } (\alpha) = \frac{\text{Reflected solar radiation by a surface}}{\text{Total solar radiation incident on surface}} \times 100$$

Mean albedo of various surfaces-

Sl. No	SURFACE	ALBEDO (%)
1	Deciduous forest	18
2	Coniferous forest	13
3	Desert	28
4	Fresh snow	80-85
5	Old snow	50-60
6	Cereal crops	22

7	Sand	20-30
8	Water	6-9

Albedo of the earth is 34% but it varies with the latitude season and nature of the surface.

RADIATION-

A. LONG WAVE RADIATION-

Radiation having the wave length longer than 4µm wave lengths is called long wave radiation. The radiation emitted by earth surface is called as long wave radiation.

PYRGEOMETER-

This is used to measure long wave radiation. It also measures atmospheric infrared radiation spectrum that extends approximately from 4.5 µm to 100 µm.

B. SHORT WAVE RADIATION-

Radiation having the wavelength $\leq$ 4 µm is called as shortwave radiation. Incoming solar radiation is short wave radiation (0.15-4µm). Short wave radiation (Rs) is measured with the help of pyranometer. It can be computed using following formula.

$Rs=Ra\ (a+b\ n/N)$

Where,

R_a=Solar radiation at outer limit of atmosphere.

a & b are constant.

n=actual sunshine hours.

N=Maximum possible sunshine hours.

SKY RADIATION-

The radiation which come to the earth surface through indirect path are known as sky radiation. Sky radiation is also called as diffuse radiation. It constitutes about 23% of total short-wave radiation.

UNITS-

Watt/m^2=1 Watt = 1 joule/sec

1 Langley=1 cal/cm^2

1 Lux=4 watt/m^2

1µ mole/sec/m^2=1µE/Sec/m^2

RADIATION AND HEAT BUDGET-

Radiation is the way of transfer by which solar energy reaches the earth surface as short wave and earth and its atmosphere losses energy to outer space in longer wavelengths. The basic form radiation balance equation for earth and its atmosphere is-

$Rn=Ra\ (1-r)-R_L$

Where, Rn=Radiation balance or net radiation

r =Global albedo

R_L=Out going long wave radiation

1-r=Solar radiation absorbed by earth and its atmosphere.

Out of total incoming radiation about 25% is reflected by clouds and 7% is scattered back to space by cloud, dust and gas molecules without heating the air, 2% is reflected to the space from earth surface.

This total 25+7+2=34% reflected radiation is called as earth albedo. About 19% of insolation is absorbed in atmosphere by the gases, clouds and solid particles suspended in air. Ozone absorbs much of the U.V radiation, which is the main source of energy in stratosphere. Water vapour, clouds and dust are mainly absorbed incoming long wave radiation in troposphere.

The earth surface absorbs 47% solar radiation out of it 24% as direct and 23% as indirect (diffuse). Thus 66% radiation is absorbed by earth and its atmosphere.

The total absorbed solar energy is radiated back to space as long wave radiation, out of which 6% is radiated back to space directly by earth surface and 60% radiated to space by atmosphere.

Ra=100 units

Ra(1-r)=66%

Rn=100(1-0.34)-66=0

So r=34%

R_L=66%

RADIATION LAWS-

1. STEFAN BOLTZMAN LAW-

This law states that radiation intensity emitted by a black body is directly proportional to fourth power of its surface temperature.

$E=\sigma T^4$

Where,

E=Radiation emitted by the surface

σ=Stefan Boltzmann constant (5.67 x 10^{-5} ergs/cm^2/sec/k^4)

(k= Kelvin, σ= sigma)

2. PLANK'S LAW-

Plank introduced particle theory and stated that light is constituted by small energy particles are flow of the energy particles. Each energy particles is called as photon (Energy quantum). The energy content of each quantum is directly proportional to its frequency.

Energy content of quantum $\propto$ frequency

Energy content of quantum is given by following equation- $E=h\nu$

h=Planks constant (6.625 x 10^{-34}Jsec)

ν=Frequency

3. WEIN'S LAW-

This law states that wave length of maximum radiation intensity emitted inversely proportional to the temperature of the body

$\lambda max= 2897/T\ (\mu m^0K)$

λmax= Wave length of maximum emission.

T=Temperature of surface (^{0}k)

Problem-

Q. The earth surface temperature is equal to 27^{0}C, sun temp. is 6000^{0}k. Find out the wavelength of maximum radiation intensity?

Ans-Earth temp. = 27^{0}C

=27+273=300^{0}k

For earth,

λmax=2897/300=965.66/100=9.66µm

For sun,

λmax =2897/6000 = 482.83/1000=0.48µm

4. KIRCHOFF'S LAW-

This law states that for a given wave length Absorptivity=Emissivity, means aλ = eλ

Where aλ & eλ absorptivity and emissivity of a material for a given wavelength.

For a given wave length and temperature, the ratio of emissivity to absorptivity of all material is constant.

So, $a_1/e_1=a_2/e_2$= constant,

Where e_1 & e_2 are emissivity of surface first and second, a_1 & a_2 are absorptivity of surface first and second.

5. BEER'S LAW-

This law states that the fraction of radiation intercepted (I/I_0) by the canopy is an exponential function of leaf area index(LAI).

$I=I_0e^{-kf}$ is called as beer's law.

Where,

I= Light intensity at any height within the crop canopy.

I_0=Light intensity at top of the canopy

K= Extension coefficient

f=LAI

Canopy= Total areal parts.

LAI= Leaf Area Index (Leaf area/Ground area)

RADIANT INSTRUMENTS-

1. PYRANOMETER-

It measures total shortwave radiation that is direct and indirect radiation. It is thermopile based instrument. Reflected radiation can be measured by inverting the sensor over the surface.

2. NET RADIO METER-

It is used to measure net radiation that is balanced between incoming and outgoing solar radiation. A different thermopile is used.

3. QUANTUM SENSOR-

It measures radiation in the wave length range of 0.4 to 0.7 µm, which is called PAR. The sensor is silicon photo diode which works on the principle of photometric effect.

4. PYRGEOMETER-

It is used for measurement of long wave or terrestrial radiation. The sensor is used is thermopile which works on the principle of thermoelectric effect.

5. LUX METER-

This instrument is used for measurement of light intensity.

Division of atmosphere into different layers (troposphere, stratosphere, mesosphere and thermosphere) is based on temperature variations.

The second criteria are on the basis of chemical composition and on these criteria the atmosphere is further divided into two spheres.

A. HOMOSPHERE-

It is the lower region upto the height of about 80kms and the various gases are well mixed and are homogeneous by the process of turbulent mixing and diffusion. This sphere is called as homosphere. Here the presence of gases governed by diffusion and composition remains normally constant.

B. HETEROSPHERE-

In this gaseous composition changes and various gases form separate compositional layers individually. Satellite data has shown the presence of different chemospheres as follows.

1. Atomic oxygen layer
2. Helium Layer
3. Hydrogen Layer

GENERAL CIRCULATION OF ATMOSPHERE-

Varying amount of isolation received at the earth surface brings about differential heating of the earth. Temperature differences produce density differences that drive or govern the atmosphere in three dimensional motions on global scale. Much of required energy to maintain the global circulation comes from the oceans in tropical region in the form of latent heat (LE) through the process of evaporation.

The general circulation brings about maintaining energy balance throughout the globe. In the absence of planetary wind system, it would have been impossible to compensate for the unequal distribution of heat in the atmosphere.

BROAD CATEGORIES OF ATMOSPHERIC MOTION-

Wind movement in the atmosphere may be classified into three broad categories-

A. PRIMARY CIRCULATION-

This includes planetary wind system which is related to general arrangement of pressure belts on the earth surface. Trade winds, westerlies and polar easterlies together form the primary circulation.

B. SECONDARY CIRCULATION-

It consists of cyclones, anti-cyclones, monsoons and air masses. These are synoptic scale circulation.

C. TERTIARY CIRCULATION-

It includes all local winds which are produced by local causes and affect weather and climate of a particular area. These are mesoscale and microscale circulation.

The general circulation is divided into three distinct zone or regions in each hemisphere and mainly controlled by pressure belts.

The following wind belts are found on the earth surface in each hemisphere under idealized global pattern.

1. DOLDRUMS-

It is the equatorial belt of calm and variable wind. Average location of doldrums is between 5^0N to 5^0S latitude. This zone is the meeting place of trade winds. It is a low-pressure area.

Doldrum is also called as ITCZ. In this region, vertical air movements occur and associated with strong convective and heavy shower.

2. TRADE WIND BELT-

The trade wind belts extending roughly from 5^0 to 30^0 latitudes in both hemispheres. Here the surface flow is equator ward and flow in upper troposphere is pole ward. Trade wind is originated due to pressure gradient from subtropical high to the equatorial belt of low pressure. In the northern hemisphere trade wind blow in north east direction and in southern hemisphere in south east direction. These winds are steady and constant throughout the year.

The zone of trade winds is also called as Hadley cell.

→ Horizontal movement of air is called as wind.

↓ Vertical movement of air is called Air Current.

↑ After air get heated up it rises upward this phenomenon is called as Convective activity.

*Convective –Upward movement

3. WESTERLIES-

The belt of westerlies lies between 30^0 to 60^0 latitudes in each hemisphere. These westerlies are winds that blow from pole ward margin of subtropical high-pressure belt towards high latitude. These winds during movement into high latitude are deflected and become south westerlies and the north westerlies winds in northern and southern hemisphere respectively.

4. POLAR EASTERLIES-

Polar easterlies are wind belts which blow from polar highs to sub polar low-pressure belt.

CIRCULATION CELLS-

The three cells model was proposed by Palmen for northern hemisphere in 1951.

1. HADLEY CELLS-

   It is also called as tropical cell. At low altitude air movement is towards the equator, where it gets it and rises vertically with pole ward movement at higher altitude. It is a circulation of air between subtropical high-pressure belt and equatorial low-pressure belt in both hemispheres. The surface wind in these cells are trade winds.

2. FERREL CELLS-

It is the mid latitude means atmospheric circulation between subtropical high-pressure belt and sub polar low-pressure belt. In this cell, the air moves pole ward and east ward near the earth surface. The surface wind in these cells are westerlies.

3. POLAR CELLS-

In this cell air rises and moves pole ward at higher levels and sinks at poles and diverges outward from the poles. This cell exists between polar high pressure and sub polar low-pressure belts. The surface wind in this cell are easterlies.

ATMOSPHERIC PRESSURE-

Pressure of air at a given place is the force exerted against a surface by continuous collision of gas molecules. Pressure is the force per unit surface area.

$P=F/A$

where, $F=$ Mass$\times$acceleration[mass$=\rho hA$]

P=Pressure

F=Force

A=Area

The air pressure is the force exerted in all direction as a result of weight of all the air above it.

So, $P=\rho ha \times g/A= \rho gh$

As P=F/A= Mass × Acceleration/ Area

Where, ρ=Density of mercury= $1.3 \times 10^3 kg/m^3$

h=height of mercury (0.76m or 76cm)

$g=980cm/s^2$ or $9.8\ m/s^2$

$P= 1.3 \times 10^3 \times 0.76 \times 9.8$

$=101300pa$

$=1.013 \times 10^5 pa$

HORIZONTAL DISTRIBUTION OF ATMOSPHERIC PRESSURE-

The horizontal distribution of pressure over the earth surface is shown by isobars. On the weather map isobar are drawn at an internal of 3,4 or 5 mb. Factors which controls the distribution of temperature on earth surface equally govern the distribution of pressure. This is mainly due to the fact that there is a close relationship between pressure and temperature. Earth surface is heated on evenly by 3 factors mainly.

1. Unequal distribution of radiation
2. Differential heating of land and water
3. Reflectivity variation of the earth surface

As the air over the area heated more than the other area, the warm air will rise and its density decreases and there by air pressure decreases. But over an area of cold air pressure will increase.

The equatorial regions have high temperature due to high insolation which results into low pressure development. On the other hand, Polar Regions are cooler which results into high pressure development.

Coriolis (disturbing) force due to earth rotation also affects the pressure distribution over the globe. Therefore, based on general circulation there are 7 alternating low and high-pressure belts on the earth surface. These pressure belts are as follows-

1. EQUATORIAL TROUGH OF LOW PRESSURE-

It is located in the basinity of equator between 5^0N to 5^0S. The width of the trough is not confirmed in different part of the equatorial region. It is also known as belt of rising air/belt of convergence. The average pressure is less than 1013 mb.

This belt is thermally produced due to high insolation over the equator. The heated air expands and become lighter and rises upward. These convectional currents are setup in the atmosphere throughout the year. It has a great potential for a large amount of latent heat of condensation. The equatorial trough of low pressure is the zone of convergence of trade winds blowing equator ward from the subtropical high.

2. SUBTROPICAL HIGH PRESSURE BELT-

This pressure belt lies between 25-35^0N and S in both hemisphere. This pressure belt is broken in to number of high pressure cells. These high-pressure cells are produced due to rotation of earth. The subtropical highs are area of sinking of equatorial air. Therefore, this belt is dynamically produced by subsidence of air.

(Subsidence-Pressure due to its own weight-sink (When Upper air sinks, it put pressure on lower air, so its temperature, rises).

The general sinking or subsidence takes place at this subtropical high-pressure belt. These high-pressure belts or zones are turned into horse latitude. The sinking air current creates stable atmosphere with dry air mass. The rainfall is extremely limited (The main deserts are found at this belt). The weather in this zone remains fair and dry. The relative humidity of descending air currents is reduced by effect of adiabatic heating. This is the region of all hot deserts of the world. The centers of subtropical high pressure are not permanent in nature.

3. SUBPOLAR LOW PRESSURE BELT-

This belt lies between 60-70^0 latitude in both hemispheres. It is also a belt of rising air/ converging air as winds coming from the subtropics and polar area converges and rises in this belt. This belt results due to rotational movement of the earth, which swings up air in this zone.

Due to a great contrast between the temperature of wind from subtropical and polar regions cyclonic storms are developed.

4. POLAR HIGH PRESSURE BELT-

The pressure at the poles is consistently high throughout the year. This belt lies over the poles in both the hemisphere. The high pressure in these belts is mainly due to extreme low temperature persist in polar region which result in heavy air mass. The easterly wind blows in these high-pressure belts towards sub polar low-pressure belts.

VERTICAL VARIATION IN ATMOSPHERIC PRESSURE-

The pressure depends on the density of the air. $P \propto d$

Air density depends upon its temperature, composition and force of gravity. Air is denser near the surface because of compression due to weight of overlaying air layers one upon the other. The air density decreases with height above the earth surface in atmosphere. Therefore, there is a decrease of air pressure with altitude. The rate of decrease in pressure with height is not same from place to place. The mean rate of decrease in pressure with height is 1cm per 100m (1cm/100m). In the first few thousand meters above the sea level, the pressure decreases at the rate of 1mb/10m (1mb for every 10cm). It drops to nearly ½ of its surface value, i.e., 1013.2 to 540.4 mb at about 5km height.

But this rate is not uniform with altitude. The atmosphere pressure at sea level is 1013.2 mb, at 50km it is about 1mb, and at about 80 km it decreases to 0.01 mb. The rate of fall of pressure with height is determined partly by rate of fall in temperature.

THERMODYNAMICS OF ATMOSPHERE-

IMPORTANCE OF THERMODYNAMICS TO ATMOSPHERIC PROCESSES-

Quantitative understanding of atmospheric phenomena ranging from smallest cloud microphysical process to general circulation depends largely on the application of thermodynamics principle. Some thermodynamics process involves the addition of heat to a fluid (air) causing its pressure and volume to change. The atmosphere is considered as a perfect gas for application of thermodynamic principles because it has mass and volume and exerts pressure and receive and loose heat from and to the atmosphere. There are two laws of thermodynamics-

FIRST LAW OF THERMODYNAMICS-

It is the law of conservation of energy and it means the energy of all types can never be created nor destroyed. It can only change its form to another.

Mathematically it can be expressed as: $dh=du+P.dV$

- dh=Small amount of heat added to unit mass of air
- du=Change in internal energy of air sample
- P.dV=Work done
- P=Pressure
- V=Volume

It can be applied to various atmospheric process involves exchange of heat. In atmosphere exchange of heat is a very slow process; such process is considered as adiabatic process.

Air is a poor conductor of heat, so rate of heat exchange from the air parcel to its surrounding environment is very slow, so this process is called as adiabatic process. When the dry air rises it expands and cool dry adiabatically because its internal energy of gas molecule is used in expansion against atmospheric pressure, so temperature of air parcel decreases and becomes cool in opposite when air is compressed air becomes warm.

SECOND LAW OF THERMODYNAMICS-

It specifies the direction in which heat may flow during a thermodynamics process. The work can be converted into heat but all the heat cannot be converted into work. During transformation heat converted into work, a portion of heat cannot be utilized for conversion. This unavailable energy portion is called as entropy.

T-ϕ gram (T-Phi gram)-

It is a thermodynamic diagram consisting of temperature and potential temperature on different axis from the knowledge of dry bulb (T), wet bulb (Tw) and air pressure (P), quantity of dew point, water vapour content and R.H can be found out from T-ϕ gram by making use of Normand’s theorem.

This theorem states that the dry adiabatic through dry bulb temperature and saturation adiabatic through wet bulb temperature and the water vapour content line through dew point (Td) always lead in a single point P. Hence by knowing amount of two quantity Tw, Td the third can be found out.

ADIABATIC PROCESS-

If the heat is neither added nor removed from air parcel the process is called as adiabatic process.

During adiabatic process, the expansion of air is accompanied by decrease in temperature and decrease in volume is accompanied by increase in temperature. Such temperature changes commonly refer to adiabatic cooling and adiabatic warming.

LAPSE RATE OR TEMPERATURE LAPSE RATE-

It is the rate of decrease in temperature with rise in height. It is the vertical cooling rate of the air. It is measured in 0^0C/km. The rate of adiabatic cooling of rising air is called as adiabatic lapse rate. There are two types of adiabatic lapse rate.

1. Dry adiabatic lapse rate (DALR)
2. Wet adiabatic lapse rate(WALR)

1. DRY ADIABATIC LAPSE RATE (DALR)

It is the rate of cooling of dry rising air under adiabatic process. It is 10^0C/km.

2. WET ADIABATIC LAPSE RATE(WALR)

It is the rate of cooling of rising air under adiabatic process beyond the level of condensation. It is 5^0C/km.

The lapse rate is very important thing in practical atmospheric thermodynamics. The concept of adiabatic lapse rate can be used to express atmospheric stability.

DALR	WALR	CONDITION OF ATMOSPHERE (NATURE OF VERTICAL STABILITY)
>10^0C/km	>5^0C/km	Unstable
10^0C/km	5^0C/km	Neutral
<10^0C/km	<5^0C/km	Stable

VERTICAL STABILITY OF THE ATMOSPHERE-

The stability indicates the condition of equilibrium when the air is given an impulse (force) in vertical direction and if it returns to its original position is called as stable atmosphere.

When air is forced upwards and if it continues its vertical movement in the direction of its impulse is called as unstable atmosphere.

If it remains in its displaced position it is called as neutral atmosphere.

If the parcel of air is in hydrostatic equilibrium with the atmosphere then the vertical acceleration of air parcel is 0 if not then at equilibrium.

The upward or down ward movement of air parcel depends upon its density related to the atmospheric density.

The state of stability can be expressed with the following hydrostatic equation-

$d^2z/dt^2=1/\rho-dp/dz-g=g(\rho^1-\rho)/\rho$

Where,

ρ=Density of air parcel

ρ^1=density of surrounding environment

g=acceleration due to gravity

d^2z/dt^2=state of stability

dz =change in height

dP=change in pressure.

STATE OF STABILITY-

Unstable atmosphere ELR (Environmental lapse rate)>Td (Dry adiabatic lapse rate)

$$\left.\begin{array}{l}ELR>Ts\\ ELR=Td\\ ELR=Ts\end{array}\right\}\text{Neutral}$$

Or

$$\left.\begin{array}{l}ELR<Td\\ ELR<Ts\end{array}\right\}\text{Stable}$$

Stability measured by an index is known as stability index.

To define stability following indices/indexes are used-

i. Rackliff index (dT)=$\Theta wb-T_5$
ii. Jefferson's index (Tj)=$1.6\Theta wb-T_5-11$
iii. Boyden index=Z-T-200

Where,

Θwb=Wet bulb potential temperature

T_5=Dry bulb temperature at 500mb pressure

Z=Thickness

T=Temperature at 700mb (^{0}C)

- A process of change of temperature that takes place without any addition or withdrawal of heat is called as adiabatic process. In the adiabatic process, the change in internal energy of a system would be due to the work performed on it compression force or the work done by the same system (expansion). This principle may be applied to the heating and cooling of atmosphere.
- Adiabatic cooling: During an adiabatic process, an increase in volume (expansion) is accompanied by a decrease in temperature. It is referred to adiabatic cooling.
- Adiabatic warming: During an adiabatic process, a decrease in volume (compression) is accompanied by an increase in temperature is referred to as adiabatic warming.
- Non –adiabatic or di-adiabatic process- The change in temperature associated with gain or loss of heat by air from an outside source is known as non-adiabatic process.
- Unstable condition- When actual lapse rate is more and if a parcel of air is moved upward adiabatically then it will be warmer and lighter than the surrounding air and therefore it will continue to rise, such a condition is called as unstable.
- Stable Condition- When the actual lapse rate is less than the dry adiabatic lapse rate, in this condition, a parcel of air moved up adiabatically will be colder and denser than the surrounding. Hence the parcel will have tendency to return to its original position. This condition of the atmosphere is called stable condition.
- Neutral Condition- When the actual lapse rate is equal to the dry adiabatic lapse rate a parcel displaced upward or downward will have the same temperature and density, hence there will be no force in either direction and it is said to be neutral equilibrium.

- Heading of the atmosphere- Sun is practically the primary source from which atmosphere receives heat. The transmission of energy in the form of electromagnetic waves is called as radiation. Out of 100% energy received at the top of the atmosphere, 47% passes to the ground however remaining 53% is absorbed, scattered or reflected by clouds, gas molecules etc. The atmosphere is heated primarily by surface below it after it is warmed up by sunlight. The processes of heat transmission viz (1) Conduction (2) Convection and (3) Radiation are involved in this heating together with the processes (4) Namely transfer of latent heat of vaporization (5) Heating by compression.

1. HEATING BY RADIATION-

Most of the solar radiation (47%) are transmitted to the ground surface which are absorbed. The ground or earth then reemitted radiations, which are lost to the atmosphere. These radiations are invisible. Thus, earth converts visible sunlight into invisible radiations. These radiations are further absorbed by water, water vapour and CO_2 in the atmosphere and they get heated which also gives out radiations to the earth thus there is mutual transfer of radiations between earth and its atmosphere. This process keeps the atmosphere warm. Also, various gases O_3, CO_2 and water vapour absorb solar radiation in the upper atmosphere.

2. HEATING BY CONDUCTION-

By solar radiation, the earth surface gets warmed up. This heat by conduction is passed on to air layer which is just above it. This layer gives its heat to the surface nearer to it and the process goes on. However, as the air poor conductor of heat, conduction does not heat atmosphere to any considerable height.

3. HEATING BY CONVECTION-

The convection process also takes part in heating of atmosphere. Heated air expands, becomes lighter and goes upward and the cold and heavy air takes its place. This air also gets heated and the process is repeated. Thus, convection is the most active vertical heat transfer mechanism in the atmosphere. The land and water are heated to different extent by insolation causing climatic differences. The combination of the conduction and convection in heating the atmosphere is known as turbulent heat exchange.

4. HEATING BY LATENT HEAT RELEASE-

Evaporation is heat taking and condensation is heat giving process. These processes also bring about vertical heat exchange in the atmosphere. Thus, water evaporated from the earth’s surface consumes heat which is taken from the surrounding. For transferring 1gm of water in to vapour about 600 calories are required. This vapour moves upward in atmosphere and reduces the heat content. Further it gets condensed into clouds or other forms of precipitation. The condensation is the process in which latent heat is released and given out to the upper atmosphere. Thus, evaporation and condensation bring about vertical heat transfer in atmosphere. But when the rain falls down to the earth, the heat is not transformed from above to the earth.

5. HEATING BY COMPRESSION-

When air descends as in subsidence or anticyclone, air experiences high pressure, gets compressed and warms up by adiabatic process.

HYDROSTATIC EQUATION-

This equation shows that the rate of decrease of atmospheric pressure with height is equal to the product of density of air (ρ) and acceleration due to gravity (g). It expresses the equilibrium between the atmospheric pressure and force of gravity at any point in a non-moving air parcel of the atmosphere. Mathematically this equation can be expressed as **$dP/dh = -\rho g$**

Where,

dP=change in atmosphere pressure with height

dP/dh=Vertical pressure gradient

g=Force due to gravity

ρ=density of air parcel

Negative (-) sign indicates that pressure decreases with height above surface. This equation is useful to explain the vertical distribution of atmospheric pressure.

AIR MASSES & THEIR STRUCTURE-

Air mass may be defined as largely and widely spread homogenous body of air of uniform properties of temperature and humidity. It may be several miles across and interaction of two air masses is responsible for change in weather.

If an air mass tends to remain in its position or to return to that position when displaced, it is said to be stable. If the vertical displacement results in further movement of air from its original position, the air mass is termed as unstable. If the air mass neither resist vertical motion nor aid it, then the air in a state of neutral equilibrium.

Air masses cover many hundred & thousands of square miles and adopt the characteristics of the surface below them. They are classified according to latitude and their continental or maritime source regions.

In general, an air mass is a volume of air defined by its temperature & water vapour content. Or

Air mass is a large body of air that has similar temperature and moisture properties throughout.

TYPES OF AIR MASSES (CLASSIFICATION & NOTATION)-

Air masses adopt the characteristics of the surface below them or air masses acquire the property of the surface where it originates.

- The Bergeron classification is the most widely accepted form of air mass classification.
- Air mass classification involves moisture properties, thermal characteristics of its source region and stability of the atmosphere.

The geographical origin where it forms is called source. The air mass formed on land surface will be warm and dry which is called continental air mass. The air mass formed on ocean will be moist and is called maritime air mass.

The air mass classification involves three letters.

The first letter describes its moisture properties (Small letter)-

‘c’= Continental (dry)

‘m’= Maritime (moist)

The second letter describes the thermal characteristics of its source region (Capital Letter)-

‘T’=Tropical

‘P’=Polar

’E’=Equatorial

‘A’=Arctic

‘AA’=Antarctic

The third letter is used to designate the stability of the atmosphere (small letter)-

‘k’= If the air mass is colder than the ground below it.

‘w’= If the air mass is warmer than the ground below it.

BASIC TYPES OF AIR MASSES ARE AS FOLLOWS-

1. Continental Polar-‘cP’
2. Maritime Polar-‘mP’
3. Continental Tropical-‘cT’
4. Maritime Tropical-‘mT’

Further subdivisions such as maritime equatorial (‘mE’), Continental arctic (‘cA’), Maritime arctic (‘mA’) etc. are possible but of little use. The air mass when it travels to new surface, acquires the property of that surface both horizontally and vertically.

Arctic, Antarctic and polar air masses are cold. The qualities of arctic air are developed over ice and snow-covered ground. Arctic airs are deeply cold, colder than polar air masses. Polar air masses develop over higher latitudes over the land or ocean are very stable. Polar air over the ocean (maritime) loses its stability as it gains moisture over warmer ocean water.

Tropical and equatorial air masses are hot as they develop over lower latitudes. Those that develop over land (continental) are drier and hotter than those that develop over oceans.

Maritime tropical air masses are sometimes referred to as trade air masses. Monsoon air masses are moist and unstable. Continental polar (cP) air masses are cold also dry due to their continental source region.

CYCLONE-

A cyclone is an area of low atmospheric pressure characterized by inward spiraling winds that rotate anticlockwise in northern hemisphere and clockwise in the southern hemisphere of the earth. Cyclone is associated with high speed winds and heavy rainfall.

Cyclone spreads from sea to land and generally affects the coastal areas. Cyclones are more common in tropical region because of high temperature and high humidity.

Types of cyclone-

1. Tropical cyclone
2. Extratropical cyclone

1.Tropical cyclone-

A tropical cyclone is developed between tropic of Capricorn and tropic of cancer.

Prerequisite for formation of tropical cyclone-

- Sufficiently large sea areas and there should be continuous supply of abundant warm and moist air.
- The sea surface temperature should be >27^0 C.
- High Coriolis force. (it makes the air to bend)
- Tropical cyclones are absent in the belt of 5^0 latitude because of the absence of coriolis force.
- Pre-existing low-pressure system is required.
- Upper air divergence above the sea level.

Structure of a tropical cyclone-

A cyclone storm is a large vortex in the atmosphere with the diameter varies from 150 to 200km. Within this vortex a strong wind circulates clockwise/ anti clockwise. Wind circulates anticlockwise in northern hemisphere. The maximum surface wind is associated with severe cyclonic storm could be as high as 250 km/hr.

Vortex-

A mass of air or water that spins around very fast and pulls objects into its empty center.

A mature tropical cyclone consists of region called as eye. An eye has a diameter of 40km. Eye is characterized by weak wind shear, high temp., low pressure. Eye is generally cloud free. Around eye the wind speed is very high. This is known as wall cloud region of cyclone storm. It is so named because with in this region thick cloud with embedded thunder storm extend about 15-16 km height. The wall cloud region produces heavy rainfall. This is the most dangerous part of the cyclone. Surrounding the wall cloud region wind is continues to be spiral in decreasing rate. The rate of decrease of wind may be rapid or gradual depends upon size & intensity.

Month	Latitude of formation (in degree)	Direction of Movement	Approaching station
Jan-March	5-8	Westerlies to North Easterlies	Tamilnadu Coast
April	8-13	North Easterlies	Burma
May	10-15	North westerlies	East Coast
June	16	North Westerlies	East Coast
July-August	18	West North Westerlies	East Coast
September	15	North Westerlies	East Coast
October	8-14	North Westerlies	East coast
November	8-13	North Westerlies	East Coast
December	5-10	North Westerlies	Tamilinadu Coast

*Embedded: -Fixed with the surface of something.

Cyclones are centers of low pressure surrounded by low isobars having increasing pressure out ward and closed air circulation from outward to center of low pressure. The air blows anti clockwise in northern hemisphere.

CORIOLIS FORCE-

It is not a true force, but it effects or arises due to movement of air. Highest Coriolis force always at poles & minimum at equator (0).

2. EXTRATROPICAL CYCLONE-

These are also known as wave cyclone or temperate cyclone. These are in fact low pressure system produced in the middle latitudes characterized by converging and rising air, cloudiness and precipitation. They are formed in the region extended between 35-65^0 latitude in both the hemisphere due to convergence of two contrasting (two different) air masses. i.e., warm and moist and light tropical air masses and cold & dense polar air masses. Polar fronts are created which are responsible for origin & development of temperate cyclone.

ORIGIN-

In 1920, two meteorologists named V.Bjerknes and J.Bjerknes put fourth polar front theory of formation of extratropical cyclone. This theory is primarily based on the formation of fronts. The fronts are formed due to convergence of two air mass of different physical properties coming from different direction. Polar air mass is cold and denser & tropical air mass is warm and lighter in northern hemisphere. When these 2 contrasting air masses converges along a line in mid latitude, they move parallel to each other, thus stationary front is formed. No cyclone develops over stationary fronts because there is no vertical movement of air. On the other hand, when two opposing air masses collide against each other and try to attack the territory of one another, unstable fronts are formed. In the beginning the surface separating two air masses is straight but it turns to unstable and wave like when warm air masses attempt to penetrate in the regions of one another. Such fronts are called as polar fronts.

When warm and moist tropical air mass penetrates the territory of cold polar air mass along the polar front, it being lighter rises upward, with the result a center of low pressure is formed. In an extratropical cyclone, the pressure at the earth surface may decrease by about 20mb in 24hrs. Now winds from all direction rush up towards the center of low pressure and thus cyclone is formed. Cyclone forming wave develops due to convergence (coming closer) of cold and warm air masses is divided into two groups (i) Eastern part, where eastward advancing warm tropical air mass ascends over cold air mass is called warm front (ii) In western part where cold polar air mass pushes warm air mass upward is called cold front.

Low pressure in the eastern part of cyclone is intensified with arrival of warm air. This draws the winds towards the center from the nearby areas. With the result cold front advances more rapidly than warm front. Consequently, cold and warm fronts come closer to each other resulting into the distraction of front. The cyclone dies due to disappearances of warm front, this process of cyclone destruction is called occlusion. The period of a cyclone i.e. cyclogenesis to frontogenesis or occlusion is called the life cycle of extratropical cyclone which is completed through six successive stages.

CONDENSATION-

It is the process of conversion of water vapor into liquid form. During this time temperature is goes below dew point and some amount of energy is released known as latent heat. Condensation depends upon amount of cooling and relative humidity (R.H). At very high R.H. little cooling is needed and at very low R.H large cooling is necessary to bring temperature below dew point.

REQUISITES FOR CONDENSATION-

1. Saturation of air
2. Presence of some surface over which condensation takes place.

There are numerous particles known as nuclei presence in atmosphere which are called as aerosols. These aerosols provide surfaces & water molecules can attach with these aerosols. Over these surfaces water droplets and ice crystals grows. Certain types of particles like salts are hygroscopic in nature. In atmosphere beside salt particles there are some other particles also suspended in atmosphere like dust, conversion products. Mostly these particles have diameter less than 1µ and their concentration are $10^4/cm^3$. These particles are so small, that they remain suspended in atmosphere at days at a time.

Certain foreign particles in water act as a nucleus that induce freezing. These tiny particles called as ice nuclei. The artificial nuclei like AgI (Silver Iodide) acts like a nucleus for condensation in artificial rain making.

*Dew Point- It is the temp. at which condensation starts.

*Hygroscopic- Capacity to bind Water.

TYPES OF CONDENSATION-

1. DEW- It is the form of direct condensation of water vapour into liquid drops over vegetative or no vegetative surfaces. It is more common in winter and early morning. It occurs in night with still air, low temperature and presence of high quality of water in the atmosphere causes dew formation. Dew is not formed in windy night.
2. FROST-

It occurs when sublimation (the direct conversion of gas into solid) of water vapour takes place and temp. falls below 0^0C. There are two types of frost.

a. BLACK FROST-
   When the temp. of a surface in an air mass is below freezing. The black frost is also called as advection frost. Freezing at subzero temp. Causes injury to plant by extracellular ice formation.
b. RADIATION FROST-

   It occurs at clear night with temp. inversion and usually results in formation of ice crystal.

These are common in winter in mid and high latitudes and create a great hazard when occurs in early autumn and late spring when crops are in critical stage of development. The radiation frost has high coverage than black frost.

FOG-

Fog is formed due to radiation cooling or movement of warm & moist air over a cold surface. Clouds at lower or ground surface is known as fog.

There are two types of fog.

a. RADIATION FOG-

It is formed due to radiation cooling at night. The lower layer gets saturated and fogs are formed. Long night, clear sky, calm air and sufficient water vapour in the atmosphere and low temperature induce formation of radiation fog.

b. ADVECTION FOG-

Condensation due to movement of warm moist air over a cold surface creates the fog.

(Advection:- The movement of heat energy from one place to another horizontally)

FRONTS-

When two air masses of different temperature and humidity characteristics come in juxta position by opposite air current, the temperature and humidity across the surface of suppression show a sudden discontinuity. Such surface is known as front. Hence, front is a boundary which separates two opposite air masses having contrasting characteristics in terms of air temperature, humidity, pressure, wind direction, density and extensive transitional zone (i.e. 1 km or more) between two converging air masses is called frontal zone which represents zone of discontinuity. Frontal zone is neither parallel nor perpendicular to ground surface. Actually, it is inclined at low angle. The process associated with formation of new fronts is called frontogenesis. The region having convergence of contrasting air mass is called region of frontogenesis. On the contrary the destruction of fronts is called frontolysis.

CONDITIONS OF FRONTOGENESIS-

Presence of two opposing air masses having contrasting properties of air temperature, air pressure, density and wind direction.

A. Temperature difference-

Two opposing air masses must have contrasting temperature i.e., one air mass should be cold, dry and dense, while the other should be warm, moist and light. In such conditions when two air masses converge then the cold and denser air mass evade the area of warm and light air mass and thus front is formed.

B. Convergence of air masses-

Convergence of two contrasting air masses is necessary condition for front genesis. When two thermally contrasting air masses meet face to face or in opposite direction they try to penetrate in to the region of one another and thus wave like fronts are formed. The fronts are always having some slope.

CLASSIFICATION OF FRONTS-

Fronts are classified into 4 main types on the basis of their different characteristics.

1. WARM FRONT-

Warm front is the gently sloping frontal surface along which warm and light air becomes active and aggressive and rises slowly over cold and denser air. The gradual rising warm air along the gently sloping warm front is cooled and gets saturated and after condensation, precipitation occurs over a relatively larger area in the form of moderate precipitation.

2. COLD FRONT-

Cold front is that frontal surface along which cold air becomes active and aggressive and in which the warm air territory being denser remains at the ground. But forcibly uplifts the warm and light air. A cold front is associated with bad weather characterized with thick cloud, heavy downpour with thunderstorms. Sometimes cold frontal precipitation is associated with snowfall and hailstorm.

3. OCCLUDED FRONT-

It is formed when cold front overtakes warm front and warm air is completely displaced from the ground surface.

4. STATIONARY FRONT-

It is formed when two contrasting air masses converge in such a way that they become parallel to each other and there is no ascent of air.

LOW PRESSURE AREA (LPA)-

Low pressure center in closed width circular closed isobars is defined as LPA. The pressure increases outwards. A low pressure with wind speed <34 knots, the system is called as depression.

In cyclone, the pressure deficiency at the center of the system is more as compared to depression.

- If wind speed >34 knots, then it is called as cyclone.
- Cyclone & depression are circular.

TROUGH-

During passage of a depression over any given place the pressure at first falls and later rises. Simply through is the V shape projection of low pressure. It is also called as valley of low pressure.

RIDGE-

It is wedge shaped high pressure which lies between two depressions. (Two low pressure area). It is an extension of an anticyclone or high pressure area shown on a weather chart.

COL-

The pressure distribution between two high pressure areas and two low pressure areas is called as col.

WIND-

Air in horizontal motion is called as wind. Horizontal flow of air takes place along the pressure gradient. The wind velocity depends upon the rate of change of pressure per unit distance between two places at the same elevation, called as pressure gradient.

Due to differential heating of earth surface a low pressure is developed over colder place. Air moves horizontally from high pressure area to low pressure area along the pressure gradient. This horizontal flow of air is called wind.

The direction of wind mainly decided by direction of pressure gradient.

FORCES ACTING ON WIND-

PRESSURE GRADIENT FORCE (P)-

The force causes air movement in the direction of low pressure. It acts at perpendicular direction of the isobar. The change of pressure per unit horizontal distance is called P.

CORIOLIS FORCE (C)-

This is a fictious (lie) force or not a true force which result due to earth rotation over its axis. It causes the wind to deflect to its right direction in northern hemisphere and deflects to its left direction in southern hemisphere. Coriolis force is minimum at equator.

$C=2V\omega\text{-}\sin\theta$

V=Velocity of wind

ω=Angular Velocity of earth

θ=Latitude

*Deflection is highest at poles and no deflection at equator.

CENTRIFUGAL FORCE (cfg)- The force come into existence when air move in current path. This force takes wind away from the center.

FRICTIONAL FORCE-

The force which results due to friction between moving air and surface below. It increases due to surface friction. It acts as of opposite direction of air motion and reduces wind velocity.

AIR CURRENT-

Vertical movement of air is called as air current.

DEFINITIONS RELATED TO WIND-

ISOTACH-

It is the line on weather map which joins the places of equal wind speed.

WIND WARD-

It is the direction from which wind is coming.

LEE WARD-

It is the direction towards which wind is blowing.

BUYS- BALLOT’S LAW-

If we stand with back towards wind direction, the low pressure will be on left hand and high pressure on right hand side in the northern hemisphere.

1 knot=1.85kmph (km/h) or 0.51 m/s

LOCAL WINDS-

These winds originate due to difference in local features.

The following local wind system are-

1. LAND BREEZE-

It prevails (occurs) during night. The land surface cool to low temperature, then temperature of adjacent low pressure. The low pressure is developed over water surface and high over land surface.

Due to this pressure gradient between land and sea, air moves from land to sea. This is called land breeze. It is developed along the sea coast. It is daily in occurrence.

2. SEA BREEZE (OPPOSITE OF LAND BREEZE)-

It occurs during day time. During day time land surface warms by temperature higher than water surface temperature. Therefore, a low-pressure area developed over land surface and high on water surface. Air moves from sea to land among the pressure gradient is called as sea breeze.

3. MOUNTAIN WINDS-

On clear night, the mountain tops radiate energy and cool to lower temperature as compared to valley. The cool denser air moves down along the mountain slope into the valley. This air movement from mountain to valley is called mountain wind or mountain breeze. It is also called as katabatic wind.

4. VALLEY WINDS-

During day time in morning the mountain tops get energy earlier and warm to the temperature higher than valley temperature. The warm air over mountain top rises above and generates flow of air from valley. This movement of air from valley to mountain top is called as valley wind or valley breeze. It is also called as Anabatic wind.

WIND MEASURING INSTRUMENTS-

1. ANEMOMETER-

Use to measure wind speed is called as anemometer. i.e., wind cup anemometer and automatic anemometer.

2. ANEMOGRAPH-

It gives a continuous record of wind velocity with time on a chart.

3. WIND VANE-

Use to measure wind direction.

4. AEROVANE-

It measures both wind speed and wind direction.

HUMIDITY AND RELATIVE PARAMETERS-

Humidity- Presence of water vapour in air at a particular time. Water vapour constitutes only a small proportional of air which varies from 0 to 4%.

HUMIDITY TERMINOLOGY-

a. ABSOLUTE HUMIDITY (A.H)-

It may be defined as the mass of water vapour per unit volume of air.

$$\text{A.H} = \frac{\text{Mass of water vapour}}{\text{Volume of air}} = \frac{\text{Mv (gm/cm3)}}{V}$$

b. SPECIFIC HUMIDITY (S.H)-

It is defined as the mass of water vapour per unit mass of moist air.

$\text{S.H}= \frac{\text{Mv}}{\text{Ma} + \text{Mv}}$ (gm/kg) (Ma= Mass of dry air)

c. RELATIVE HUMIDITY (R.H)-

Unit=% (Temp. increases R.H value Decreases)

It is defined as the ratio of mass of water vapour present in air at a particular temperature to the mass of maximum water vapour that air can hold at the same temperature. It may also be defined as ratio of actual vapour pressure to saturation vapour pressure.

$$\text{R.H}=\frac{\text{Mass of water vapour in a given volume of air at a particular temperature}}{\text{Mass of maximum water vapour that air can hold at the same temperature and in same volume}}$$

Also, $\text{R.H}=\frac{\text{AVP}}{\text{SVP}}\times 100$

d. ACTUAL VAPOUR PRESSURE (AVP)-

It is the partial pressure exerted by water vapour by given volume of air at a given temperature. It may also be defined as the pressure exerted by water vapour actually present in air. It is the saturated vapour pressure at dew point.

e. SATURATED VAPOUR PRESSURE (S.V.P)-

The pressure exerted by water vapour, when the air is saturated. It is also defined as AVP at dew point.

f. DEW POINT-

It is the temperature to which air is cooled and becomes saturated and condensation of water vapour starts.

g. VAPOUR PRESSURE DEFICIT(VPD)

VPD=SVP-AVP

It is defined as the mass of water vapour required to bring the air at saturation at the same temperature in the same volume of air. It is also the difference between SVP and AVP.

h. MIXING RATIO-

It is the ratio of mass of water vapour to the mass of dry air in a moist air sample. It is represented as or its unit is gm/of water vapour / kg of dry air.

MIXING RATIO = $\frac{Mv}{Ma}$

FACTOR AFFECTING HUMIDITY-

1. WATER VAPOUR CONTENT-

Air humidity increases with increase in water vapour content at same temperature. The maximum limit of water vapour content that air can held at same temperature is called saturation. Specific humidity higher in tropic than in polar regions.

2. AIR TEMPERATURE-

The capacity of air holding water vapour increases with decreases in temperature. The temperature and humidity are inversely related.

3. DISTANCE FROM WATER BODIES-

The places near the water bodies have high humidity. That is why humidity is higher in coastal region as compare to interior of continent.

4. PREVAILING WIND-

Easterlies winds are more humid than westerlies in summer season.

5. VEGETATION-

The presence of vegetation also increases humidity through loss of water vapour in atmosphere by evapotranspiration process. So vegetated region is more humid.

PSYCHROMETER AND PSYCHROMETRIC EQUATION-

It is the device used to measure actual vapor pressure and hence the state of dampness of atmosphere. A psychrometer consists of two thermometers placed in air, side by side one known as dry bulb thermometer and second is wet bulb thermometer. Both are mercury in glass thermometer.

Hence both thermometers are similar. Wet bulb is wrapped in a muslin piece of cloth. In the month of May-June (hot summer) wet bulb depression is more as compared to rainy season (because of more evaporation and high temperature, wet bulb have more depression).

The cloth is kept wet by supply of water from reservoir through capillary action. As the air passes by the wet bulb water from wet surface absorbs it from its surrounding air and evaporates causing cooling. So, in this process air surrounding the wet bulb cools from temperature Td (Initial temperature of wet bulb which is equal to dry bulb temperature) to Tw (Indicated by wet bulb after attaining equilibrium with air in its surrounding). The basic principle of psychrometer is based on the fact that temperature difference between dry and wet bulb (Td –Tw) is a function of actual vapor pressure (AVP). If temperature difference is more then the vapour pressure deficit is more.

The difference between dry bulb temperature (Td) and wet bulb temperature (Tw) is called as wet bulb depression.

There are mainly two types of psychrometer-

a. Unaspirated Psychrometer
b. Aspirated Psychrometer

a. UNASPIRATED PSYCHROMETER-

It is a simple psychrometer consisting of a set of dry and wet bulbs installed in screen with no artificial ventilation from the dry and wet bulb reading the vapour pressure is calculated using the following formula.

i. When $Tw < 60^0C$

$$e_a = esw - \frac{0.48\,(Td-Tw)P}{670-\mathrm{Tw}}$$

ii. When $Tw > 40^0C$

$$e_a = esw - \frac{0.48\,(Td-Tw)P}{610-\mathrm{Tw}}$$

Where,

e_a=Actual Vapour Pressure

e_{sw} =Saturated vapour pressure

P=Atmospheric Pressure

b. ASPIRATED PSYCHROMETER-

In this type of psychrometer the air is drawn over the thermometer artificially to maintain the state of equilibrium.

SEASONS AND ASSOCIATED WEATHER-

As per IMD criteria a calendar is divided into 4 seasons i. winter (cold weather season) (Jan-Feb) ii. Pre-Monsoon season (Hot weather season) (mar-apr-may) iii. South west monsoon (Rainy season) (Jun-Sept) iv. Post Monsoon Season (Any North-East Monsoon Season) (Oct-Dec).

During winter season, North West India particularly Jammu & kashmir and Punjab receives significant amount of rainfall due to western disturbances. Also, the south-east peninsula receives rainfall mainly due to easterlies waves. Cold wave condition occurs over many part of northern and north central India, also wide spread fog occurs in majority part of the country.

The rainfall during hot weather season is accompanied with thunderstorms and hailstorms. Dust storm also occurs over North-West India. The activity of these storms is systemic regulates and governed by western disturbances. The important synoptic scale system which causes damage during this system is tropical cyclones, which in most cases originates in the latitude of 10-15^{0}N over the ocean regions. The heat wave condition develops over major part of the country during the mid-season, which often persists until the monsoon advances over the region.

India receives major part of annual rainfall in southwest monsoon season. The main component of SW monsoon over India are Mascarenes high, Somali low-level jet, heat low, Tibetan anti cyclone and tropical easterlies jet. The location and intensity of these SW components affect the strength and distribution of rain fall.

During post monsoon season, cyclonic storms forming over Bay of Bengal as well as over the Arabian Sea, which moves inland and the easterlies wave which moves west wards across the peninsula are the important rain making system. Tamilnadu and adjoining states receives rainfall during this season.

CLOUDS-

They are visible aggregate of liquid water droplets and ice crystals suspended in the air. They are as many as 500 to 600 droplets per cm^3. The clouds over land have greater concentration of nuclei. The size of droplets in non-precipitating clouds are so small that they fell very slowly on to the earth.

Mostly clouds are resulted from dry adiabatic cooling of rising air up to condensation level and above this level by wet adiabatic cooling. Condensation depends upon air temperature, relative humidity and height of condensation.

The clouds accompanied with strong rising air currents have vertical development and a puffy appearance where as those produced by gentler lifting or by other methods of cooling tend to form in layers.

Clouds are classified primarily on the basis of height, shape, color, transmission and reflection of light. There are 3 basic types of clouds on the basis of appearance.

i. CIRRUS (Ci)-
ii. CUMULUS (Cu)
iii. STRATUS (St)

i. CIRRUS-

Fibrous (hair like) clouds formed at 10 to 12 km height. All cirrus or cirro type clouds are composed of ice crystals. Cirrus clouds have brilliant colors of sunset and sunrise. These clouds generally do not give precipitation. These are highest clouds.

ii. CUMULUS (Cu)-

They are formed in heaps, rounded tops like comes or cauliflower with flat base. Cumulus generally found in the dry time over land areas. They produce only light precipitation.

iii. STRATUS (St)-

Generally gray cloud layer with uniform base which may give drizzle, ice prisms or snow grains.

These above clouds exist in pure form in combination.

If any cloud associated with rainfall then we prefix nimbus to its form.

WMO CLASSIFICATION (1957)-

Clouds have been classified in to 10 types on the basis of its height and appearance.

1. CIRRUS (Ci)-

These are highest clouds above the earth surface to tropopause. These are delicate detached fibrous feathery, silky appearance and made of ice crystals.

2. CIRROCUMULUS (Cc)-

These appears in patches of small white flaky or tiny globular mass. These are also made of ice crystals. This type of cloud is not common and is often connected with cirrus or cirrostratus.

3. CIRROSTRATUS (Cs)-

Made of ice crystals. It is a thin white veil of fibrous and covering a large portion of sky. It is nearly transparent so that sun and moon can be seen. It produces halo phenomena around sun and moon which are resulted from refraction of light.

4. ALTO STRATUS (As)-

These clouds are fibrous veil of grey or bluish grey. These are responsible for corona phenomena around sun and moon due to diffraction of light by water droplets. Precipitation may fall from these clouds sometimes.

5. ALTO CUMULUS (Ac)-

Made of ice and water. These have layers of globular clouds arranged in regular pattern of waves. These clouds may occur in groups. Vertical air currents in these clouds may cause the cloud to build upward or vertical. Sometimes referred as “Sheep Clouds” or “Woolpack Clouds”.

6. STRATUS (St)-

Made of water only. These are grey cloud sheets or layer. These clouds have no particular form or structure and usually overcast the sky. If these clouds are broken then it called as fractostratus (fs).

7. NIMBOSTRATUS (Ns)-

These are thick, dark grey, shape less cloud made of water and ice crystals. These are associated with steady precipitation. It never accompanied by lightening, thunder or hail. Streaks of water (rain) or snow falling from these clouds but not reaching the ground are called “Virga”.

8. STRATO CUMULUS (Sc)-

Made of water droplets. These are formed due to flattening of cumulus clouds.

9. CUMULUS (Cu)-

Made of water droplets. These clouds are developed vertically. These are dome or cauliflower shaped clouds having flat base. They are associated with fair weather.

10. CUMULONIMBUS (Cn)

Made of ice and water. They have tremendous vertical development, towering at times to 18 kms. These are thunder clouds produces heavy rainfall, hail storm, snow fall.

*Specific heat of water -1 cal/cm^3

*Specific heat of soil -0.34 cal/cm^3.

So, soil warm faster.

INDIAN MONSOON-

Monsoon is a wind pattern that reverses direction with the season.

1. South-West Monsoon (Jun-Sept)
2. North –East Monsoon (Oct-Dec)

Tamilnadu receives most rainfall during N-E monsoon.

In case of south-West Monsoon India receives 70-80% of annual rainfall.

Monsoon word is derived from Arabic word “Mawsin”. The word monsoon is applied to such a circulation which reverse its direction in every six months, that is from winter to summer or vice versa.

MONSOON SYSTEM-

Monsoon is caused by seasonal cycle of temperature over land as compared to the adjacent oceans. This differential warming result from the fact that the heat in the ocean is mixed to a greater depth of 50 m. whereas the land surface conducts heat slowly. More over the specific heat of liquid water is markedly higher than land surface. These factors influence differential heating of land and sea surfaces. The hot air over the land tends to rise and creating area of low pressure. Contrary to this the high-pressure center exists over sea surface. The rainfall is caused by moist ocean air which is drawn to the land.

In winter, the land cools quickly but the ocean surface remains warmer and the center of low and high pressure shifted and hence the monsoon circulation also changes its direction.

There are two types of monsoon system over India.

SUMMER MONSOON (S-W MONSOON)-

During the hot and dry season (month of April and May), when temperature rises rapidly and pressure over land decreases, the warm and moist air from the adjacent ocean start blowing towards the low-pressure center. By the end of May or first week of June when low pressure center is fully developed and the pressure gradient is steeple, the trade winds from the southern hemisphere are drawn towards the thermal low in northern latitudes (India). India receives 80% of rainfall during summer monsoon.

The southern trade wind when crosses the equator deflected to their right direction, then the S-E trade winds becomes S-W winds. The normal rainfall over this season in India is about 88 cm (Jun-Sept). It reaches first in Kerala; hence Kerala is called as gateway of India monsoon. The S-W monsoon has two branches.

1. ARABIAN SEA BRANCHES-

Arabian Sea branch strikes the western ghats of India at almost 90^0. The windward slope receives heavy orographic precipitation, however the westerlies current from Arabian sea continues its journey across Indian peninsula. But amount of rainfall continues to decrease on leeward side with distance from sea coast. These air currents ultimately unite with Bay of Bengal branch in northern India.

2. BAY OF BENGAL BRANCH (BOB BRANCH)-

One current of Bay of Bengal branch moves towards Assam and cause heavy rainfall in Mawsynram (near Cherrapunji) situated on the khasi hills (HIGHEST RAINFALL OF THE WORLD). One current of BOB branch recurved and advances up to the gangetic plane of Punjab. It is to be noted that rainfall decreases from east to west direction. The main reason of decrease in rainfall in west ward direction is because of increase in distance from the source of moisture.

WINTER MONSOON (N-E MONSOON)-

The secondary high-pressure system develops over Kashmir and Punjab. The high-pressure area controls the prevailing wind direction over the rest of the continent. Low pressure areas are developed over Indian Ocean, Arabian Sea and northern Australia due to high temperature. In the cold season, therefore there is pressure gradient from land to sea. As a result of which winds begin to more from land to sea. The Indian peninsula receives significant amount of rainfall during this monsoon season. The Tamilnadu state receives maximum rainfall during this season (47% of the total). This monsoon is also called as retreating monsoon. Normal rainfall is around 12 cm. Winter monsoon occurs during October to December months.

CHAPTER.2

AGROMETEOROLOGY

METEOROLOGY-

It can be defined as the study of physics of atmosphere. It is also called as weather science. It deals with day to day atmospheric conditions and their causes.

AGROMETEOROLOGY-

In the meeting of agrometeorologists in Moscow 1951, the definition of agrometeorology described as follow-

“It is the science which investigates the meteorological, climatological, hydrological conditions that are significant for agriculture.”

In brief, agrometeorology aims to put the science of meteorology to the service of agriculture in all its forms and facts for sustainable crop production.

SCOPE OF AGROMETEOROLOGY-

- Knowledge of agrometeorology is necessary for crop production as it is concerned with the interaction between meteorological and hydrological factors on one hand and agriculture on the other.
- It links the physical environment with biological processes under natural conditions to define an ideal environment for plant growth.
- The scope of agrometeorology is to make use of meteorology knowledge for sustainable agricultural systems.

IT’S IMPORTANCE-

- It has practical utility in timing of agricultural operations to make the best use of favorable weather conditions and adjust for adverse weather.
- The danger of crop production due to pest and disease incidence, occurrence of prolonged drought, erosion, frost and other weather hazards can be minimized.
- It also provides guidelines for long range or seasonal planning and provides the climatic conditions for crops and cultivates.
- Agrometeorological information can be used in bad use planning risk analysis of climatic hazards, production and harvest forecasts.

HISTORY-

IMD-India Meteorological Department

Established in-1875

Head Quarter-New Delhi

It has a second campus as agromet division in pune.

Established in-1932

WMO-World Meteorological Organization

Established in -1950

Head Quarter-Geneva, Switzerland

It was forming known as IMO (International Meteorological Organization) established in 1878.

*AICRPAM-All India coordinated research project on Agrometeorology. It was launched by ICAR at CRIDA in 1983, Hyderabad.

*NCMRWF- National center for medium Range weather forecasting. It was launched by Department of science and Technology (DST), New Delhi in 1988.

- According to Planning commission, India have been divided in to 15 agro climatic zones.
- According to NARP there are 127 agroclimatic zones.

RADIATION BALANCE ON THE EARTH-

Approximately 50% of solar radiation reaches earth surface.

- Incoming solar radiations are short wave& outgoing are long wave.
- Generally short wave radiation is infrared radiation and it have wave length between 1-30 µm. This is known as terrestrial radiation.

RADIATION BALANCE IN EARTH ATMOSPHERE-

Absorption by ozone (O_3)-3%

Absorption by water-13%,

Absorption by Cloud-2%

Absorption by ground-24%

Absorption by cloud-23%

Total=47%

Back scatter by cloud-24%

Back scatter by air, gases-7%

Back scatter by surface-4%

Total= 53%

So, total=53+47=100%

OUTGOING TERRESTRIAL RADIATION-

It has two parts-

1. Shortwave 2. Long wave

1. SHORTWAVE RADIATION (Incoming solar radiation)

Back scattering by cloud, gases-31%

Back scattering by surface-4%

Total=35%

2. LONGWAVE RADIATION-

Back Radiation-5 %(from ground)

Back radiation from clouds, H_2O, CO_2 -60% (GREEN HOUSE GASES)

So total =35 +65=100%

AT EARTH SURFACE-

168 watt/m^2 of solar radiation received on earth in every year and effectively radiated 66 watt/m^2 of longwave radiation to the atmosphere. Difference is +102 watt/m^2 is the net radiation gained by earth's surface and mainly released to atmosphere by evaporation.

Thus, at atmosphere, net radiation gain= -102 w/m^2/Year

Thus, atmosphere receives radiated energy per year is received by earth to maintain energy equilibrium. Vertical heat exchange occurs due to evaporation of water from the surface of the earth (heat losses) and by condensation in atmosphere (heat gain).

SOLAR RADIATION-

The solar energy that reaches the earth surface in the form of electromagnetic wave is called solar radiation. It is also called as shortwave radiation 99% of incoming solar radiation lies within the wave length range of 0.15 to 4 µm.

TYPES-

1. LONGWAVE RADIATION-

   Radiation having the wave length longer than 4 µm is called as long wave radiation. The radiation emitted by earth surface is called as long wave radiation. It is measured by pyrgeometer.
2. SHORT WAVE RADIATION-

   Radiation having the wave length ≤4µm is called as short-wave radiation. Incoming solar radiation is short wave radiation. Short wave radiation (Rs) is measured with the help of pyranometer. It can be computed by using following formula-

   $$Rs=Ra\ (a+b\ n/N)$$

   Where,

   Ra=Solar radiation at outer limit of atmosphere
   a & b are constant
   n=Actual sunshine hours
   N=Maximum possible sunshine hours

INSOLATION-

Incoming solar radiation is called as insolation. It consists mainly short-wave radiation which travels across 15 million km of space from sun to the earth. In space when it is travelling it does not increase the temperature of air or anything, because it is a short-wave radiation. When it struck and return from earth surface it starts heating by converting into long wave radiation.

Earth intercepts the tiny portion of sun radiation or earth absorbs only 0.0005% of sun radiation. Angle of incidence of sun rays varies from 0.90^0. As equator receive solar radiation at 90^0, so more temperature.

If incoming & outgoing radiation varies more then temperature increases.

E.g. In summer incoming is more, outgoing is less temperature increases and in winter its vice versa.

DURATION OF OUTGOING & INCOMING RADIATION-

In summer,

- During of incoming radiation is more so amount of energy is more (Temperature is slowly increases)
- Duration of outgoing radiation is less then amount of outgoing radiation is less.

In winter,

Its vice versa. (of summer)

FACTOR GOVERNING INSOLATION-

1. Solar output
2. Earth-Sun Relationship
3. Latitude (Latitude increases temperature decreases)
4. Cloud cover
5. Distance from the sea
6. Effect of elevation (mean sea level)

SOLAR CONSTANT-

Average amount received per unit area over a plane at the right angle to the solar beam per unit time at the outer most boundary of the atmosphere is referred as solar constant.

It usually gives the value about 1360 ± 20 watts per m^2 or 1.96 calorie per cm^2 per minute. Or $1360 \pm 20 w/m^2$ or 1.96 $cal/cm^2/min$.

EFFECT OF SOLAR RADIATION ON THE CROP PLANT-

Solar radiation is the energy source that sustain organic life on earth. Crop production is in fact an exploitation of solar radiation. The 3 broad spectra of solar energy described in this are significant to plant life.

The shorter than visible wave length radiation in the solar spectrum is chemically very active. When plants are exposed to excessive amount of this radiation, the effects are harmful. However, the atmosphere acts as a regular in this type of solar radiation and none of the cosmic, gamma and X-rays reach the earth. The ultraviolet radiation of this segment reaching the earth surface is very low and is normally tolerated by plants.

Solar radiation in the higher than visible wavelength segment, referred as infrared radiation has thermal effects on plants. In the presence of water vapour this radiation does not harm plants; rather it supplies necessary thermal energy to the plant environment.

The third spectrum, lying between the ultraviolet and infrared is the visible part of solar radiation and is referred as light. This segment of solar radiation plays an important part in plant growth and development through the processes of chlorophyll synthesis and photosynthesis and through photo sensitive mechanisms such as phototropism and photoperiodic activity.

Light of the correct intensity, quality and duration is essential for normal plant development. Poor light availability is frequently responsible for plant abnormalities and disorders. Virtually all plant parts are directly or indirectly influenced by this part of the spectrum. It affects the production of tillers, the stability, strength and length of the culms, the yield and total weight of plant structure and the size of leaves and root development. The length of day or the duration of the light period determines flowering. The majority of plants flower only when exposed to certain specific photoperiods. It is based on this response that the plants have been classified a short-day plant, long day plants and day neutral plants. When other environmental factors are not limiting it, photosynthesis increases with long direction of the light period.

REFLECTION, TRANSMISSION & ABSORPTION-

Reflection and transmission from the leaves have similar spectral distributions. The maxima for both are in the green light as well as in the infrared region. The impression of the green colour of the plants depends on the high reflectivity, high intensity of solar radiation and the greater sensitivity of the human eye for green light.

The strong infrared reflection from plants is an important natural device for protection of plant life against damage due to overheating. On average, the plant canopy absorbs about 75% of the incident radiation with about 15% reflected and 10% transmitted.

GREEN LEAF RESPONSE TO SPECTRAL RADIATION COMPONENTS-

Wave Length(μm)	Reflection (%)	Transmission (%)	Absorption (%)
0.34	9	0	91
0.44	11	2	14
0.58	14	10	76

0.64	13	9	78
1.0	45	50	5
2.4	7	28	65

It is also found that plant leaf strongly absorbs blue (0.45-0.492µm) and red (0.62-0.77) wave lengths, less strongly absorbs the green, very weakly absorbs the near infrared and strongly absorbs far infrared wavelengths.

The quality of radiation affects flowering, germination and elongation.

- Red light with a wave length of 0.66 µm is by far the most effective inhibitor of flowering in the case of long day plants.
- Red light helps mature apples to turn red.
- Germination of seeds is inhibited when they are exposed to green, blue and other short wavelength colours.
- However, germination is induced (increase) when seed are exposed to red portion of the spectrum. The red and infrared parts of the spectrum have reversible effects on seed germination.
- Stem elongation is promoted by exposure to far red wavelengths.
- U.V and Gamma rays have biological effects like it may kill microorganisms, disinfect the soil etc. It also (U.V ray) influence the germination and quality of seed.
- U.V and γ rays may leads to many irregularities in the growth and development of plants.

The solar spectrum can be divided into following 8 broad bands on the basis of the physiological response of plants.

Wave Length=λ

1. λ >1.0µm-
   Most of this radiation is absorbed by plants is transformed into heat without interfering with the biochemical processes.
2. λ is Between 1 to 0.7µm-
   Elongation effects on plants.
3. λ is Between 0.7 to 0.61 µm-
   Very strong absorption by chlorophyll, strongest photosynthesis activity and in many cases strong photoperiodic activity.
4. λ is Between 0.61 to 0.51 µm-

Low photosynthesis.

5. λ is Between 0.51 to 0.4µm-

   Strong chlorophyll absorption, strong photosynthetic activity and strong formative effects.

6. λ is Between 0.4 to 0.315µm-

   Produce Fluorescence in plants.

7. λ is Between 0.315 to 0.28 µm-

   Significant germicidal action, practically no solar radiation of wave length shorter than 0.29 µm reaches the earth surface.

8. λ<0.28µm-

Very strong germicidal action. Injurious to eye sight and when below 0.26 µm can kill some plants. No such radiation reaches the earth surface.

SOLAR RADIATION INTERCEPTION BY PLANTS-

Three aspects of solar radiation are biologically significant. The first is the intensity of radiation, the amount of radiant energy falling on a unit of surface area in a unit of time. The second is the spectral distribution of radiation that governs the photochemical process of photosynthesis. The third aspect is the radiation distribution in time, which is important for photoperiodic phenomenon.

The intensity of radiation and spectral distribution of radiation within crop canopies is important because of its control of the photosynthetic process and the microclimate of the plant community. The rate of photosynthetic is dependent on the availability of PAR. The rate of transpiration is also controlled by radiation energy.

The capture of radiation and its use in dry matter production depends on the fraction of the PAR. PAR is the amount of light available for photosynthesis which is light of 0.4 µm or 400 nm wave length to 0.7 µm or 700nm wave length. PAR changes seasonally and arises depending on latitude and time of a day.

Higher PAR promotes the plants growth and it is important to ensure that plants are receiving adequate light. PAR at night is 0. PAR values range from 0 to 300 millimoles/m^2. PAR is measured by silicon photovoltaic detector. Thus, detector measures the light in 400 to 700 nm range.

Intercepted radiation (Si) is often estimated as the difference between the quantity incident radiation (s) and that transmitted through the canopy of the soil (St).

Si=S-St

The quantity of radiation intercepted (Si) depends on the amount received by the canopy, canopy size duration and fraction interception (f). f is defined as Si/St.

FACTORS AFFECTING THE DISTRIBUTION OF SOLAR RADIATION WITHIN THE PLANT CANOPY-

The distribution of radiation in a plant canopy is determined by several factors, such as transmissibility of the leaf, leaf arrangement and inclination, plant density, plant height and the angle of the sun. Leaves of deciduous trees, herbs and grasses (including cereals) have transmissibility ranging from 5 to 10%. The broad leaves of ever green plants have a value 2 to 8%. Transmissibility varies slightly with the age of the leaf. The transmissibility of young leaf is relatively high. With the maturing of the leaf, it declines but then rises again as the leaf turns yellow. The transmissibility of a leaf directly related to its chlorophyll content.

Plant height is also having an important part. In case of young plants, the % of light interception is low but when height increases, interception of light by the canopy increases. This governs by Beer's law.

$I=I_0 e^{-kf}$

Where, I=Intensity of light at a particular height within the canopy

I_0=Intensity at the top

k=Extension coefficient

f=LAI

THERMAL EFFECT OF ENVIRONMENT ON GROWTH AND DEVELOPMENT OF PLANT-

The measurement of intensity of heat energy is called as temperature. The plant growth is greatly influence by temperature. Extreme temperature is destructive to the plants.

Plants are adopted to the wide range of temperature. Some species are capable to grow in extreme low and extreme high temperature.

The earth has divided in to three major zones.

1. Tropical 2. Temperate 3. Freeze
    1. TROPICAL ZONE-
       It is varying from 0^0-$23½^0$ in both hemisphere. It has certain range of temperature.
    2. TEMPERATE ZONE-
       It varies from $23½^0$ to 66.5^0 in both hemisphere.
    3. FREEZE ZONE-
       It varies from 66.5^0 to 90^0 in both hemisphere.

- Air temperature above 90^0F (22^0C) is most favorable to tropical plant but plant in temperate zone grown well between 15^0 to 22^0C.
- Physical and chemical process within the plant also affected.
- Solubility of different substance are depending on temperature.
- Day temperature may affect the grain productivity.
- In mountains temperature factors affected by snowfall etc. which also have effect on crop production.

CARDINAL TEMPERATURE-

Every plant community have own minimum, optimum and maximum temperature known as cardinal point or cardinal temperature.

This critical low and high temperature are required for better growth and development of plant. Flat or constant temperature is not suitable for growth and development of plant. They differ with various seasons.

OPTIMUM TEMPERATURE-

The temperature at which plant functions best is called optimum temperature or ideal temperature 18.3^0 to 23.9^0C.

MAXIMUM TEMPERATURE-

It is one that can tolerate without injury to the plant. At about 40^0C changes began to occur within the protoplasm. Temperature is between 45^0C-55^0C (most plant cells are killed at this temperature). Higher Temperature→Greater the rate of respiration →Rapid exhaustion of food reserves.

MINIMUM TEMPERATURE-

It is the temperature at which any plant may continue its activity. It is approximately freezing point of water. The tropical plant with stands 20^0C but frequently killed at 10^0C.

PHOTOPERIODISM-

It is the physiological reaction of an organism genes to the length of day and night. It occurs in plants and animals. It can also be defined as the developmental response of plants to the relative length of light and dark phase.

Many flowering plants use a photo receptor protein such as phytochrome and cytochrome to sense seasonal changes in night length or in photoperiod which they take as signals to flowers. In a further subdivision obligate photoperiodic plant absolutely required.

Short or long phase of light before flowering. Whereas facultative photoperiodic plants are more likely to flower under the appropriate light conditions but will eventually flowers regardless to the night length. Other than flowering photoperiodism in plants includes the growth of stems, roots, during certain season or loss of leaves. Artificial lightening should be used for long and extra-long days.

In 1920 W.W. Garner & H.A Allart publish a discovery on photoperiodism and felt the length of day and night is critical. Each plant has a different critical photo period (Night length is critical).

They are classified as-

a. SHORT DAY PLANT-

It flowers when day length is less than the critical photoperiod. They cannot flower under long day and if artificial light is shown on a plant several minutes during night. It required consolidated period of darkness before floral development can begin, Natural night time light such as moon light, lightening is not sufficient brightness or duration to effect flowering respectively.

In general, short day (long night) plants flowers as the day grows shorter and night grows longer. After 21stJune in northern hemisphere which is during summer.

Plants like cotton, rice, sugar cane etc. are short day plants.

b. LONG DAY PLANTS-

They typically flower in northern hemisphere during late spring or early summer as the days are getting longer. Longest day in northern hemisphere is on or about 21stJune after that day goes shorter and night goes longer till 21st December. These situations reversed in southern hemisphere.

Ex-wheat, Barley, Oat, lettuce, turnip etc.

EVAPORATION-

It is the process during which a liquid change in to a gas. Evaporation of water is a diffusing process in which liquid water is lost from natural surface (water bodies, bare soil, and vegetative cover) into vapour form to the atmosphere through the absorption of heat energy. The source of energy is may be solar energy or wind. The minimum energy required for evaporation 590 cal/gm of water at 20^{0}C.

ESSENTIAL REQUIREMENT FOR EVAPORATION-

1. Source of heat to vaporize the liquid water.
2. The presence of a vapour pressure concentration gradient of water between the evaporating surface and the surrounding air.
3. The evaporation occurs only when the vapour concentration at the evaporating surface exceeds that in the overlaying air. Dalton (1882) gave the concept of evaporation from a free water surface and said that evaporation is the function of the difference in the vapour pressure of water and the vapour pressure of surrounding air.

DALTON’S LAW-

$E=(e_s-e_d)\times f(u)$

E=Evaporation

e_s= Saturation vapour pressure at the temp. of evaporation surface (mmHg).

e_d= Surface vapour pressure at the dew point temperature (mmHg).

f(u)= Function of horizontal wind velocity.

FACTORS AFFECTING EVAPORATION-

1. Degree of wetness of surface
2. Temperature of air and soil
3. Atmospheric humidity
4. Wind velocity
5. Density of Vegetation

   At high moisture content, evaporation from land surface is nearly equal to that from free water surface it means evaporation is maximum. At lower moisture level evaporation decreases.

   If atmospheric temperature is higher then evaporation is higher. The evaporation from land surface is confined to shallow depth. Evaporation reduces rapidly with the increase in depth below surface. Mulches are effective in decreasing evaporation through reducing solar energy and restrict air movement near the soil surface.

TRANSPIRATION-

It is basically an evaporation process in which loss of water takes place from living green plant bodies in vapour form to the atmosphere. This process includes cuticular transpiration (Direct evaporation from moist membranes to cuticles) and stomata transpiration (outward diffusion of water vapour into the atmosphere through stomata). The water is lost primarily through stomata.

Transpiration is the dominant factor in plant water relations because evaporation of water produces energy gradient which causes movement of water into and throughout the plant.

FACTOR AFFECTING TRANSPIRATION-

1. Supply of energy for vaporizing water (Light intensity, heat energy and wind)
2. Water vapour concentration gradient between plant surface and atmosphere.
3. Resistance to diffusion in the vapour path way.
4. Plant factors- leaf area, leaf arrangement and structure, stomata behavior, efficiency of root system for water absorption.

EVAPOTRANSPIRATION-

It is the combination of loss of liquid water into vapour form from cropped or vegetative field. Under field condition incoming solar radiation supplies energy for ET process. Wind temperature and humidity condition also play important role in ET process. In addition to it all other factors which influencing evaporation and transpiration also govern the ET process. If demand of the atmosphere is high then rate of ET will also be higher. In evapotranspiration process, there are two terms.

1. Potential Evapotranspiration (PET)
2. Actual Evapotranspiration(AET)

1. Potential Evapotranspiration-

   It is the condition of ET in which water is lost from completely covered actively growing vegetation and there is no limitation of soil moisture. It is the upper limit of ET from a crop in a given climatic condition.
2. Actual Evapotranspiration-

   It is the AET or water loss occurring in a cropped field and greatly influenced by atmosphere, soil and plant factors in a given climate condition.

CONDITION RELATED TO AET AND PET-

1. AET< PET:

   It is due to limitation of atmosphere, soil and plant factors in a given climate condition. E.g., if soil moisture is low and there is no fully grown vegetative cover or if light intensity is less then AET < PET.

2. AET=PET:

When there is no limitation of soil moisture in actively growing vegetation and atmospheric demand is very high then AET=PET.

3. AET > PET:

   In sometimes AET>PET and it occurs due to advection of hot and dry air in peak summer season during mid-day.

CONSUMPTIVE USE (Cu)-

The term consumptive use is used to designate the losses of water due to evapotranspiration and the water that is used by a plant for its metabolic activities.

Since the water used in actual metabolic process is insignificant (about 1% of ET), the term CU generally taken equivalent to ET. It thus includes all water consumed by the plant + the water evaporated from bare land and water surface in the area occupied by the crop. The rate of average daily water consumption by vegetative cover is called as daily consumptive use rate and the average daily water use rate during few days of the highest consumptive use of the season is called the peak period of consumptive uses. The total amount of water used in ET by a crop during the entire growing season is called seasonal consumptive use. It is expressed as depth of water in cm or volume in cm/ha. Seasonal consumptive use varies are required to evaluate the seasonal irrigation requirement of any particular crop.

FACTOR AFFECTING CONSUMPTIVE USE-

A. CLIMATE FACTOR-

   Mainly solar energy, wind blowing over crop field, temperature and humidity condition over cropped field.

B. SOIL MOISTURE CONDITION-

   If soil moisture increases the Cu is also increases.

C. CROP FACTORS-

   i. Plants structure, stomatal distribution and leaf orientation.
   ii. Cuticular and stomatal resistances.
   iii. Stages of crop growth.

If the other factors being equal the stage of a crop growth influences its consumptive use rate. These are-

a. Emergence to development of complete vegetative cover, then Cu rate increases rapidly.
b. Maximum vegetative Cover- Cu rate will maximum and constant if there is adequate soil moisture.
c. Crop Maturity Stage- The rate of Cu decreases with maturity stage of crop.

METHODS FOR MEASUREMENT OF EVAPOTRANSPIRATION-

1. FIELD WATER BALANCE METHOD-

   Field water balance is an account of all quantities of water added to, subtracted from and stored within the root zone during a given period of time. The difference between the total amount added and that withdrawn must equal to the change in storage. When gain exceeds losses storage increases, in opposite to it when losses exceeds gains storage decreases. Thus,

$$\text{Accretion} = \text{Gains} - \text{Losses}$$

This general equation can be written as-

Eqn (i) dS= (P+I+U)-(R+D+E+T)

Where,

dS= Change in soil water storage in the root zone.

P=Precipitation

I=Irrigation

U=Upward capillary flow into the root zone from below.

R=Run off

D=Down ward drainage beyond the root zone.

E=Direct evaporation from soil surface.

T=Transpiration by Plants.

All quantities included in the field water balance are expressed in term of volume of water per unit area (Equivalent depth unit) during period considered. In principle, the field water balance seems to be simple and readily understandable. It is rather difficult to measure in practice. To obtain ET from the water balance we must have accurate measurement of all other terms of ET to represent ET in crop field under shallow water table condition then the equation is as follow-

Eqn (ii) ET= P+I+U- dS-R-D

From a crop field under deep water table condition U is assumed to be 0 and ET can be computed using water balance eqn (iii) as follows-

Eqn(iii) ET=P+I-R-dS-D

For dry land condition, I=0 and therefore third eqn. can be written as-

Eqn(iv) ET=P-R- dS-D

If the fields are plain and bunded then R is assumed to be 0 and ET is written as below-

Eqn(v) ET=P- dS+D

Hence after knowing all the condition of equation, ET can be computed by using the water balance equation.

LIMITATIONS-

1. Water balance method is not used for daily estimation. It should be weekly or monthly.
2. Computation of rain water and surface runoff cannot be done on daily basis.

MEASUREMENT OF COMPONENTS OF WATER BALANCE-

1. PRECIPITATION-

   Snowfall and rainfall are the major form of precipitation. In north India rainfall is the major form of precipitation and measured by rain gauge.

2. IRRIGATION-

   Irrigation water is measured by parshall flume. It is a device in which discharge is obtained by measuring the loss in head caused by forced stream of water through converge section of a flume.

The simplified equation for discharge of irrigation water (Q) through parshall flume is $Q=4WHa\ (0.522W)^{0.226}$

Where,

Q=Throat width

Ha=Head at converge section

3. RUN OFF-

   The rational method is the simplest method for estimation of run off.

$$Q=CIA$$

Where,

Q=Peak runoff rate (m/s)

C=Run off Coefficient (per ha)

I=Rain fall intensity (mm/hr)

A=Area of watershed (ha)

4. DRAINAGE-

   It is measured with Lysimeter. Downward flux of water is calculated by hydraulic conductivity.

$$Vz=K\ (1+dh/dz)$$

Where,

Vz=Down ward flux of water (cm/s)

K= Hydraulic conductivity (cm/s)

dh/dz=Rate of change of soil water section with depth (z)

5. UPWARD MOVEMENT OF WATER-

The upward movement of water through the soil is commonly known as capillary rise(Uz).

$Uz=a(d\psi/dz-1/(\psi n+b)$

Where,

For saturated soil $\psi=0$

Ψ (psi)=Water potential

a, b, n=Constant

z= Height above water level

SOIL MOISTURE DEPLETION METHOD-

Soil moisture depletion technique is usually employed to determine the consumptive use of irrigated field crops grown on fairly uniform soil, where the depth of ground water is such that it will not influence the soil moisture fluctuation within root zone. This technique involves the measurement of soil moisture of various depth in effective root zone at a number of times throughout the crop growth period. The greater the number of measurement more will be accuracy. By summing moisture depletion of each of the soil layer and for each interval for the growth period ET can be found as-

$$U= \sum_{i=1}^{n}(\mathrm{M1}-\mathrm{M2})/100 \times \mathrm{Bi} \times \mathrm{Di} + \mathrm{Ei}$$

Where, U=Moisture depleted from soil profile at a certain interval (cm)

M1= Moisture content (%) in the i^{th} layer at the time of first sampling

M2=Moisture content (%) in i^{th} layer at the time of next sampling.

Bi=Bulk density of the i^{th} layer (gm/cm^3)

Di=Depth of i^{th} layer (cm)

Ei=Effective rainfall (cm) between irrigation day and sampling day.

The water used for crop growth period is determined by adding moisture depleted (Ui) during all intervals.

$$\mathrm{ET}=\sum_{i=1}^{n}\mathrm{Ui}+\mathrm{CPE}$$

CPE=Cumulative pan evaporation between irrigation rate and sampling rate.

LIMITATIONS-

1. This method is labour intensive (more labour).
2. It cannot be employed under shallow water condition.

INSTRUMENTS USED FOR MEASUREMENT OF SOIL MOISTURE-

1. Tensiometer
2. Neutron meter
3. Dielectric units
4. Resistance blocks
5. Heat conductivity units
6. Calorimetric units

These instruments or equipments with their mechanical/electronic device are placed progressively at different depth. Initially, so that moisture records can be obtained every day at scheduled times. Among these the neutron meter is very useful because it has a wide range of moisture determination.

Moisture content using Neutron meter is calculated as

$$Mv= (Rs/Rstd)b-j$$

Where,

Mv=Volumetric moisture content (cm).

Rs=Observed counts per minute in soil.

Rstd=Standard counts per minute in the shield.

b and j= Calibration factors

Ex- Compute the moisture content by using following data -

Rs=4000 counts/min

Rstd=5000 counts/min

b=0.3, j=0

So, $Mv= (4000/5000)0.3-0$

$=0.24$cm

ATMOMETER-

An atmometer or evaporimeter is a scientific instrument used for measuring the rate of water evaporation from a wet surface to the atmosphere. Atmometers are mainly used by farmers and growers to measure evapotranspiration rates of crops at any field location.

Atmometer measures water loss by evaporation of water from surface like porous filter paper (Piche atmometer), porous porcelain sphere and plates (Bellani types). These instruments is over sensitive to wind speed and less responsive to radiation.

ADVANTAGES-

1. Low Cost
2. Convenience
3. Easy Operation
4. No computer or power required

DIS ADVANTAGES-

1. Potential weather damage can occur to the device.
2. Constant need to refill water supply.
3. Gauge must be read manually.

USWB OPEN PAN EVAPORIMETER-

It can be easily maintained and less expensive. Being directly exposed to atmosphere, adjustments for any rainfall received have to be made besides a correction factor (pan coefficient). Potential evapotranspiration represents mean value over a period is calculated as-

$$PET=K_{pan} \text{ x } E_0$$

Then,

$$ET = KC \text{ X } PET$$

Where, E_0=Pan evaporation (mm/day)

K_{pan} =Pan Coefficient (0.8)

ET= Actual Evapotranspiration (AET)

KC=Crop Coefficient.

Ex: Compute ET-

E_0=10 mm/day, K_{pan} =0.8, KC=0.85

Then, ET=6.8 mm/day

LIMITATIONS-

1. In arid and semi-arid locations where advection is considerable, the pan may give unrealistically low values.
2. Use of screens reduces the radiation and wind effect on evaporation.

LYSIMETER-

It is a device used for direct measurement of E/ET from land/vegetation surface. A lysimeter is a tank (1.2mdeep) and 1-6m in length and breadth in which an undisturbed block of soil and vegetation is located and its water balance is carefully monitored and controlled. The changes in the weight of lysimeter is monitored by either a sensitive balance installed underneath or by a manometer measuring difference of hydrostatic pressures. In a floating lysimeter, soil tank is floated on the liquid and difference in weight (dW) is determined by fluid displacement.

IT IS OF TWO TYPES –

A. Non- weighting type (floating) or drainage type.
B. Weighing type (Gravimetric)

WEIGHING TYPE-

Structure –The weighing type lysimeter consists of following parts.

1. LYSIMETRIC TANK-

   It is a steel tank of size 1.3 x 1.3 x 0.9 m contains undisturbed block of soil in which the plants are grown. The tank carries a perforated plate at a depth of 75cm so as to form a hollow chamber at the bottom. A tube is inserted through the perforated sheet into the bottom of hollow chamber to facilitate the removal of percolated water by pumping. This lysimeter tank is maintained on weighing balance.
2. RETAINING TANK

   It is used to protect the lysimeter tank from the seepage of water from the main field. It size is 1.4 x 1.4 x 1.25 m.
3. DUMMY TANK-

It is of size 0.3 x 0.3 x 0.9 m is placed near the gap between lysimeter tank and weighing machine pillar. It prevents overheating of the lysimeter tank near the weighing pillar.

4. WEIGHING MACHINE (2 TONNE CAPACITY MACHINE IS USED)-

The lysimeter is installed in the middle of the experimental field. It is filled with the same soil as in the field. The plants are grown with same spacing, density as in the field. when main field is irrigated then lysimeter plants are also irrigated. On first day, the weight of lysimeter is recorded and from the next day change in the weight is recorded (change in weight is negative when water losses & +ve when rainfall occurs).

The ET through lysimeter can calculated as under:

ET= dW × 0.6 + Rain fall

When, dW= Change in weight of lysimeter (it is +ve in case of loss of weight and -ve in case of gain of weight)

0.6=Conversion factor.

For close relationship of ET and Crop water loss, the lysimeter must be surrounded by same crop area. For short crop lysimeter volume is $1m^3$, for tall crop (sugarcane) lysimeter volume is $4m^3$.

LIMITATIONS-

1. These are costly which limits their wide use and multiple installations.
2. Maintenance is costly and combustion.

EMPIRICAL/STATISTICAL METHODS FOR ESTIMATION OF PET-

Based on weather elements like temperature, day light, vapor pressure deficit, humidity, wind velocity etc. Several empirical formulas have been developed from time to time.

These empirical formulas represent a simple mathematical and statistical relationship between ET and meteorological parameters without due record to a system. Of these the method of Thornthwaite, Papadakis, Hamon, Makkink, Jensen and Haise, Blaney Criddle, Turc, Stephens and Stewart and Grassi & Linaere methods are important.

1. THORNTHWAITE METHOD-

Thornthwaite (1948) gave the following formula for computing ET.

$E=1.6(10T/I)^a \text{ x } (D/12) \text{ X } (N/30)$

Where, D= Days

N=Hours

For a month consisting 30 days and 12 hours a day, the above equation can be written as, $E=1.6(10T/I)^a$.

Where, E=Unadjusted PET (cm/min)

T=Mean air temperature (^{0}C)

I=Annual heat index (it is the sum of 12 values of monthly heat index)

For daily computation equation is modified as-

$PET=\frac{K \times E \times 10}{30}$(mm/day)

Where, K= Adjustment factor.

LIMITATIONS-

1. The calculated PET is under estimated at the time of annual maximum radiation reception during summer.
2. Application of method to short time period often leads to serious error.

2. PAPADAKIS METHOD (1965)-

For computation of daily PET, can be written as-

$PET=[0.5625(e_{max}-e_{min}-2) \times 10]$/No of days in month.

Where, PET= Daily PET (mm)

e_{max}=Saturation Vapour Pressure (mb) corresponding to daily max. temperature.

$e_{min}-2$= Saturation vapour pressure corresponding to dew point temperature (mb).

3. HAMON METHOD-

Hamon gave the following formula for PET estimation-

$PET=0.0055(D/12)^2[217ed \times 2.88/T] \times 25.4$

Where, PET-Daily PET (mm)

D= Day Length (hrs)

ed= Actual vapour Pressure (mb)

T= Mean air temperature (^{0}k)

4. MAKKINK METHOD-

PET=Rs[(S/γ)/ (S/γ+t)] + 0.12

Where,

PET=Daily PET (mm)

Rs=Solar Radiation in water Equivalent.

S= Slope of saturation vapour pressure vs temperature.

γ=Psychrometric Constant.

5. BLANEY CRIDDLE METHOD-

Blaney Criddle in 1950 proposed following formula for PET Calculation-

PET=(0.0173Ta-0.314) Kc × Ta (D /446.56)25.4 (mm/day)

Where,

Ta=Mean air temperature (^{0}k)

Kc=Crop Coefficient

D=Day length

LIMITATIONS-

1. This method does not account for climatic parameters which greatly influence PET.
2. The value of Kc varies from plant species, place of the crop and crop growing stage.

6. TORQUE METHOD-

He gave the following formula for estimation of daily PET.

PET= 0.40Tc (RI+50)/(Tc+15) N

Where,

Tc= Mean air temperature

RI=Solar Radiation

N=No. of days in month

MEASUREMENT OF EVAPORATION-

The pan evaporimeter is most widely used instrument for measurement of evaporation from free water surface. The rate of evaporation from an open water surface can be expressed as the volume of water evaporated per unit area in unit time. For a given area this is proportional to the depth of water lost in unit time from the whole area. Evaporation is usually expressed in unit of depth of water lost in mm per day (mm/day).

The class ‘A’ pan evaporimeter measures evaporating powers of air layer near the ground.

PRINCIPLE-

The class ‘A’ pan evaporimeter is an instrument for measuring amount of water lost by evaporation per unit area in a given time interval from a shallow container.

The amount of water lost by evaporation from pan in any given interval of time is measured by adding known quantity of water to the pan from a graduated cylinder (Scaled cylinder) till the water level touches the reference point. The amount of water added equals amount of water lost by evaporation from pan and this divided by the time interval provides the rate of evaporation.

DESCRIPTION-

The pan with 122cm in diameter and 25.5 cm deep is made of copper sheet which is tinned inside but maintained white outside. A stilling well provides an undisturbed water surface around the point of fixed point gauge for breaking any ripples that may be present on the water surface in the pan. The stilling well has 3 small holes in the bottom which permit the flow of water from or into the stilling well. The reference point is provided by brass rod, fixed at center of the stilling well and tapered (become narrower) to end in a point exactly at 190mm from the base. The pan rests on a white painted wooden base which keeps the pan protected in rainy season and there will be no effect of soil temperature and water bodies.

The pan is covered with a wired mesh so that there is no loss of water from pan due to birds and animals. A thermometer is fixed and it measures the surface temperature of water.

The measuring cylinder with which water is poured into the pan has a gradual scale of 0 to 20cm. It has a diameter of 1/10 of that of pan, so that the cross-section area of the cylinder is exactly 1/100 that of pan and thus adding 200mm of water from cylinder will raise 2mm level of pan water.

PRECAUTIONS-

1. Wire mesh should be tight and painted.
2. Temperature of evaporating surface should be recorded.
3. The outside surface of pan will always have painted white to reflect radiation falling on the instrument.

MICROMETEOROLOGICAL METHOD FOR ET ESTIMATION-

These methods are developed with micrometeorological observations which can be measured using sophisticating instrument at various level inside the crop canopy. These methods facilitate more accurate estimation of ET as compared to empirical method. The important methods are as below.

A. MASS TRANSPORT METHOD-

Penman (1948) proposed the following equation for ET estimation.

$E_0=0.40(e_s-e_a)\ (1+0.17u_2)$

Where,

E_0=Potential evaporation(mm)

e_s=Saturated vapour pressure

e_a=Actual vapour pressure

u_2=Wind speed at 2m height (miles/hr)

Ex-Calculate the potential evaporation using following data e_a=10.9mm Hg, e_s=12.24mm Hg, u_2=48 miles/hr.

So,

E_0= 0.40 (12.24-10.90) (1+0.17×48)

= 0.40(1.34) (1+8.16)

= 4.90976mm

= 4.91mm

B. AERO DYNAMIC METHOD-

Thornthwaite and boltzman in 1939 proposed the following formula involving specific humidity (q) and logarithmic wind profile.

$E=\rho_a k^2(q_1-q_2)(u_2-u_1)/[\ln(z_2/z_1)]^2$

Where, E= Evaporation (mm/hr)

ρ_a= Density of air (kg/m^3)

K= Vonkarman's constant=0.41

q_1 and q_2= Specific humidity at height z_2 and $z_1$respectively (gm/kg)

u_2 and u_1= Wind speed (m/s) at height z_2 and $z_1$respectively.

Q. Calculate the rate of evaporation with the data set given: ρ_a=1.3kg/m^3, K=0.4, q_1=7.73 gm/kg. q_2=6.7 gm/kg, u_1=1.34 m/s, u_2=1.63 m/s, z_2=2m,z_1=0.5m.

Sol. Formula to be used: $E=\rho_a k^2(q_1-q_2)(u_2-u_1)/[\ln(z_2/z_1)]^2$

So, by using formula and input the values.

$E=1.3 \times (0.4)^2(7.73-6.70)(1.63-1.34)/[\ln(2/0.5)]^2$

$=1.3 \times 0.16 [(1.03)(0.29)]/[\ln 2-\ln(0.5)]^2$

$=1.3 \times 0.16 [(1.03)(0.29)]/[\ln 2-\ln(5/10)]^2$

$=1.3 \times 0.16 [(1.03)(0.29)]/[\ln 2-\ln(½)]^2$

$=1.3 \times 0.16 [(1.03)(0.29)]/[\ln 2-(\ln 1-\ln 2)]^2$

$=1.3 \times 0.16\ [(1.03a)\ (0.29)]/\ [\ln 2+\ln 2-\ln 1]^2$

$= 0.208(0.2987)/(0.3010 + 0.3010-0)^2$

As log2=0.3010 and log1=0

$= 0.2080(0.297)/\ (0.6020)^2$

= 0.2080(0.2987/0.3624)

= 0.2080 x 0.824

= 0.17 mm/hr.

So, E=0.17 mm/hr.

ENERGY BALANCE BOWEN RATIO METHOD FOR ET ESTIMATION-

Energy balance is the partitioning of net radiation available over the earth surface into different component viz-latent heat flux (LE), Sensible heat flux (A), ground heat flux (G) and Plant metabolic activities (Mi). Since the energy utilized in plant metabolic process is negligible, that is less than 1% of net radiation or net energy. So, we generally consider LE, A and G Components and eliminate plant metabolic process in the final energy balance equation.

The basic energy balance equation can be written as under:

Rn=LE+A+G+Mi ----------------------------------- -eqn(i)

Where,

Rn=Net Radiation

A=Sensible heat flux

G=Ground heat Flux

Mi=Energy utilized in plant metabolic activities

LE=Latent heat flux.

As described above that energy used by plant metabolic activities is less than 1% of net energy.

Then the final eqn. is = Rn = LE + A+G------------------------ Eqn (ii)

The Bowen ratio (β) is the ratio of sensible heat flux to latent heat flux.

So, β= A/ LE= γdT/de

dT and de are temperature and vapour pressure difference at two levels of crop canopy.

So, A= βLE, by putting the value of A in equation (ii)

= Rn = LE+βLE+G

= Rn =LE(1+β) +G

= Rn-G =LE(1+β)

Now,

LE=Rn-G/1+β --Eqn (iii)

Now The value of sensible heat flux (A) = $\rho_a C_p K_h dT/dz$

$LE=L\varepsilon K_v de/dz$

Where,

ρ_a= Air density

Cp= Specific heat of air

L= Latent heat of evaporation

ε= Mixing ratio

K_h and Kv= ET diffusing co-efficient

dT/dZ= Temperature gradient

de/dz= Vapour pressure gradient

So as β= A/LE

$\beta = \rho_a C_p K_h dT/dz / L\varepsilon K_v de/dz$

Now assume that K_h and Kv are equal: K_h=Kv

So, $\beta = \rho_a C_p K_h dT/dz / L\varepsilon K_v de/dz$

= $\beta=\rho_a C_p dT/L\varepsilon de$

As, $\rho_a C_p/L\varepsilon = \gamma$

So, $\boldsymbol{\beta=\gamma \; dT/de}$

IMPORTANTANCE OR SIGNIFICANCE OF ENERGY BALANCE METHOD-

1. This method is very useful to evaluate latent heat under a variety of condition.
2. It is very useful because it depicts the interaction of the soil plant with the micro climate above.
3. If water is available then β value will be small. The β value at sufficient moisture condition varies from + 0.1 to -0.1 generally. Under drought condition β value will be large. Under advection β value will be negative.

DISADVANTAGE-

1. The temperature gradient and vapour pressure gradient measurement is quite difficult.
2. It requires sophisticated instruments.

RELATION BETWEEN ET AND CROP PRODUCTION-

The ET is directly related with crop yield and ET is dependent on soil moisture also. When the soil moisture is fully available then ET is nearing to PET. When soil moisture gets depleted the ET also simultaneously gets reduces. This indicates that there is a bio regulation in the crops, so should have soil, plant and water continuum (measurement). In other words, physiological, biochemical, biological activities of crop plants are also adjusted based on soil moisture reserve and based on potential demand of atmosphere. Hence the study on ET is important considering the followings-

1. Critical need of the water for different phenological stage of the crop could be understood.
2. The actual quantity of water needed by the plant at critical stages could be quantified.

3. Scientific irrigation management practices could be introduced so as to increases the water use efficiency (WUE) as the context of change in hydrological cycle due to climate change or some other change.
4. Interstate river water dispute could be solved.
5. The effectiveness of agronomic practices with reference to ET and crop yield could be experimentally quantified.
6. Further research can be promoted based on ET study of the crops i.e., ET of pulse crop is around 400mm, under this situation the potential yield does not cross 500kg/ha, while in case of rice crop average yield is 4-5 tons/ha, with an ET value of more than 1300 mm. This naturally brings the philosophy that ET is directly related with yield.

IMPORTANT TERMS UNDER ET-

1. LATENT HEAT-

   The heat released or absorbed per unit mass by a system during change of phase. In meteorology at 0^0C, the latent heat of vaporization, latent heat of fusion and sublimation of water are about 600, 80 and 680 calories per gm respectively.
2. REFERENCE CROP EVAPOTRANSPIRATION (ET_0)-

   The rate of ET from an extended surface of 8-15cm tall green grass covers a uniform height, actively growing completely shading the ground and not short of water.
3. TRANSPIRATION RATIO-

   The effectiveness of the plant in the use of water is often given in terms of its transpiration ratio. This is the amount of water transpired by a crop in its growth to produce unit weight of dry matter.

CHAPTER.3

METEOROLOGICAL INSTRUMENTS

METEOROLOGICAL OBSERVATIONS-

The meteorological observations of rainfall, air temperature, soil temperature, soil moisture, humidity, evaporation, evapotranspiration, cloudy rains, radiation, sunshine hours, dew, wind speed and direction. The occurrence of phenomenon like thunderstorm, hailstorm, dust storm, frost, cold wind, drought and flood are also weather abnormal features affecting agricultural production. Therefore, the record of meteorological observation of experimental area must include daily observation as well as abnormal weather features to interpret the relationship.

OBSERVATORY-

It is a place for recording meteorological observations.

METEOROLOGICAL OBSERVATORIES-

IMD has three types of meteorological observatory spread all over the country with central forecasting and training station at Pune.

These are of three types-

1. CLASS ‘A’ TYPE-

At these stations, continuous record of weather elements is made. These observatories are provided with manual and self-recording instruments.

ITS MAIN ACTIVITIES-

a. Recording large number of meteorological parameters related to agriculture.
b. Preparation of agroclimatic areas and measurements of evaporation.
c. Balloon observation is also recorded at some of these stations (Temperature, pressure, relative humidity).

It is also called as principal agrometeorological observatory.

2. CLASS ‘B’TYPE- At these observatories, observations are made twice a day for various weather elements. These are also provided with eye reading and self-recording instruments. It is also called ordinary Agrometeorological observatories.

There are two types of observatories in this category.

a. CROP WEATHER OBSERVATORIES-

These observatories record side by side meteorological data on growth and yield of one or more major crops (rice, sorghum, wheat, cotton, sugarcane) according to standard plan. Then the data are sent to agromet division, Pune, where these are compiled and weather relationships will be drawn.

b. NON-CROP WEATHER OBSERVATIORIES-

This class includes-

1. Agrometeorological observatories located at soil conservation research and demonstration centers.
2. Agrometeorological observatories located at agricultural schools, colleges and Universities.

The NARP (National Agricultural Research Project) divided the country into 127 agro climatic zones with a regional agricultural research station (RARS) for each agro climatic zone.

3. CLASS ‘C’ TYPE-

The C-type observatories or Auxiliary agrometeorological observatories send qualitative data on pest and diseases. These observatories are usually agricultural farms.

AGRICULTURAL METEOROLOGICAL NETWORK-

The agrometeorological stations are divided into 5 categories-

1. Ordinary agricultural meteorological stations
2. Auxiliary agricultural meteorological stations
3. Principal agricultural meteorological stations
4. Pilot balloon cum micro meteorological stations
5. Evapotranspiration stations

SOME USEFUL TERMS-

1. Altitude- Vertical height above sea level.
2. Equator- It is the imaginary line lying midway between the poles on the earth surface. It is also the longest circumference of the earth.

3. Latitude- It is the distance of a place in north and south of the equator. It runs from west to east and parallel to the equator, at 1^0 intervals 360 latitudes are drawn.

4. Longitude- It is the distance of a place east or west of prime meridian.

*Indian standard time (IST) is calculated from longitude of Allahabad. Longitude of Allahabad is 82 ½ degree East (82.5^0E).
*Prime meridian passes through Greenwich of London.

5. Poles- The two points at northern and southern extremities of the earth known as North Pole and South Pole respectively.

6. Local time- It is calculated by the calculation of the position of sun. It is also called as solar time. In view of the rotation of the earth from west to east on earth axis, place lying on the same latitude will thus have same noman and same local time. As the earth rotates through 360^0 once in 24hrs, local time changes by an hour for every 15^0 longitudes.

So, 15^0=1hr (60mins)

15^0 = 60mins

So, 1^0 =60/15=4mins.

7. Standard time- The surface of the earth is divided into 24 zones according to the hours in a day, these are called time zones and each zone extends over 15^0 longitudes. In India longitude is 82.5^0 East near Allahabad is selected for Indian standard time (IST).

8. GMT (Greenwich Mean Time)- It Means time measured from Greenwich situated on 0^0 Longitude in U.K.

AGROMETEOROLOGICAL WEATHER ELEMENTS-

The main objective is to set up an agricultural meteorological observatory is to take observations of the following weather elements characterizing the agricultural environment influencing the growth and development of different biotic factors-

1. Solar radiation and sunshine / cloudiness
2. Air and soil temperature
3. Relative humidity / dew point
4. Wind speed and wind direction
5. Soil moisture

6. Evaporation (E)
7. Evapotranspiration (ET)
8. Precipitation (Rain, snow, hail, drizzle)
9. Microclimatic Observations
10. Continuous record of rainfall, temperature, humidity with self-recording devices.

SELECTION OF SITE FOR AGROMETEOROLOGICAL OBSERVATORY-

Following points must be kept in view-

1. The ideal site of an agromet. observatory is well exposed, bare leveled plots having length of 55m in north-south direction and breadth of 36m in east-west direction.
2. The agromet observatory should be located more or less at the center of research farm.
3. The plot should represent the natural soil topography free from any salts and concretion layers.
4. The observatory should well away from high mountains, buildings, trees, high structure, main irrigation channels, rivers, water tanks.
5. Site should be free from water lodging area.
6. Proper fencing of observatory should be done around site.

The observatory is established with standard meteorological instruments. The important characteristics for selection of instruments are-

1. Reliability
2. Accuracy
3. Sensitivity
4. Simplicity of design
5. Convenience of operation and maintenance

AGROMETEOROLOGICAL INSTRUMENTS ARE DIVIDED INTO 4 CATEGORIES-

1. Conventional (traditional) and ordinary instruments
2. Self-recording instruments
3. Semi-automatic instruments
4. Fully automatic data collection systems

DETAILS OF AGROMETEOROLOGICAL INSTRUMENTS

Sl. No.	WEATHER PARAMETER	NAME OF INSTRUMENTS	ACCURACY	OBSERVATION FREQUENCY	TIME OF OBSERVATIONS
1	Rain fall	a. Ordinary rain gauge b. Self-recording rain gauge	±0.2 mm ±0.5 mm	Twice daily Continuous (24hrs)	08:30 & 14.30 IST Chart Setting at 08:30 IST
2	Air temperature	a. Maximum thermometer b. Minimum thermometer c. Bimetallic Thermometer d. Grass minimum thermometer	±0.5℃ ±0.5℃ ±0.25^{0}C ±0.5℃	Twice Daily Twice Daily Continuous Once Daily	07:00 & 14:00 IST 07:00 & 14:00 IST Continuous (Chart Setting at 08:30 IST) Just before sunrise
3	Evaporation	USWB Open pan Evaporimeter	±0.1 mm	Twice daily	08:30 & 14:30 IST
4	Relative Humidity (R.H)	a. Dry & Wet bulb thermometer b. Assmann Psychrometer c. Hair Hygrograph	±0.1^{0}C ±0.1^{0}C ±2%	Twice daily Twice Daily Continuous	07:00 & 14:00 IST 07:00 & 14:00 IST Chart setting at 08.30 IST
5	Wind speed	Cup anemometer	±0.1Km	Twice Daily	07:00 & 14:00 IST
6	Wind direction	Wind vane	±10^0	Twice Daily	07:00 & 14:00 IST
7	Sunshine duration	Sunshine recorder	1 meter/ hour	Continuous	Card fitting before sunrise
8	Soil Temperature	Soil thermometer at different depth	±0.1^{0}C	Twice daily	07.00 & 14:00 IST
9	Dew	Dew gauge	±0.1 mm	Once daily	Before sunrise
10	Microclimatic data	Assmann Psychrometer	±0.1^{0}C	Based on requirement	--------------------

OBSERVATORY TIMINGS-

In agromet observatory some observations are to be recorded at 07:00hrs and 14:00hrs LMT (Local mean time of Allahabad). This is also IST of Allahabad. To find out LMT of different stations we should first find the difference between the longitude of a particular station with respect to Allahabad longitude as,

$LMT=IST\pm4 \times(82^0 30^{\prime}E\text{-Station longitude})$

Where, /=Minute

The timing of observation for rainfall and evaporation is at 08:30 & 14:30 IST.

GENERAL PRECAUTIONS FOR INSTALLATION OF METEOROLOGICAL INSTRUMENTS-

1. All the tall instruments should be kept on north side of the observatory so that their shadow may not fall on the other instruments.
2. The face of the Stevenson screen is always open in the north direction in northern hemisphere, so that the direct solar radiation may not fall on the instrument while recording the observation.
3. All the instruments should be installed according to the norms and instruction of IMD.
4. Soil thermometer should always face south direction in northern hemisphere.
5. The instrument should be properly well spaced.

Measurement of rainfall-

Rainfall is measured in term of depth of rain water (in mm) on a solid surface if rain water neither allowed to percolate nor runoff nor lost in any form. The device used for measurement of rainfall is called rain gauge.

There are two types of rain gauges-

1. Ordinary or non-recording type rain gauge.
2. Recording or Self-recording type rain gauge.

1. ORDINARY RAIN GAUGE-

The instrument is designed to measure the rainfall amount. It is simple and easy instrument to operate. The standard rain gauge is Simon’s pattern widely accepted all over the world.

It consists of a collector with a gun metal rim funnel, a base and a bottle. The collector has a deep-set funnel and the complete rain gauge has a slight tapper with the narrower portion at the top. The rain gauge has the capacity of 200mm of rainfall.

The amount of rainfall collected by the gauge is measured with help of a measuring cylinder known as rain measure. Separate rain measures are available for 100cm^2 and 200cm^2 collector rain gauges. For a 100cm^2 collector (diameter-112.9mm) 100cc of water is equal to 10mm of rain fall.

For 200 sq cm collector, 200 cc of water is equal to 10mm of rain.

INSTALLATION-

The rain gauge is placed on a leveled ground at the standard height of 30cm above the ground surface. The structural work is constructed with the standard principles.

PRECAUTIONS-

a. The rain water should be poured carefully into the rain measure taking care to avoid spilling of any drop of water.
b. The rain gauge should be placed on a horizontal surface while recording rainfall.

2. SELF RECORDING RAIN GAUGE-

There are three types-

a. Tipping Bucket type
b. Weighing Type
c. Floating Type

This instrument is designed for giving continuous recording of rainfall with time. It can be used to find out total amount of rainfall, time of onset and closing of a rainy event and intensity of rainfall.

PRINCIPLE-

Rain water entering the gauge at the receiving funnel is carried through a filter to a receiver consisting of a float and syphon arrangement. The pen is mounted on the stem of float. As the water level rises in the receiver the float rises and record the rain on the graph fixed on a clock mounted drum. The clock drum records once in 24hrs, so that continuous record of rainfall curve is obtained. The vertical scale of the graph records the amount of rainfall and after 10 mm of accumulated rainfall the syphonic action take place with draining of the water. The pen will be come to the bottom of the graph. It again rises by receive of rainfall. If there is no rain the pen draws a horizontal line. The slope of rainfall curve gives the intensity of the rainfall with time.

INSTRUMENT DESCRIPTION-

The main parts are-

1. Float Chamber

2. Funnel
3. Strip of bottom of float
4. Entrance tube
5. Float
6. Float rod
7. Clock drum
8. Syphon chamber and tube
9. Chart no-395 is used for harvesting 10mm capacity of rainfall scale on vertical side.

OPERATION-

The chart of the rain gauge is daily changed at 08.30 IST. The pen should be set at 0 reading after pouring sufficient water into the receiver till the pen reaches the top of the chart and water is drained out by syphonic action. The pen should be cleaned and use fresh ink every day for good marking on chart paper.

THERMOGRAPH-

It is an automatic instrument with particular record of temperature.

There are two types of the thermograph-

a. Bourdon tube type
b. Bimetallic type

Bimetallic thermograph consists of sensitive elements of two strips of different metal. i.e., Brass and iron welded together along their flat surfaces and bent into arc, one end of the arc is fixed to the base of instrument and other end is connected to the pen which draws changes on graph paper. Changes in temperature cause two metal to expand or to contrast by different amount so that they bend and unbend and pen traces accordingly. This instrument should be placed in double Stevenson screen. It should be standardized twice a day.

UNIT AND DIMENSION-

UNIT-

The unit is a physical quantity defined as the reference standard used to measure it.

Physical Quantity-

These are length, mass, time and quantity of a substance.

Need for unit-

Measurement is the process of comparison. For the measurement of a physical quantity we need to have the parameters.

Q=nu

Where, Q= Quantity

n= Number

u= Unit

From the equation, we can draw some conclusion that small size of unit means more will be the value of n for a given physical quantity.

Characteristics of a unit-

A unit should have following basic characteristics-

1. Unit should be well defined
2. Of suitable size
3. It should be coherent
4. It should be simple in use

CATEGORY OF UNIT-

Unit are divided into following categories-

Fundamental Unit	Supplementary Unit	Derived Units
Unit in which fundamental Physical Quantity (Length, Mass, time, quantity of substance, temperature) are expressed.	Units in which plane and solid angle are expressed.	Units in which derived quantities like speed, pressure, energy etc. are expressed are called derived units.

SCIENTIFIC INSTRUMENTS-

The Scientific instrument is a device used to measure a physical quantity which describes a physical phenomenon.

Basic principle of scientific instruments-

Basic principle involves in all scientific instruments is related to the physical phenomena to also related to the sense of users by same process i.e., thermometer measures changes in the degree of warmth of atmospheric air. In this case change in warmth is a physical phenomenon, quantity involve is degree of warmth (temp), expansion of mercury is a physical process which correlates the change in the warmth to the sense of user.

CHARACTERISTICS OF A GOOD INSTRUMENT-

1. An instrument should be accurate as required for the problem in hand. Ex-If temperature variation within ±0.5^{0}C, a thermometer graduated in 0.5^0 will be sufficient for accuracy.

The following are the basic requirements for the accuracy of instruments

a. All instruments should have and maintain calibration under a given condition within the required precision. The error under other condition should be known and should be constant in time within required limit.

b. The instrument should be sensitive. Sensitivity of the instruments refers to the change in final message to be sensitive by the user per unit change in quantity to be measured.

*Sensitivity and accuracy are different and not be confused i.e., more sensitive instrument with incorrect scale is less accurate.

c. The instrument should be reliable means there should be minimum or no chance of failing the instrument during the recording period.

d. It should be compact and durable and should have minimum handling problem.

e. It should be of low cost and easy maintenance.

f. An instrument should respond immediate to change in the quantity being measured.

MICROMETEOROLOGICAL INSTRUMENTS-

Thermometer-The device used to measure temperature is called as thermometer.

Meteorological thermometer are classified as under-

Sl no.	CLASS	BASIC PRINCIPLE	EXAMPLE
1	Liquid in glass Thermometer	Liquid expands on heating	Mercury thermometer

2	Deformation Thermometer	Solid expands on heating	Bimetallic thermometer
3	Liquid in metal Thermometer	Liquid expands on heating	Mercury in steel & other combination
4	<u>Electrical thermometers</u>		
a.	Resistance thermometer	Resistance of a conductor increases with increase in temperature.	Platinum resistance thermometer
b.	Thermistor	Resistance of a semiconductor decreases with increase in temperature.	Platinum resistance thermometer
c.	Thermo couple Thermometer	See back effect	
5	Radiation thermometer	Stephan Boltzmann law of radiation	Infrared thermometer

ELECTRICAL THERMOMETERS-

A. RESISTANCE THERMOMETER-

Resistance thermometer is based on the fact that resistance of a conductor increases with increase in temperature and increase is given by-

$R_2=R_1\,[1+\alpha\ (t_2-t_1)]$

Where, R_1 and R_2 are resistances at temperature t_1 and t_2 respectively.

α=Temperature coefficient of a material of thermometer.

Platinum, nickel and copper are the metal used for constructing a resistance thermometer. Of these platinum resistance thermometer is preferred because of the following reasons-

1. It has large temperature coefficient.
2. It is resistance to corrosion.
3. It is able to maintain its characteristics over a longer period.

Source of error-

1. Heat produced by current passing through the sensor charge the resistance hence recorded value is more than actual value.

2. Needs calibration time to time.

B. THERMISTOR-

It is a temperature measuring device based on a fact that resistance of certain material like germanium and silicon decreases with increase in temperature. Such material has negative temperature coefficient and their resistance is related to temperature as under.

$R_t=R_0ae^{-b/t}$

Where, a & b are constant.

R_t=Resistance at temperature t.

R_0 =Resistance at 0^0temperature.

Advantage-

1. It is more sensitive as change in resistance during temperature is larger.
2. It has low or less time lag as sensor size is very small.
3. It needs calibration check.

C. THERMOCOUPLE THERMOMETER-

These are based on thermoelectric/see back effect. According to this effect, when two wires of different thermal properties (physical) are joined together and one end of the junction heated keeping other cold, the emf is produced.

The pair of wire so joined is called thermocouple. The emf produced depends on following factor-

i. Nature of material of which a thermocouple is made (bismuth antimony material). Thermocouple is most sensitive.

ii. The temperature difference between hot and cold junction i.e.,

$V= \alpha\theta+1/2\beta\theta^2$

Where, V=emf

β, α are Constant.

θ=Temperature difference between both junctions.

Advantages-

1. Calibration curve is linear up to a range of temperature and measurement needed in micrometeorological studies.

2. Lag time is very low as sensor size is a point size.

Demerits-

1. Low output needs sensitive milli microvolt meters.
2. It needs calibration check from time to time.

RADIATION THERMOMETER-

Infrared thermometer is one of such kind of thermometer which sense the surface temperature without making any physical contact with the surface.

It works on the principle of Stefan Boltzmann's law of black body radiation.

According to this law radiation emitted by a surface at any temperature is given by-

$E=\sigma\sqrt{T^4}$

E=Energy radiated per unit time per unit area (w/m^2)

σ=Stefan constant (5.67×10^{-8} $w/m^2/k^4$)

T=Temperature of the surface (^0K)

Advantage-

It does not disturb the surface whose temperature is to be measured.

RADIOMETERS-

Radiometers are used to measure solar radiation. The sensor used in various radiation thermometer is a thermopile which is a series combination of a number of thermocouples.

Radiometers are classified according to their use as given below-

SL. NO	RADIOMETERS	USE	SENSOR/PRINCIPLE
1	Albedometer	To measure reflected solar radiation from crop and other surfaces.	Thermopile (See back effect)
2	Pyrheliometer & Solarimeter	To measure global diffuse and Direct radiation.	-Do-

3	Net radio meter	Use to measure overall net radiation.	Do
4	Soil heat flux plate	Use to measure heat conducted inside the soil	Do
5	Quantum sensor	Use to measure PAR	Photodiode

*All the radio meters mostly in use except quantum sensor used thermopile sensor.

STRUCTURE OF RADIOMETER-

The blackened surface of the sensor consists of alternate thin strip of manganin and constantan with one set of the junction along the central line of surface while the remaining junction are in good thermal contact with the relatively massive supporting poles which are insulated electrically not thermally from the base plate (reference junction). The temperature difference between the active reference junctions of sensor system sets emf which is a function of solar radiation and can be recorded on suitable multiple meter.

The Surface receiving radiation is covered with hemispherical glass zone. It protects the sensor from wind and rain and also prevents from the convective currents. It helps in bringing blackened surface into thermal equilibrium that is loss of heat by all causes is equal to the gain of heat due to the radiation. This state is essential for thermo emf to the function of radiation only.

The whole instrument is supported in a solid brass case, outer part of which is highly polished to prevent direct absorption of radiation so that temperature of the case kept near the temperature of the surrounding air. The air bubble is provided on the base of instrument to make the surface horizontal.

QUANTUM SENSOR-

This sensor is sensitive within photosynthetically active radiation (PAR) with spectral distribution of wave length ranging between 400 to 700 nm.

PSYCHROMETER-

It is the device used to measure actual vapour pressure and hence the state of dampness of atmosphere. A psychrometer consists of two thermometers placed in air side by side, one is known as dry bulb thermometer and second is wet bulb thermometer.

1. Dry bulb thermometer
2. Wet bulb thermometer

*Both thermometers are Hg in glass thermometers.

Hence both thermometers are similar. Wet bulb is wrapped in a muslin piece of cloth. In the month of May-June (hot summer) wet bulb depression is more as compared to rainy season (Because of more evaporation and high temperature wet bulb have depression).

The cloth is kept wet by supply of water from reservoir through capillary action. As the air passes by the wet bulb, water from wet surface absorbs it from its surrounding air and evaporates (causes cooling). So, in this process (Td to Tw), air surrounding the wet bulb cools from temperature. The basic principle of psychrometer is a fact that temperature difference between dry and wet bulb is a function of actual vapour pressure (AVP). If temperature difference is more then vapour pressure deficit (VPD) is more.

There are mainly two types of psychrometer-

1. Unaspirated psychrometer
2. Aspirated psychrometer

*The difference between dry bulb temperature (Td) and wet bulb temperature (Tw) is called as wet bulb depression.

1. UNASPIRATED PSYCHROMETER-

It is a simple psychrometer consisting of a set dry and wet bulb installed in a screen with no artificial ventilation. From the dry and wet bulb reading the vapour pressure is calculated using the following formula.

i. When Tw <60℃

$$e_a = e_{sw} - \frac{0.48(Td-Tw)P}{670-Tw}$$

ii. When Tw>40℃

$$e_a = e_{sw} - \frac{0.48(Td-Tw)P}{610-Tw}$$

Where,

e_a= Actual vapour pressure

e_{sw}= Saturated vapour pressure

P= atmospheric pressure

ASPIRATED PSYCHROMETER- In this type of psychrometer the air is drawn over the thermometer artificially to maintain the state of equilibrium.

CHAPTER.4

ENVIRONMENTAL PHYSICS

COMPOSITION AND DIVISIONS OF THE ATMOSPHERE-

The earth has three great realms: Lithosphere (solids), Hydrosphere (water) and Atmosphere (gases). The gases realm extends over the earth's surface to a height of about 9,600km and envelops it. It consists of several gases and minute suspended liquid and solid particles.

MAJOR CONSTITUENTS-

Air is a Mixture of several gases. Four gases: Nitrogen, Oxygen, Argon & carbon dioxide account for more than 99 percent of the dry air.

CONSTITUENT	BY VOLUME (%)
Nitrogen	78.088
Oxygen	20.949
Argon	0.93
Carbon Dioxide	0.033
Total	100.00

These gases are mixed in constant proportions up to 80 km. In addition to these gases, very minor amount of neon, helium, krypton, xenon, methane, hydrogen, nitrous oxide, carbon monoxide, ozone, ammonia, nitrogen oxide, sulphur dioxide comprise the remaining part. Along with these gases, water vapour which is more variable in its occurrence in time and space is vital atmospheric constituent.

DIVISIONS OF THE ATMOSPHERE-

On the basis of composition, the atmosphere is broadly divided into two spheres. Homosphere, the zone of homogenous composition of gases and Heterosphere, the zone of variable composition. Homosphere extends to about 80km above the earth surface and the composition of the atmosphere is almost uniform at different levels.

Homosphere is further subdivided in to 4 layers.

1. Troposphere

2. Stratosphere
3. Mesosphere
4. Thermosphere

The transition zone between two spheres is called pause such as-

- Tropopause (Transition zone between troposphere and stratosphere)
- Stratopause (Transition zone between stratosphere and Mesosphere)
- Mesopause (Transition zone between mesosphere and Thermosphere)

TROPOSPHERE-

- This atmospheric layer is nearest layer to the earth's surface, extending to around 16 to 17 km. Extension of this layer is not same at all latitudes. It is about 17 km at the equator, 12.5km at 45^0 latitude and 4.5 km over polar region.
- This layer contains almost all the water and dust and represents the belt of all atmospheric phenomena-clouds, rain, snow, fog, lightning, thunderstorms, cyclone etc. No visible weather phenomenon occurs above this layer.
- In this layer, the temperature decreases at 6.5^0C/km, which is known as lapse rate.
- In the troposphere, instead of decrease in temperature with altitude, sudden abrupt raise in temperature is seen at certain points, which is known as temperature inversion. For instance, the lapse rate changes abruptly at 14 km.
- Convection current is present and wind speed increases with height.

STRATOSPHERE-

- The stratosphere is about 50 km thick at equator and about 70 km at the poles.
- Temperature remains nearly constant (isothermal) in lower layers and increases very gradually up to stratosphere. Lower stratosphere within 20 km is more isothermal than the upper stratosphere.
- There are no convection currents. Cirrus clouds may occasionally form in the lower atmosphere.

MESOSPHERE-

- It extends up to about 80 km from the earth's surface. Maximum chemical activity takes place in this sphere and hence it is also called chemosphere.

- It is a warmer layer due to selective absorption of ultraviolet rays by ozone. Temperature increases with height at about 5^0C/km and reaches a maximum around 77^0C at about 40-50 km. Then the temperature falls to as low as around -100^0C at the top of mesosphere.
- It contains ions which reflects ratio waves back to earth surface and enables us to have wireless communication.

THERMOSPHERE-

- It extends upward from 80 km.
- Temperature increases rapidly (around 1000^0C at 350 km) with height due to absorption of ultraviolet radiation.
- Its lower portion consists of atomic oxygen and nitrogen.

Above the thermosphere is ionosphere where ionization of atmosphere begins and temperature increases with height due to very low air density. According to some scientists, thermosphere includes ionosphere.

HEAT TRANSFER-

Heat energy moves from a hotter object to a cooler one. The movement of heat energy will stop when the temperature of each object becomes the same. The three methods by which heat moves are called conduction, convection and radiation.

One end of the metal rod is being heated by the Bunsen burner. After a period of time, the other end of the rod becomes heated. Heat energy has travelled along the rod. This method of heat transfer is called conduction. The only group of substances that can be called good conductors of heat are metals. All other substances are classed as insulators (bad conductor of heat).

Transfer of heat by movement of a mass or substance from one place to another, generally vertical is called convection. The third way in which heat energy is transferred is called radiation or more properly heat radiation. The heat energy is carried by waves called electromagnetic waves. The type of electromagnetic wave which is felt as heat is called ‘infrared’. These heat waves can travel through a vacuum and this is one of the forms of energy that reaches us from the sun.

HEATING OF ATMOSPHERE-

Sun is the ultimate source of atmosphere heat and energy, but its effect is not direct for example as we climb a mountain or ascend toward the sun in an airplane, temperature become steadily lower rather than higher as we might expect. This is because the mechanism of heating the atmosphere are not simple. There are three heating process directly responsible for heating the atmosphere.

They are:

RADIATION-

When the source of heat, transmit heat directly to an object through heat waves, it is known as radiation process. In this process heat travels through the empty space. The vast amount of heat energy coming to and leaving the earth is in the form of radiation.

- All objects whether hot or cold, emit radiant energy continuously.
- Hotter objects radiate more energy per unit area than colder objects.
- Insolation reaches the earth’s surface in short waves and heat is radiated from the earth in long waves.

The atmosphere is transparent to short waves and opaque to long waves, hence energy leaving the earth’s surface heats up the atmosphere more than the solar radiation.

CONDUCTION-

The atmospheric conduction occurs at the zone of contact between the atmosphere and the earth’s surface. However, this is a minor method of heat transfer in terms of warming the atmosphere. Since it only affects the air close to the earth. This is because air is a bad conductor of heat unlike certain metals.

CONVECTION-

The air of the lower layers of the atmosphere gets heated either by earth’s radiation or by conduction. The heating of the air leads to its expansion. Its density decreases ant it moves upwards. Continuous ascent of heated air creates vacuum in the lower layer of the atmosphere. As a consequence, cooler air comes down to fill the vacuum leading to convection. The cyclic movement associated with the convectional process in the atmosphere transfer heat from the layer to the upper layer and heats up the atmosphere.

As the beam of sunlight enters the atmosphere, it first passes through the mesosphere with little change. In the stratosphere, the density of atmosphere gases increases. There is more oxygen available, which reacts with the shortest or ultra violet wavelengths and effectively removes them. The atmosphere, is thus warmed in the process. By now about 2 percent of the sun's rays has been lost.

Then in troposphere, it loses about 48% of sun's rays due scattering in many directions by the gas molecules, dust particles etc.

By the time, the sun rays reach the ground surface they retain with only 50 percent of its original energy. Even then not all of this is absorbed. This is because the surface itself has an albedo. The albedo varies from surface to surface. For example, the albedo of freshly fallen snow may reach as high as 90%. The greatest variable is over water. When the sun is high in the sky, water has a very low albedo. This is why the oceans appear dark on satellite photographs at low angles of the sun, such as at dusk at dawn or in midwinter in sub polar latitude and temperate latitudes, the albedo may reach nearly 80 percent.

HEAT LOST BY REFLECTION/SCATTERING	HEAT LOST BY ABSORPTION
1.Reflected by clouds=24%	1.Absorbed by clouds=3%
2.Reflected /Scattered by air + dust+ water=6%	2.Absorbed by air + dust + water vapour=14%
3.Total reflection by atmosphere=30%	3.Total absorption by atmosphere=17%
4.Reflection from earth surface=6%	4.Absorbed by earth surface=47%
Total reflection (Earth + Atmosphere) =36%	Total Absorption (Earth + Atmosphere) =64%

THERMODYNAMICS OF THE ATMOSPHERE-

Thermodynamics is that branch of physics which is mainly concerned with the transformation of heat into mechanical work.

THERMAL EQUILIBRIUM AND ZEROTH LAW OF THERMODYNAMICS-

A thermodynamics system is said to be in thermal equilibrium if all parts of it are at the same temperature and this temperature is that same as that of the surroundings. If these conditions are not satisfied, a change of state will take place until a thermal equilibrium is reached.

Now consider two systems A and B separated from each other by an adiabatic wall (one that conducts no heat), but each being in contact of a third system C through a diathermal wall which permit heat to pass. Then the system A will be in thermal equilibrium with system C and similarly system B will also be in thermal equilibrium with system C.

It gives general conclusion:

If two systems are in thermal equilibrium with a third system then they must be in thermal equilibrium with each other.

This statement is called the zeroth law of thermodynamics.

MECHANICAL EQUILIBRIUM-

For a system to be in mechanical equilibrium there should be no unbalanced forces existing between different parts of the system or between the system and the surroundings.

THERMAL EQUILIBRIUM-

For a system to be in thermal equilibrium, the temperatures at all parts of the system must be the same and should be identical with that of the surroundings.

CHEMICAL EQULIBRIUM-

For a system to be in chemical equilibrium, the composition of the system should remain fixed and definite.

A system which satisfies all the above three equilibriums i.e., uniformity of pressure, temperature and chemical composition is said to be the thermodynamic equilibrium.

THERMODYNAMIC PROCESS-

1. ISOTHERMAL PROCESS-

If a thermodynamic system is perfectly conducting to the surroundings and undergoes a physical process in such a way that its temperature remains constant throughout the process is said to be isothermal process.

The equation connecting the pressure P and Volume V of one mole of a gas for an isothermal process is

PV=RT=CONSTANT

For n Moles of a gas-

$PV= nRT$

In isothermal changes, there is no change in temperature, no change in internal energy i.e., $dU =0$

$dQ =0+dW$

Or, $dQ=dW$

Thus, during an isothermal process, Heat added (or subtracted) = work done by (or on) the gas.

2. ISOBARIC PROCESS-

If the working substance is taken in an expanding chamber in which the pressure is kept constant, the process is called isobaric process.

3. ISOCHORIC PROCESS-

If a substance undergoes a process in which the volume remains unchanged the process is called an isochoric process.

4. ADIABATIC PROCESS-

If a thermodynamic system is perfectly insulated from the surroundings and undergoes a process in such a way that no exchange of heat takes place between it and the surroundings the process is said to be adiabatic process. In such a process, no heat is allowed either to enter the system or to leave it, but all along the process there is a change in temperature.

5. REVERSIBLE PROCESS-

If a process can be carried out in such a way that the effects produced by on the system as well as on the surroundings can be completely restored to their initial states and no changes are left in any of the system taking part in the process or in the surroundings then the process is said to be reversible process.

6. IRREVERSIBLE PROCESS-

If a process does not satisfy these conditions, it is called irreversible. Thus, the process which produce a permanent change in the thermodynamic state of the system and cannot be retraced in the opposite order are known as irreversible process.

THE FIRST LAW-

The first law of thermodynamics may be stated in two slightly different forms.

1. The first form of this law is one which express the equivalence between mechanical work and heat energy. According to it "when mechanical work is spent in producing heat, a definite quantity of heat is produced for each unit of work spent and conversely, when heat is employed to do work, the same definite quantity of heat disappears for every unit of work obtained". Thus if W is the amount of work, then the amount of heat Q, that can be produced by it is given by

$$W \propto Q$$

$W=JQ$

Where, $J= 4.2 \text{ X } 10^7$ergs/cal

=4.2 J/cal

$=4.2 \text{ x } 10^3$Joule/kilo cal.

This form of law is true only if the whole of work done is used in producing heat or vice versa.

2. The second statement of this law is a particular form of the general law of the conversation of energy.

Let us suppose that a quantity dQ of heat is supplied to a body. It is in general, spent in 3 ways-

a. Partially, it is spent in raising the temperature of the body. This is equivalent of increasing its internal kinetic energy.

b. A part of it is spent in increasing the internal potential energy of the body.

c. A third part of it is spent in doing external work.

So, $dQ=dU +dW$………………… eqn (1)

This equation represents the differential form of first law of thermodynamics, which may therefore be stated "In all transformations, the energy due to heat supplied must be balanced by the external work done plus the increase in internal energy".

While using equation (1) two things should be kept in mind,

1. dQ, dU and dW are all to be measured in the same units i.e., all the three either in joules or in calories or kilo calories.

2. If heat is taken by the system then dQ is +ve and if it is given by the system then dQ is –ve. Similarity if the work is done by the system then dW is +ve and if the work is done by some external agency on the system then dW is –ve.

SIGNIFICANCE OF THE 1ST LAW-

The first law of thermodynamics establishes an exact relationship between heat and work. According to it a definite quantity of heat will produce a definite amount of work and vice versa. It denies that work or energy can be created out of nothing. It means that it is impossible to construct a thermal machine which may operate without any expenditure of fuel and may thus create energy out of nowhere. A machine that would do this could run itself and is generally called a perpetual motion machine of the first kind.

Three ideas are included in first law of thermodynamics;

1. Heat is a form of energy in transit.
2. Conservation of energy takes place in thermodynamics system.
3. Every system in equilibrium, possess an internal energy which is a function of state.

SPECIFIC HEAT OF GASES-

Suppose that an amount of heat Q is given to a body. If its temperature rises by dT then the heat capacity of the body is defined as

$$\text{Heat capacity}=Q/dT$$

Heat capacity per unit mass is known as specific heat and represented by the letter C.

$$\text{Thus, } C= \frac{\text{Heat Capacity}}{\text{Mass}} = Q/m.dT$$

Thus, specific heat of a material is the quantity of heat required so as to raise the temperature of unit mass of the material through 1^{0}C.

In order to find the value of the specific heat of a gas, either the pressure or the volume has to be kept constant. Consequently, we have two specific heats.

a. The specific heat at constant volume-

It is defined as the amount of heat required to raise the temperature of unit mass of the gas through 1^{0}C when its volume is kept constant. It is denoted by Cv and given by

$Cv= \ dQ/dT\times m$

As m=1

So, $Cv = \frac{dQ}{dT}$

b. The specific heat at constant pressure-

It is defined as the amount of heat required to raise the temperature of unit mass of the gas through 1^0C when its pressure is kept constant. It is denoted by Cp and given by

Cp= dQ/dT at constant pressure.

SECOND LAW OF THERMODYNAMICS (Heat engines and entropy)-

HEAT ENGINE-

Any device which converts heat continuously into mechanical work is called a heat engine.

Thus, for instance, when water is boiled in a vessel closed by a lid, the steam generated inside throws the lid off showing there that high pressure steam can be made to do work.

For any heat engine, there are three essential requirements.

1. SOURCE-

A hot body at a fixed temperature T_1 from which the heat engine can draw heat is called as source.

2. SINK-

A cold body at a fixed lower temperature T_2 to which any amount of heat can be rejected is called a sink.

3. WORKING SUBSTANCE-

The material which on being supplied with heat performs mechanical work is called as working substance.

Thus, in a heat engine the working substance takes in heat from the source converts a part of it into external work, gives out the rest to the sink and returns to its initial state. This series of operation constitute a cycle. The work can be continuously obtained by performing the same cycle over and over again.

Let Q_1 be the amount of heat absorbed by the working substance from the source, Q_2 that rejected by it to the sink and W the net amount of work done by it. Therefore, the net amount of heat absorbed by the working substance is Q_1-Q_2. Since working substance returns to its initial state so change in internal energy, du=0. By first law of thermodynamics-

$Q_1-Q_2=W$………………… (1)

The thermal efficiency of the engine n is defined as the ratio of the net work obtained in the cycle (output) to the heat absorbed by the working substance from the source (input).

So, n= Work output/ Heat input

= W/Q_1

From Equation (1) $W=Q_1-Q_2$, So $n=Q_1-Q_2/Q_1$

or $n=1-Q_2/Q_1$

or $n=1-T_2/T_1$ (in terms of temperature)

If $Q_2=0$ or in other words if an engine could be built to operate in such a way that no heat at all is rejected by the working substance in a cycle, there will be 100% conversion of heat into work which is not practically possible. (Efficiency of 100%)

CARNOT ENGINE-

It is the type of engine which converts all the heat into mechanical work. It is an ideal engine and not practically possible.

RADIATION LAWS-

1. PLANK'S LAW-

Electromagnetic radiation consists of the flow of quanta or particles. The energy content (E) of each quantum is proportional to the frequency and it is given by the following equation.

$E=h\nu$

Where, h=Plank's constant

$=6.625 \times 10^{-27}$ erg sec^{-1}

The equation indicates that the greater the frequency the greater is the energy of the quantum.

2. KIRCHOFF'S LAW-

Any grey object (other than a perfect black body) that receives radiation disposes of a part of it in reflection and transmission. The values of absorptivity, reflectivity and transmissivity are less than or equal to unity.

This law states that the absorptivity 'a' of an object for radiation of a specific wavelength is equal to its emissivity 'e' for the same wave length.

$$a\ (\lambda)=e\ (\lambda)$$

3. STEFAN –BOLTZMAN LAW-

This law states that the intensity of radiation emitted by a radiating body is proportional to the fourth power of the absolute temperature of that body.

Flux= σT^4

Here σ is the Stefan Boltzmann's constant (5.67 x 10^{-5}erg.cm^{-2}sec^{-1}k^{-4}) and T is the absolute temperature of the body.

4. WEIN'S LAW-

The wave length of maximum intensity of emission from a black body is inversely proportional to the absolute temperature (T) of the body. Thus,

Wave length (λ) of maximum intensity (μm)=2897/T

5. LAMBERT'S LAW-

This law states that the permeability of the atmosphere to solar radiation. The intensity of solar radiation on a vertical irradiation at the earth's surface is gives by the equation.

$Im=I_0qm$

CHAPTER.5

CLIMATOLOGY

WEATHER

It refers to the physical state of atmosphere at a given time over a place hence weather may be defined as instantaneous condition of atmosphere over a place. It is highly variable and continuously changing from hour to hour and day to day, weather condition may defer from one place to another.

CLIMATE

It is defined as average weather condition over long period of time for larger area. For development of climatology of a place we need weather data of last 30 years (of minimum). Climate can be simply defined as average state of weather. It also includes deviations from average condition as well as extreme weather condition (Heat wave, Cold wave, frost).

According to Trewartha, who defined climate as a composite of day to day weather conditions and of the atmospheric elements within a specified area over a long period of time.

According to Critchfield it the science that seeks to describe and explain the nature of climate, why it differs from place to place and how it is related to other elements of the natural environment and human activities.

Climatology may be defined as the study of distribution of climatic elements over a region for a long period of time. Briefly climatology is defined as study of climate.

AGRICULTURAL CLIMATOLOGY-

It may be defined as the science, which applies scientific knowledge to understand agricultural problems or may be defined as study of climatic element with relation to agriculture.

WEATHER ELEMENTS-

An entity that controls the weather is called weather elements. There are various factors which individually or in combination control the weather.

List of Weather elements given below

1. Solar radiation

2. Temperature
3. Air pressure (unit: bar or pascal or mb)
4. Wind
    a. Wind Speed
    b. Wind Direction
5. Sunshine Hours (Unit =Hour)
6. Humidity (%)
7. Cloudiness (Unit: Octa or okta)
8. Precipitation (Unit: mm)

WIND SPEED-

It is a scalar quantity (like 20 m/s, 30 m/s).

WIND VELOCITY-

It is vector quantity (It has both speed and direction) i.e., 20m/s East.

*Vector Quantity-It has both magnitude and direction.

*Scalar Quantity-Body has only magnitude not direction.

All these weather elements are highly variable and constitutes the weather. Day to day changes in weather as mainly the result of variation in amount intensity and distribution over the earth of weather element given above.

Weather is the dominant factor determining the success or failure of agricultural enterprises. This is because farmers have no control over this natural force. Weather manifests its influence on agricultural operations and farm production through its effect on soil and plant growth. Out of the total annual crop losses, a substantial portion is because of aberrant weather. The avoidance of all these crop losses due to weather factors is not possible. But loss could be minimized by making adjustment with coming weather through timely and accurate weather forecasting.

By forecasting of anticipated heavy rains, the irrigation from wells can be avoided by which we can save electricity; the harvesting could be advanced if the crop is in maturity stage; threshing of the harvested produce could be done before rains by which crop losses can be avoided. The losses in seed, diesel, labour and time can be avoided by not sowing the crops, if anticipated weather is not suitable for the operation. Saving of fertilizer by avoiding losses through leaching, gaseous loss and fixation loss could be achieved if the farmers are informed well in time that the coming weather may not be suitable for fertilizer application. A similar wastage can be minimized in the use of plant protection chemicals.

DIFFERENCE BETWEEN WEATHER AND CLIMATE

WEATHER	CLIMATE
1. It is the instantaneous physical state of atmosphere.	1. It is the generalized physical state of atmosphere.
2. Weather changes refers to short term duration on specific instant of time.	2. Climate change refers to long term changes in long span of time. (Minimum=30yrs)
3. Weather changes from place to place.	3. Climate covers the general region or place and does not change so easily.
4. It is expressed in terms of numerical values of weather elements.	4. It is expressed in terms of time average and area average of weather elements.
5. It does not include magnitude of extreme values of weather elements	5. It includes extremes of weather elements. Ex-Cyclone, flood, frost, drought, hailstorm etc
6. It is indicated by measuring weather elements in observatory.	6. It is the derived information on regional basis.
7. It provides meteorological information.	7. It constitutes geographical information in respect of weather.
8. It can characterize as fair, unfair, settled, fine, excellent etc.	8. Climate may be characterized as desert, continental, marine, tropical, savanna.
9. Weather decides the crop yield & success or failure of crop growing season.	9. Climate decides suitability of introduction of new crop in a region.
10. Adverse weather results in to crop failure or loss.	10. Climate is considered in long term agricultural planning.

CLIMATE CONTROL-

The physical climate of a place is dominated by some local factors accounting for different types of climate. The climate of hill/mountain is dominated by its height above sea level and makes it cool. When a climate of a coastal station is dominated by sea or ocean water making it humid. Thus, all parameters of physical, geographical, edactic, physiographic, biotic or manmade activities i.e., industry which interacts with weather elements and determines and dominates the climate of a place.

CLIMATIC CONTROLS AS FOLLOWS-

1. LATITUDE-

It is defined as the angular distance of a place from equator. It is the principle controlling factor of climate. It determines the solar energy received and temperature of a place.

2. ALTITUDE-

It is the vertical height from MSL and its unit is m. Temperature decreases with height, i.e. mountain and plateau.

3. WATER BODIES-

It moderates the temperature and increases humidity, i.e.-coastal climate or marine climate.

4. DISTANCE FROM SEA-

As the distance from sea of a place increases then the difference between maximum and minimum temperature during a day in an area increases. Difference is higher at continental stations and lower for marine stations.

5. RELIEF (MOUNTAIN)-

The mountain barrier with wind flows controlling the temperature and rainfall windward side receives more rainfall as compare to lee ward side getting less rainfall.

6. TOPOGRAPHY-

Topography or topographic changes the wind velocity which may changes temperature and weather.

7. OCEAN CURRENTS-

It carries tropical temperature towards temperate (low temperature) region and cold water towards tropical seas.

8. VEGETATION-

Vegetation or forest evapotranspire water vapour increasing humidity and lowering temperature of the area. The other climatic control are snow and ice, permanent wind direction, soil types and color thus climatic control acts upon weather elements and introduce different types of varieties of weather and climate.

TYPES OF CLIMATE-

i. MACRO CLIMATE-

The general large-scale climate of a large area or a country.

i.e., Climate produced due to westerlies.

*WESTERLIES- They are prevailing winds in the middle latitude between 30^0 and 60^0 latitudes, blowing from high pressure areas towards the pole.

ii. MESO CLIMATE-

The climate of small area intermediate between macro and micro climates. Climate produced in area such as due to land sea breeze, mountain and valley breeze.

iii. MICRO CLIMATE-

The climate of small area near the vary surface of the earth up to some height. Within this height the character of micro climate distinguishes from general local climate i.e., climate over pond.

DISTRIBUTION OF TEMPERATURE-

HORIZONTAL DISTRIBUTION-

Temperature of any particular place depends primarily on the amount of insolation received there. The amount of insolation largely depends on latitude. Our globe is divided into 5 temperate zones and latitude are the boundary lines. Equator (0^0 Latitude), tropic of cancer (23 ½^{0}N), tropic of Capricorn (23 ½^{0}S latitude), arctic circle (66 ½^{0}N) and Antarctic circle (66 ½^{0}S). There is a general decrease in temperature from equator towards poles. Latitude is the main factor for horizontal distribution of temperature throughout the globe. Besides latitude there are other important geographical factor which affects the temperature distribution. It has been found that the spatial (area wise) variation of temperature is very important. In fact, the regional variation in temperature are analyzed with the help of meteorological records on maps, isotherms (The line joining places having equal temperature commonly used to show the horizontal distribution of temperature. Isotherms are lines connecting points with equal temperature values. The isotherms generally run east-west and they are highly irregular. The isotherm over certain part of the globe are closely spaced, they may be widely spaced too, and hence a wide variation in temperature gradient in various part of the globe is seen. Besides the isotherms showing temperature distribution, there are additional factors (heating between land and water, ocean current effect, mountain barrier and topography relief) affects distribution of temperature.

DIURNAL VARIATION OF AIR TEMPERATURE-

Temperature rises or falls during a day (24hrs). This phenomenon is called daily cycle or diurnal variation of temperature. The difference between the highest and lowest values recorded locally is termed as or referred as the diurnal range. The sun is the primary control of diurnal variation of temperature. The temperature of the earth surface represents the balance between insolation and outgoing long wave terrestrial radiation. So long as the angle of the sun rises reaching a peak in the noon the incoming solar radiation exceeds the outgoing earth radiation. However, the maximum temperature is recorded in the late afternoon hours. Thus, delay in the occurrence of the maximum temperature is called as lag of the maximum temperature. This is caused because of the receipt of maximum amount of insolation at noon, the earth surface and the air lying close to it continue to receive more heat then they lose during the afternoon, that is why the temperature continues to rise but from the middle of the afternoon to next day sunrise the loss of heat by earth radiation exceeds the receipt of solar radiation. Therefore, the temperature continues to drop. This is the case of periodic variation of diurnal temperature.

Besides there are non-periodic variations which are not controlled by sun. These irregularities are caused by the passage of atmospheric disturbances which occurs sometimes. These disturbances are accompanied by cloudiness, precipitation and winds which modify temperature. In these condition, the maximum temperature and minimum temperature may occur at any time of the day or night. Generally, the tropical region exhibited some control of temperature, while in the middle and high latitude the non-periodic control is dominated.

In temperate zone, the diagonal range is larger in summer than in winter because in summer the weather is generally clear and fine which favors hot day and cold night. In winter, the cyclonic weather dominates the control of temperature. Thus, night may be warmer than day in such condition. The diurnal range in polar region is always smaller because near the poles the angle of incidence of sun's ray with low angle throughout the day. Similarly, along the coastal area the diurnal temperature variation is not higher, it is moderate. In coastal areas, such condition is brought by land and sea breezes. The cloud also affects diurnal variation of temperature. An overcast or cloud day receives less amount of insolation and at night the cloud cover act like a shield or hurdle against the loss of heat from earth surface inform of long wave radiation.

The following factors affects the temperature variation-

1. Sky condition
2. Stability-

Under inversion (Temperature increase with height) condition night time cooling is retarded so minimum temperature is high.

3. Nature of the Surface-

The places away from the ocean bodies have higher diurnal range of temperature which the coastal area have less diurnal range of temperature.

4. Wind speed-

On windy day, diurnal range of temperature is comparatively small or less.

5. Soil Composition-

In humid region fraction of insolation received at ground is expanded in evaporating the moisture. This is additional factor causes the higher diurnal range of temperature in dry region.

6. Effect of Latitude.

PHENOLOGY AND SEASONAL CHANGES OF WEATHER CONDITIONS-

Phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and inter annual variations in climate, as well as habitat factors (such as elevation). Phenology has been principally concerned with the dates of first occurrence of biological events in their annual cycle. Examples include the date of emergence of leaves and flowers, the first flight of butterflies and the first appearance of migratory birds, the date of leaf coloring and fall in deciduous trees, the dates of egg laying of birds and amphibian or the timing of the developmental cycles of temperate zone honey bee colonies.

Because many such phenomena are very sensitive to small variations in climate, especially to temperature phenological records can be a useful proxy for temperature in historical climatology, especially in the study of climate change and global warming.

Observations of phenological events have provided indications of the progress of the natural calendar since ancient agriculture times. Many cultures have traditional phenological proverbs and saying which indicates a time for action “when the sloe tree is white as a sheet, sow your barley whether it be dry or wet”.

In Japan and China, the time of blossoming of cherry and peach trees is associated with ancient festivals and some of these dates can be traced back to the eighth century.

Robert Marsham is the founding father of modern phenological recording. Marsham was a wealthy landowner who kept systematic records of “Indications of spring” from 1736. These were in form of dates of the first occurrence of events such as flowering, bud burst, emergence or flight of an insect.

Recent technological advances in studying the earth from space have resulted in a new field of phenological research that is concerned with observing the phenology of whole ecosystems and stands of vegetation on a global scale using proxy approaches. These methods complement the traditional phenological methods which recorded the first occurrences of individual species and phenophases.

The most successful of these approaches is based on tracking the temporal changes of a vegetation index [like Normalized Difference Vegetation Index (NDVI)]. NDVI makes use of the vegetation’s typical low reflection in red (red energy is mostly absorbed by growing plants for photosynthesis) and strong reflection in the near infrared (infrared energy is mostly reflected by plants due to their cellular structure). Due to its robustness and simplicity NDVI has become one of the most popular remote sensing based products.

THERMOPERIODISM-

The response of living organisms to regular changes in temperatures, either day/ night or seasonal is known as thermoperiodism. Thermoperiodism exerts effect on the seasonal biology of insects and the growth and development of plants. Effects on insects include rates of growth and development, determination of diapauses and dormancy and acclimatization to low temperatures. Effect on growth and development of plants vary from one species to another. Crops such as soya bean, maize, tomato, potato, eucalyptus and mango are classified as thermoperiodic, while wheat, oats, pea and cucumber are classified as non thermoperiodic.

In soyabean a cool day/night temperature combination of $18^0/14^0$C disrupts floral development, leading to physically malformed parts. Normal floral initiation and pod development occurs at $30^0/18^0$C and $30^0/22^0$C respectively while the greatest number of pods per plant is obtained at $26^0/14^0$C.

Tomatoes grow faster when the temperature is 26^0C by day and 17^0C by night at the constant temperature of 26^0C or any intermediate temperature. For this reason, tomatoes do not grow well in warm countries except in those locations where the temperature falls appreciably at night.

Some maize cultivars respond to a daily temperature fluctuation. For early lines (early sowing) for best chlorophyll content and grain yield, it is best at high during temperature (day/ night=$24^0/15^0$C) and for mid-season at a constant day and night temperature of 21^0C.

Potato plants grown under the fluctuating temperature treatment develop normally, develop tubers and have a fivefold or greater total dry weight compared to those under constant temperature. This suggests a thermoperiod could allow normal plant growth and tuberization in potato cultivars that are unable to develop effectively under continuous radiation.

Two important aspects of the environment influencing induction of flowering in mango are photoperiodism and thermoperiodism. Studies in the Maharashtra region of India indicated that minimum temperature below 10^0C and above the freezing point stimulated heavy flowering in mango. Furthermore, flowering occurred only in a single flush compared to two to three flushes under normal environmental conditions.

Many crop seedlings will grow perfecting well at a constant temperature but others such as celery, germinate best at fluctuating temperatures. The emergence of carrot seedlings from soil is faster in fluctuating temperatures that at constant temperature.

The ecological significance of this response to a diurnal alteration of temperature may be that it promotes germination of those seeds close to the soil surface. When such fluctuations do not occur, germination, especially of more deeply seated seeds may remain suppressed.

Apart from daily fluctuation in temperature, seasonal fluctuations are important in the development of many plants. Annual plants do not need a cold period during their development, except for plants that germinate in autumn and flower in the spring or summer after a cold winter.

An example is winter wheat. Peaches cannot flower at high temperature but the vegetative growth phase continues. They need a period of cold weather before flower buds can open.

HEAT UNIT CONCEPT AND ITS APPLICATION-

Growing degree days (GDD), also called heat units or effective heat units or growth units are a simple means of relating plant growth, development and maturity to air temperature. The concept is widely accepted as a basis for building phenology and population dynamic models.

Degree day units are often used in agronomy essentially to estimate or predict the lengths of the different phases of development in crop plants.

We know that all the physiological processes and physical processes are temperature dependent. It is also known fact that the increases in the rate of these processes corresponds with increases in yield.

The heat unit system or growing degree day (GDD) concept assumes that there is a direct and linear relationship between growth of plants and temperature. It starts with the assumption that the growth is dependent on the total amount of heat to which it is subjected during its life time.

A degree day or a heat unit is the departure from the mean daily temperature above the minimum threshold (base) temperature. This minimum threshold is the temperature below which no growth takes place. The threshold varies with different plants and for the majority it ranges from 4.5 to 12.5^{0}C with higher value of tropical plants and lower values for temperate plants.

CROPS	THRESHOLD TEMPERATURE (^{0}C)
Wheat, Barley	4.4
Potato, Oats, Sugar Beet	5.0
Sorghum, Maize, Groundnut	8-10
Rice	10-12
Tobacco	13-14

METHODS OF DEGREE DAY ESTIMATION-

An exhaustive review of degree day methods was reported by Zalom and colleagues (1993).

1. Standard degree day method:

   $GDD=\sum [(Tmax + Tmin)/2] - Tbase$

   Where $(Tmax + Tmin)/2$ is the average daily temperature and Tbase is the minimum threshold temperature for a crop.
2. Maximum instead of means method:

   $GDD= \sum (Tmax- Tbase)$
3. Reduced ceiling method: Where $Tmax \leq Tceiling$,

   $GDD= \sum (Tmax- Tbase)$ or

   Where $Tmax> Tceiling$, then

   $GDD= \sum [Tceiling- (Tmax-Tceiling))-Tbase]$

USES AND LIMITATIONS OF GDD-

USES-

1. To decide optimum sowing time of crops.
2. Use for calculating the temperature dependent development of insects, birds and plants is widely accepted as a basis for building phenology and population dynamic models.
3. It guides various agricultural operations and planning land use.
4. For forecast of crop harvest dates and yield of crops and quality.
5. It helps in forecasting labour needs for factories and in reducing harvesting and factory costs.
6. Applied to the problems of growth and development of insects and plant pathogens.
7. Applied to the selection of varieties to be grown in a new area.
8. To modify the microclimate to produce optimum conditions at the development cycle of an organism.
9. As an index for making crop zonation.
10. It is easy to compute and simple to use for various aspects of agriculture.

LIMITATIONS-

1. A lot of weightage is given to high temperature although higher temperature above 27^0C may have detrimental effects.
2. No differentiation can be made among the different combinations of the seasons. For example, the combination of a warm spring and a cool summer cannot be differentiated from a cold spring and a hot summer.

3. The daily temperature is not taken into consideration which is more significant than the mean daily temperature.
4. A single threshold temperature is used throughout the crop season.
5. Plant, leaf or canopy temperature is more important for plant growth and development rather than the screen temperature measured in the observatory.
6. The effect of topography, altitude and latitude on crop growth cannot be considered.
7. The influences of wind, hail, insects and diseases are not considered.
8. Soil fertility may also affect crop maturity which cannot be explained in this concept.

PHOTOPERIODISM-

It is the physiological reaction of an organism to the length of day and night. It occurs in plants and animals. It can also be defined as development response of plants to the relative length of light and dark period.

Many flowering plants (angiosperms) use a photoreceptor protein, such a phytochrome or crypto chrome to sense seasonal changes in night length or photoperiod which they take as signals to flower. In a further subdivision, obligate photoperiodic plants absolutely require a long or short enough night, before flowering whereas facultative photoperiodic plants are more likely to flower under the appropriate light conditions but will eventually flower regardless of night length.

In 1920, W.W. Garner and H.A. Allard published their discoveries on photoperiodism and felt it was the length of day light that was critical, but it was later discovered that the length of the night was the controlling factor. Photoperiodic flowing plants are classified as long day plants or short day plants even through night is the critical factor because of the initial misunderstanding about day light being the controlling factor. Each plant has a different length critical photoperiod or critical night length.

LONG DAY PLANTS-

Long day plants flower when the night length falls below their critical photoperiod. These plants typically flower in the northern hemisphere during late spring or early summer as days are getting longer. In the northern hemisphere, the longest days of the year (summer solstice) is on or about 21 June. After that date days grow shorter (i.e. night grows longer) until 21 December (winter solstice). This situation is reversed in the southern hemisphere.

Some long day obligate plants-

Carnation, Oat

Some long day facultative plants-

Pea, Barley, Lettuce

SHORTDAY PLANTS-

Short day plants flowers when the night lengths exceed their critical period. They cannot flower under short nights or if a pulse of artificial light is shown on the plant for several minutes during the night, they require a continuous period of darkness before floral development can begin. Natural night time light such as moon light or lightning is not sufficient brightness or duration to interrupt flowerings.

In general, short day (i.e., long night) plant flower as days grows shorter after 21st June in northern hemisphere which is during summer or fall.

The length of the dark period required to induce flowering differ among species and varieties of a species. Photoperiodism affects flowering by inducing the shoot to produce floral buds instead of leaves and lateral buds.

EX-Cotton, Rice

DAY-NEUTRAL-

Day neutral plants such as cucumbers, roses and tomatoes do not initiate flowering based on photoperiodism. Instead they may initiate flowering after attaining a certain overall developmental stage or age or in response to alternative environmental stimuli, such as vernalisation (a period of low temperature).

CLIMATIC WATER BUDGETING TECHNIQUE AND ITS APPLICATION IN EVALUATION OF MOISTURE AVAILABILITY PERIODS WITHIN CROP GROWING SEASON: -

Almost of all the water available on the earth, 97% occurs as salt water in the oceans. Of the remaining 3%, 66% occurs as snow and ice in polar and mountainous regions which leaves only about 1% of the global water as liquid fresh water. More than 98% of fresh water occurs as ground water, while less than 2% occurs in virus and lakes. Ground water is formed by excess rainfall (total precipitation-surface runoff + evapotranspiration) that infiltrates deeper in to the ground and eventually percolates down to ground water formations (aquifers). For temperate humid climates about 50% of precipitation ends up in the ground water. For Mediterranean type climates, this figure is 10 to 20% and for dry climates, it can be as little as 1 percent or even less.

The global renewable water supply is about 7000 m^3 per person per year (present population). The per capita minimum water requirement is estimated at 1,200m^3 annually of which 50m^3 is for domestic use and 1,150 m^3 is for food production [food and Agriculture organization (FAO), 1994]. In western and industrialized countries, a renewable water supply of at least 2,000m^3 per person per year is necessary for adequate living standards. These figures suggest that enough water is available for at least three times the present world population. Hence water shortages are due to imbalances between populations and precipitation distributions.

WATER FOR CROP PRODUCTION-

Rain fall contributes to an estimated 65% of global food production, while the remaining 35% of global food is produced with irrigation. In most parts of the world, rainfall is for at least part of the year, insufficient to grow crops and rainfed food production is heavily affected by annual variations in precipitation.

A major part of the developed global water resources is used for food production. In most countries 60 to 80% of the total volume of developed water resources is used for agriculture and may reach well over 80% for countries in arid and semiarid regions.

Irrigation is an obvious option to increase and stabilize crop production. The irrigated areas in the world during the last three decades of 20th century, increased by 25%. Ground water resources have become over exploited at an alarming rate during these times.

MAKING EFFECTIVE USE OF RAINFALL-

An inadequate and variable water supply and extremes of temperatures are the two universal environmental risks in agricultural production. High temperature in tropical climate limit the production of crops native to temperate latitudes and low winter temperatures in high latitudes are a check on growing crops native to tropical areas. Inadequate and variable water supply however has a negative impact on crop production in every climatic region. The problem is more pronounced in tropical and subtropical semiarid and arid climates in which the water losses in evaporation and evapotranspiration are very high throughout the year. Management of water resources is a much greater and more universal problem than any other factors of the environment.

Not all rainfall that falls on a field is effectively used in crop growing as part of it is lost by runoff seepage and evaporation. Only a portion of heavy and high intensity rains can enter and be stored in the root zone and therefore effectiveness of this type of rainfall is low. With a dry soil surface with no vegetation cover, rainfall up to 8mm/day may all be lost by evaporation. A rainfall of 25 to 30mm may be only 60 percent effective with a low percentage of vegetative cover. Frequent light rains intercepted by a plant canopy with full ground cover are close to 100 percent effective.

In most parts of the world crop production depends on rainfall. Knowledge of the probable dates of commencement and end of the rainy season and the duration of intermittent dry and wet spells can be very useful for planning various agronomic operations such as preparing a seedbed, manuring, sowing, weeding, harvesting, threshing and drying. This results in minimizing risk to crops and in optimum utilization of limited resource including water, labour, fertilizer, herbicides and insecticides. There are critical periods in the life history of each crop from sowing to harvesting. With knowledge of frequency of occurrence of wet and dry spells a farmer can adjust sowing periods in such a way that moisture sensitive stages do not fall during dry spells. Under irrigated farming irrigation can be planned using data regarding consecutive periods of rainfall to satisfy the demands for critical periods. Knowledge of wet and dry spells can also help a great deal in improving the efficiency of irrigation water utilization.

Hydrological balance equation is a useful balance parameter of water availability and water needs at a place expresses as-

$$P+I=AET/PET+SM+RO+D$$

P= Precipitation

I= Amount of irrigation applied

SM=Change in soil moisture storage

RO=Surface runoff

D=Deep Percolation

AET= Actual evapotranspiration

PET= Potential evapotranspiration

INFLUENCE OF AGROMETEOROLOGICAL FACTORS ON INCIDENCE OF PEST AND DISEASES-

SOME IMPORTANT INSECT PESTS OF CROP PLANTS-

1. APHIDS-

- Weather factors, especially temperature and rainfall, play a dominant role in the population dynamics of aphids in all the climatic regions of the world where crop production is possible.
- Aphids are highly sensitive to temperature changes.
- Increase in temperature leads to a greater number of aphids in the absence of the predator.
- Temperature below 20^{0}C and above 25^{0}C limits the buildup, while an increase from 20 to 22^{0}C enhances the aphid population.
- A max 45^{0}C in the post rainy season has been observed to be lethal for the sugarcane aphid species (*melanaphis sacchari*) in sorghum.
- Aphids in the tropics show remarkable adaptability to climate regulating their population etc.
- If there were substantial increases in minimum temperature and evening humidity and an appreciable decrease in sunshine hours with occasional rain, aphid infestation was observed at high levels.

2. GRASSHOPPERS-

   - Their growth and development rates increase with temperature for each species. Nymphal development, adult mass and size and egg production rate also increases with temperature.
   - Grasshoppers are larger in warmer, sunnier and from northern sites grow faster.
   - Prolonged drought conditions suppress the population of grasshoppers.

3. LOCUSTS-

- Locusts can travel long distance and colonize new habitats. Therefore, their distribution is variable time and space and can occur within a large area. The pest is feared for both its destructive capacity and its constant threat to the region. It is capable of sudden appearances and severe devastation to standing crops.
- Survival and populations are greatest with an increased frequency of sufficient rainfall, where rain water is enhanced by runoff and flooding.
- Locust avoids thermal extremes.

4. COTTON BOLLWORMS-

    - No egg hatch at less than 10^0C or more than 37.5^0C.
    - Mortality of larvae and pupae also increased at temperatures greater than 37.5^0C. Development of larvae was successful at all temperatures between 15^0C to 35^0C. Larval period and adult longevity decreased as relative humidity increased.
    - In china distribution of rainfall affects the incidence of bollworms. Populations of the pests less when total precipitation is greater than 500mm and dense when total precipitation is less than 400mm. Continuous rain produced more severe damaging effects on pupal stage.
    - In India, pink boll worm (*pectinophora gossypiella*) requires26.7^0C to 31.4^0C mean air temperature and 62.2 to 77.7% relative humidity for growth.

5. FRUITFLY-

- The abundance of fruit fly is greater in regions where the daily maximum temperature does not exceed 38^0C during summer. Immature adults are unlikely to survive when the maximum temperature exceeds 40^0C.
- Population increases in wet (rainy or rainfall) years and decline in dry years. Rainfall excess of 170mm resulted in high population and less than 170mm resulted in low population.

6. MITE RELATED DISEASES-

Barn itch (*sarcoptic mange*) occurs in all species of animals, causing a severe itching. Animals in poor condition appear to be most susceptible. The disease is most active in cold, wet weather and spreads slowly during the summer months.

Pigs are commonly affected but it is an important disease of cattle and camels and also occurs in sheep, it is noticeable disease in most countries and is important because of its severity.

ROLE OF WEATHER AND CLIMATE-

- Weather controls the development rate, survival, fitness and level of activity of individual insects.
- Phenology, distribution, size and continuity of insect populations, migration and their establishment and the initiation of insect outbreaks also control by weather.
- Weather influence may be immediate, cumulative, direct, indirect, time lagged.

- Indirect effects arise through host quality and parasite population.
- Temperature, humidity and wind play the major roles in insect life.
- Solar radiation and photoperiods have lesser effects.

TEMPERATURE AND ITS EFFECT ON INSECT AND PEST-

Each species has a range of temperature within which it can survive. This range is referred as the tolerate zone. Within the zone, there are different optimal temperature ranges for a variety of vital functions. Exposure to a temperature toward the upper or lower limit of the tolerable zone will usually result in death if it persists for a long enough time. At extremes of the tolerable zone, death will occur after a short duration of exposure.

- Most insects have an upper temperature tolerance between 40 to 50^0C and no known insect survive temperatures more than 63^0C.
- Some insects adopt physiologically to survive several months of hot, dry weather in a dormant state called summer diapauses.
- The absolute minimum temperature tolerated by any insect is not well defined but is almost certainly below -30^0C (others comes to dormancy).
- Bark beetle survives -29^0C in winter.
- Insect able to function at higher temperature but it reduces their life span and vice versa in low temperature.
- Temperature may determine the time of flight, height of flight and thus the spread and direction of the transporting wind as well as flight duration.

MOISTURE-

Moisture content in the habitat of an insect directly determines whether or not an individual survives. It also has indirect effects on insect populations through its influence on plant growth.

- Environmental moistures (atmospheric humidity, rain, snow, hail, dew, soil moisture and surface water) influences the water balance of the insect.
- The susceptibility of insects to fungal, bacterial and viral diseases also changes with environmental moisture. Moist conditions seem to facilitate the spread of some insect pathogens and may also affect the survival and virulence.
- Heavy and excessive rain can cause light mortality, either directly through knock down, saturation or flooding or by providing conditions favorable for disease. Heavy rain washes aphids off their host plants and both beetles and bugs may be killed by violent thunderstorms.

- Rain also plays a role in altering a host's susceptibility to wind borne insects and disease vectors.

WIND-

- Wind is an important factor of the environment of insects; and it influences insect populations in several ways. It is a vital component of broad weather patterns, giving rise to fronts and convergence zones. Low pressure systems and anticyclones is temperate regions determines migration trajectories of insects, while trade winds and monsoons determine the trajectories in tropical and subtropical areas.
- Wind causes insect displacement and therefore affects population changes by influencing the numbers moving into or out of an area. Many insects and pathogens appear to undertake enormous migrations covering hundreds if not thousands of km on occasions. They perform this feat by exploiting the wind as an external source of energy.
- Strong wind could kill the insects by carrying individuals to unsuitable areas, completely out of their habitat range.

LIGHT-

- It is not a true climatic factor, but it is interrelated with solar radiation and temperature.
- Photoperiodism exercises a great deal of control over processes directly related to survival of insects. Light intensity greatly influences insect behavior.
- Day length can also be used as a signal or trigger by insects to enter diapause during potentially harsh conditions such as summer heat, winter cold and drought.
- Wild bean weevil has whole life cycle of 75 to 80 days, when it receives 15-16hrs of day light per day night cycle.
- Migratory capacity of insects may be influenced more by photoperiods during development than by temperature.

ARTIFICIAL RAIN (CLOUD SEEDING)-

Cloud seeding is an attempt to stimulate natural precipitation processes by injecting seedable materials (iodine compounds, solid carbon dioxide, dry ice, iodine etc.) into clouds, typically from aircraft. It is observed that even in dry regions, there is no girth of clouds. The problem is that they do not produce rain. There are two reason why clouds do not produce rain.

1. The droplets do not grow large enough to initiate coalescence.

2. The temperature is not low enough (below -10^0C) to produce ice crystals naturally. These reasons must be overcome to produce rain. This can be done by artificially introducing some nuclei, which will induce ice crystal formation. These nuclei can be silver iodide or dry ice (AgI).

   AgI is a substance has crystal properties similar to those of ice.

By dropping AgI into the cloud the Bergeron process is stimulated. When AgI is dropped into a cloud, ice crystals form around them or they collide with and freeze some of the cloud droplets. These ice particles grow large enough to initiate coalescence even when the temperature is as high as -4^0C. Sometimes cold clouds are dioxide and has a temperature of about -80^0C. Thus when dry ice falls through a cloud they cools the nearby air parcel below -10^0C, it then encourages the natural freezing nuclei and activates the Bergeron process. In warm clouds, sea salt crystals and other hygroscopic substances are injected to encourage the growth of few large drops, which then can fall to the ground. The statistical significance of the result is hard to assess and there is lack of undisputed evidence (careful) studies have shown that when clouds are seeded properly precipitation increases by 10-20% but the question remains would the rain or snow that follows would have fallen anyway.

Cloud seeding is not always successful. If too many ice crystals are produced as a result of seeding, none will be able to grow large enough to start coalescence. There is therefore always a possibility that if cloud seeding is overdone it can actually prevent a cloud from producing precipitation.

There are also some problems in cloud seeding-

1. It does not work in very dry areas where it is most needed because there are rarely any clouds available.
2. There could be serious ecological side effects, including-
   a. The unknown effects of AgI on human being and wildlife.
   b. Changes in original snowfall and rainfall.
   c. Additional flooding that could alter or destroy vegetation and wildlife.
3. Cloud seeding, meant for a particular dry area, may bring rainfall to other already wet area.

Cloud seeding can also occur naturally. When ice crystals from cirrus clouds fall into the stratus clouds below, thus increasing precipitation.

WEATHER FORECASTING-

The advance information regarding forth coming weather is called weather forecasting. Plant growth and development are primarily governed by climate and soil. Prevailing weather conditions decide whether farming would be successful. Beside crop production, transport, trade, aviation, navigation, communication etc. depends on weather.

Weather manifests its influence on agricultural operations and farm production through its effects on soil, plant growth and development. Therefore, the primary requirement for initiating agronomic measures against weather hazards is fore knowledge of weather situations that is likely to develop is an area. Advance information regarding weather related to agriculture and farmers is known as agrometeorological forecast.

IMPORTANCE OF FORECASTING-

Accurate weather forecasting can help the farmers in realizing economic yield by minimizing the crop losses.

Forecasting aids in:

1. Planning for necessary inputs during the season.
2. Timely land preparation to take advantage of earliest rain for timely sowing.
3. Selection of crops and cultivars.
4. Efficient use of fertilizers.
5. Predicting pests and diseases incidence for timely action.
6. Timing of weeds, pests and diseases control.
7. Planning for mitigating, adverse effects of weather hazards.
8. Adjustments in crop harvest timing to reduce the losses at harvest.

TYPES-

1. Short range (up to 72 hrs (3 days).
2. Extended (up to 5 days)
3. Medium range (up to 10 days)
4. Long range (10-30 days)

TYPES	EMPHASIS ON	APPLICABILITY
Short range (70-80% accuracy)	Temperature, wind velocity and direction, sunshine duration, time and amount of precipitation, RH	1. Irrigation scheduling 2. Timing of Agricultural operations 3. Plant protection
Medium range (60-70% accuracy)	Types of weather, sequence of rainy days, weather hazards such as strong wind, dry spell etc.	1. Decision on sowing time 2. Sowing depth 3. Scheduling irrigation 4. Time of harvest 5. Timing of plant protection 6. Labor Requirement
Long range (60% accuracy)	Abnormal temperature and Precipitation.	1. Soil moisture management 2. Timing of irrigation 3. Crops and cultivars selection 4. Decision on cropping pattern 5. Predicting crop yield.

METHODS OF WEATHER FORECASTING-

1. SYNOPTIC METHODS-

It is the primary method used for making weather prediction. It uses the diagrammatical representation of weather systems through time and its development in the future. They are called synoptic which means “coincident in time” because they display synopsis of the weather conditions at a given moment. These weather charts are a symbolic representation of the atmosphere. To a trained eye a weather chart is a snapshot that shows the status of the atmosphere including variations in temperature, humidity, pressure and air flow.

2. STATISTICAL METHODS-

Statistical methods are used mostly in long range and seasonal climatic forecast. In this method correlation and regression are calculated using weather elements.

The formula used by forecasters used are-

Fs=100 (R-E/T-E) %

Where,

Fs=Amount of skill shown in forecast.

R=Number of correct forecasts of an entity.

E= number of expected to correct.

T= total number of forecasts.

3. NUMERICAL METHODS-

Equation can be used for prediction of final state of weather through a purely mathematical process. Considering the current state of weather in a fairly large number of synoptic stations of a given region this is known as numerical methods.

WEATHER FORECASTING IN INDIA-

Indian economy is very much dependent on the monsoons. The success and failure of the Indian agriculture and consequently the economy largely dependent on monsoon.

Realizing the importance of weather forecast in agriculture a separate department of agriculture meteorology or agrometeorology was set up under the Indian meteorological department (IMD) in 1932.

The IMD gets weekly average of various meteorological data like cloud amount, wind velocity and direction, maximum and minimum mean temperatures relative humidity etc., from weather forecasting unit. The data is then analyzed and forecast for the next 2 days.

It is now possible to clearly demonstrate spatially the areas which are currently under the influence of the monsoon clouds and the areas to which clouds are advancing. Fairly accurate forecast of cyclones, heavy rainfall or other such disasters are now given for various regions on an operational basis.

However, it is the long-range forecast that predicts monsoon. For long and medium-term weather forecasting the government has set up a National centre for medium Range weather forecasting (NCMRWF). A super computer has been installed at the centre.

In 1989, the team of Dr. V. Gowarikar developed a new LRF technique consists of parametric and power regression models (PRM) which considers the influence of a total of 16 parameters both locals and global.

IMPORTANCE OF WEATHER FORECASTING IN CROP PRODUCTION-

1. The forecast of the weather events helps for suitable planning of farm.
2. It helps to undertake or withheld the sowing operation.
3. To irrigate crop or not.
4. When to apply fertilizer.
5. Whether to start complete harvesting or to withhold it.
6. It also helps in to take measure to fight frost.
7. It helps in transportation and storage of food production.
8. Helps in management of cultural operations like ploughing, harrowing, hoeing etc.

CROP WEATHER RELATIONSHIP-

Crop-weather relationship enable to understand, quantitatively the role played by weather elements on crop production, growth and yield. Such models have been applied to wheat, paddy, cotton and groundnut and other crops and response of these crops in various phenological stages in relation to meteorological factors have been studied. Variability of soil moisture, soil temperature and the contribution of dew have also relationship with crop growth. Fluctuations in temperature (weather) with regard to crop factors like LAI, stomatal resistance, crop co-efficient, dry matter production are also major factors.

In case of cotton more sunshine during crop period and more rainfall up to the middle of January are beneficial. More relative humidity during elongation and branching period is useful for crop. Minimum temperature plays the most important role in controlling about 72% of the total variation in cotton yield.

CLIMATIC CLASSIFICATION-

It is a device by which the multiplicity of the atmospheric condition upon the earth is meaningfully organized. It is also a method of comprehending the variation and distribution of the fundamental elements of the climates of our earth as well as their relations to the other phenomena.

In climatic classification, we describe and do mapping of homogeneous set of climate conditions. There are two basic approaches for classification of climates.

1. EMPERICAL APPROACH-

It is based on statistical experiment or physical characteristics related to climate. It is based on observation and usually more stable over time.

2. GENETIC APPROACH-

It is based on the cause of the genesis of climate variation. The explanations are theoretical, incomplete and non-quantitative. Unlike empirical classification genetic classification needs frequent relation because it is less stable than empirical method.

OBJECTIVE OF CLIMATIC CLASSIFICATION-

1. To establish different type of climate found over earth.
2. To establish relationship among different types of climate.
3. To extend application of the classification to the whole world.
4. To demonstrate the factors that causes any particular climate.

ADVANTAGES-

1. By identifying climate types, we can predict various associated visible aspect of the environment.
2. It may also enable the geographer to predict the climate of a region through his observation on the vegetation, animal life, soil etc.

KOPPEN'S CLASSIFICATION-

Koppen classified the climate into 5 major classes (A, B, C, D, and E). 4 of these major classes (A, C, D, and E) are based on temperature characteristics however B class has been classified based on precipitation and temperature characteristics. Temperature characteristics of 5 major classes are as follows-

CLASSES	TYPES
A.	Tropical Rainy Climate
Average Temperature of the coldest month is more than >18^0C.	
B.	Dry climate
Here, Evaporation > Precipitation, low temperature limit.	
C.	Humid mesothermal climate

Average temperature of the coldest one is between 18^0C to -3^0C and average temperature of the warmest month is more than 10^0C.

D. Humid microthermal climate

Average temperature of the coldest month is $<-3^0$C and temperature of warmest month is $>10^0$C.

E. Polar climate

Warmest month temperature is $<10^0$C.

Except E Class each of above primary classes are further subdivided into 2 or more secondary categories.

KOPPEN'S CLIMATIC CLASSIFICATION OF INDIA-

Analyzed according to the Koppen's system the climate of India resolves into six major climatic subtypes, their influence give rise to desert in the west, alpine tundra and glaciers in the north, humid, tropical regions supporting rain forests in the southwest and Indian ocean island territories that flank the Indian subcontinent. Regions have different but have clustered microclimates. The nation is largely subject to four seasons: winter (January and February), summer (March to May), a monsoon (rainy) season (June to September) and a post monsoon period (October to December).

India's geography and geology are climatically pivotal. The Thar Desert in the North West and the Himalayas in the north work to affect a culturally and economically break all monsoonal regime. As earth's highest and most massive mountain range the Himalayan system bars the influx of katabatic winds from the icy Tibetan plateau and northerly central India. Most of north India is thus kept warm or is only mildly chilly or cold during winter the same thermal dam keeps most regions in India hot in summer.

THORNTHWAITE'S METHOD-

A.1931 Scheme- He introduced climatic classification based on climatic efficiency. He used two climatic indices-

1. Temperature efficiency (TE)
2. Precipitation efficiency (PE)

The TE is calculated as, $TE=1/4\sum_{i=1}^{12}(Ti-32)$

Where, Ti= Mean temperature in ^{0}F in ith month.

i=1 to 12 is because of 12 months.

$PE=115\sum_{i=1}^{12}(\frac{Pi}{Ti}-10)^{10/9}$

Where, Pi= Mean precipitation in ith Month.

TE	SYMBOL	DESCRIPTION	PE	SYMBOL	DESCRIPTION
>127	Á'	Tropical	>127	A	Per humid
64-127	B'	Mesothermal	64.127	B	Humid
32-63	C'	Microthermal	32-63	C	Sub humid
16-31	D'	Taiga	16-31	D	Semiarid
1-15	E'	Tundra	<16	E	Arid
<0	F'	Frost	----	-----	---

B. 1948 SCHEME-

In 1948, he introduced the concept of potential evapotranspiration (PE) and the soil water balance. He defined potential evapotranspiration as the water loss from large homogeneous vegetation area under sufficient water condition and PE is primarily being a function of climatic condition and not a function of type of vegetation, soil type, soil moisture content.

PE is calculated from the mean monthly temperature as follows-

$PE=(\frac{10t}{I})^{a}$

Where,

PE=Potential evapotranspiration (in cm)

I=Sum of 12 months of $(t/5)^{1.514}$

a=Function of I.

t=Temperature in ℃.

By comparing precipitation and PE, the surplus water (s) available for runoff and deep percolation and the water deficit (d) can be calculated through the soil water balance computation. By combining s and d the moisture index (Im) is calculated as,

$Im=I_h-0.6Ia=100s-60d/PE$

Where, Im= moisture index

I_h= humidity index

I_a= aridity index

The different climate types can be delineated by using moisture index as under-

SYMBOL	CLIMATE TYPES	MOISTURE INDEX
A	Per humid	≥100
B_4	Humid	80 - 100
B_3	Humid	60 - 80
B_2	Humid	40 - 60
B_1	Humid	20 - 40
C_2	Dry sub humid	0 - 20
C_1	Moist sub humid	-20 - 0
D	Semi-arid	-20 - -40
E	Arid	-40 - -60

He subdivided the climate type based on humidity and aridity index-

SYMBOL	MOIST CLIMATES (A, B, C_2)	ARIDITY INDEX (%)
γ(Gamma)	Little or no water deficiency	0 - 10
S_1	Moderate summer water deficiency	10 - 20
W_1	Moderate winter water deficiency	10 - 20
S_2	Large summer water deficiency	≥20
W_2	Large winter water deficiency	≥20

Symbol	Dry Climates (C_1, D, E)	Humidity index (%)
D	Little or no water surplus	0 - 16.7
S_1	Moderate summer water surplus	16.7 - 33.3
W_1	Moderate winter water surplus	16.7 - 33.3
S_2	Large summer water surplus	≥33.3
W_2	Large winter water surplus	≥33.3

PHYSICAL CLIMATE-

Physical climate is simply a solar climate modified by the atmosphere and by the various controls. We will consider in this chapter the effects of these controllers on the climate.

EFFECT OF VARIOUS CLIMATIC CONTROLS ON CLIMATE-

1. Effect of latitude on the climate (Solar climate)-

The sun or we may say latitude is the principal control of climate. The climate of any place by the solar radiation is called as solar climate. Solar radiation is named as insolation. The heat energy received from the sun at any place depends on the following factors-

a. Distance from the sun since insolation varies inversely as square of distance.

$$Insolation \propto \frac{1}{distance\ X\ distance}$$

b. Inclination of the rays to the solar elevation, since the rays when falling obliquely upon a surface are spread out over a larger area than when falling normally.
c. Duration –i.e., length of the day.
d. Transmission and absorption by the atmosphere.
e. Output of solar radiation.

2. Mountain and Plateau Climates (Effect of altitude on climate)-

Altitude also influences the climate at a given place as the various controls varies with altitude. Thus, climate at mountain and plateau are different. The climates on mountain are characterized by decrease in temperature, pressure and absolute humidity. They are also characterized by an increase in insolation and in relative humidity. The mountains are cool in summer because increase in loss of heat by radiation (40%) is more than increase in gain of heat by insolation (20%). Precipitation increase with increase in altitude. Winds of local nature such as mountain and valley breeze exists.

3. Marine Climate (effect of water on climate)-

Marine climate exists wherever water is the dominant control. They are therefore found over the open ocean on small islands and along coasts. Marine climates are characterized by moderate temperatures with small diurnal and annual ranges by high humidity both absolute and relative and by much cloudiness and rainfall.

4. Continental Climate (effect of land on climate)-

Continental climate is exactly opposite to the marine climate. The land body has lower specific heat as compare to the specific heat of water on sea. The temperature ranges, both annual and diurnal are large. The limited amount of water for evaporation is responsible for low relative humidity. The higher temperature of summer and the greater water vapor content (i.e., absolute humidity) of the air during that season favor more convection than in winter but the average percentage of cloudiness may vary little with the season since relative humidity is greater in winter.

5. Desert Climate-

Desert climate is also referred to as extreme continental climate because of the similarity in the high ranges of temperatures, humidity, cloudiness and rainfall. Two physical characteristics of the deserts are-

a. A low relative humidity that results in a small amount of clouds but unless there is sufficient cooling of the air no precipitation takes place.
b. A great diurnal range of temperature.

6. Monsoon Climate-

In winter, continents favor high pressure and outflowing wind and in summer they favor low pressure and inflowing wind. Oceans favors the opposite conditions, high pressure and out flowing wind in summer and low pressure and inflowing wind in winter. Thus, in winter the wind flow from continents to oceans and in summer wind flow in opposite direction that is from ocean to continents and these winds are called as monsoon winds and climate is called as monsoon climate. A monsoon climate is characterized by:

1. In summer, high humidity (Both relative and absolute) and intense rainfall.
2. In winter, low humidity little or no precipitation and clear skies.

Such climates exist in India, southern and eastern Asia, east central Africa and northern Australia.

EVAPORATION-

It is the process where liquid and ice changes into water vapour.

Essential requirements for evaporation-

1. Energy supply to provide latent heat for conversion of water into vapour.
2. Vapour pressure gradient to help vapour movement into atmosphere.
3. Wind speed to remove water vapour from evaporating surface.

MAJOR FACTORS INFLUENCING EVAPORATION RATE ARE-

1. Surface soil moisture content
2. Soil and air temperature
3. Atmospheric humidity
4. Wind Velocity
5. Vegetative cover

If actual vapour pressure of air is more than saturated vapour pressure, then there will be no evaporation. Thus, rate of evaporation directly depends on the difference in these two pressures.

Dalton’s law of Evaporation-

$E=K(e_s-e_a)f(u)$

Where, E=Evaporation

K=Proportionality Constant

e_s=Saturated vapour pressure of water

e_a =Actual vapour pressure of air

f(u)=Function of wind velocity

Relation of salinity of water with evaporation-

1. Dissolved material reduces the rate of evaporation.

2. Evaporation rate is greater on ocean than on surface.

3. Evaporation rate is greater on equator than on pole.

EVAPOTRANSPIRATION-

Evapotranspiration (ET) is the sum of evaporation and plant transpiration from earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception and water bodies. Transpiration accounts with the movement of water within a plant and the subsequent loss of water as vapour through stomata in its leaves. Evapotranspiration is an important part of the water cycle. An element such as tree that contributes to evapotranspiration can be called as evapotranspirator.

The loss of water is directly controlled by the stomata which open and closes depends on R.H, movement of air and concentration of water available in soil.

Local factors influencing evapotranspiration-

1. Radiation intensity
2. Length of the day
3. Wind velocity
4. Soil moisture condition
5. Tillage
6. Atmospheric temperature
7. Photoperiods
8. Type of Vegetation
9. Type of precipitation
10. Weed management

EVAPOTRANSPIRATION IS OF TWO TYPES-

1. ACTUAL EVAPOTRANSPIRATION-

   The evapotranspiration under actual field conditions is known as actual evapotranspiration (AET). AET can be measured by gravimetric and lysimetric methods. It is generally influenced by nature of ground and vegetative cover.

   AET=f (soil, plant, weather) f= Function.

2. POTENTIAL EVAPOTRANSPIRATION-

   The dependence of ET on meteorological factors at a given place has led to the concept of potential evapotranspiration in which soil and plant factors are ignored. It is the upper limit of evapotranspiration. The maximum evaporation rate which the atmosphere is capable of is obtained from well-watered field.

HYDROLOGICAL CYCLE-

The water cycle also known as the hydrological cycle describes the continuous movement of water on, above and below the surface of the earth. The water moves from one reservoir to another such as from river to ocean or from ocean to the atmosphere by the physical processes of evaporation, condensation, precipitation, infiltration, runoff and sub-surface flow. In so doing the water goes through different phases: liquid, solid (ice) and gases (vapour).

The water cycle involves exchange of energy, which leads to temperature changes. For instance, when water evaporates it takes up energy from its surroundings and cools the environment. When it condenses it releases the energy and warm the environment. These heat exchange influence climate.

Due to sun, which derives the water cycle, water evaporates as water vapour in to air. Ice and snow can sublimate directly into water vapour. Evapotranspiration is water transpirated from plants and evaporated from soil. Rising air currents takes the vapour up into the atmosphere. Where cooler temperature causes it to condense into clouds. Air currents moves water vapour, cloud particle collides grows and fall out as precipitation. Some precipitation falls as snow, hail, sleets which can store frozen water for 1000 years. Then again, the process continues.

BASIC MECHANISM-

1. Evaporation of water into water vapour.
2. Condensation of water vapour into clouds.

3. Precipitation.

LATENT HEAT AND SENSIBLE HEAT-

Latent heat and sensible heat are types of energy released or absorbed in the atmosphere. Latent heat is related to changes in phase between solid, liquid and gases. Sensible heat is related to changes in temperature of a gas or object with no change in phase.

LATENT HEAT-

Latent heat is the energy absorbed by or released from a substance during a phase change from a gas to a liquid or a solid or vice versa.

For example,

When water is boiled over a stove, energy is absorbed from the heating element and goes into expanding water molecules into a gas known as water vapour. When liquid water is put into ice cube trays and placed in the freezer, the water gives off energy as the water becomes solid ice.

Water vapour is a greenhouse gas located in the atmosphere and very important component for cloud formation. If the air is dry or unsaturated, clouds are not likely to form because there is minimal water vapour in the air. If air is moist or saturated the water vapour is condensed to form clouds. When these gas molecules condense into liquid drops latent heat is releases in to the atmosphere which warms the air surrounding the molecule.

SENSIBLE HEAT-

Sensible heat is the energy required to change the temperature of a substance with no phase change. The temperature change can come from the absorption of sunlight by the soil or the air itself or it can come from contact with the warmer air caused by release of latent heat. Energy moves through the atmosphere using both latent and sensible heat acting on the atmosphere for the movement of air molecules which create wind and vertical motion.

HOW DOES LATENT AND SENSIBLE HEAT RELATED TO AGRICULTURE-

On a day with a lot of water vapour in the air (high humidity) the potential for latent heat release makes it more likely for showers and thunderstorm to develop. Rain that falls from these storms hits the hot ground and evaporates which removes a lot of energy from the ground and cools it off. If you are going to apply an herbicide or pesticide which needs to sit on the leaves of your crops for a while to work then you may have problems on days when the high humidity is more likely to lead the development of showers. On the other hand, the cooling effect of the rain may feel refreshing or a hot summer afternoon.

GREEN HOUSE EFFECT-

The atmospheric gases (water vapour, carbon dioxide, methane, Cfcs, Bfcs and Nitrous oxide) allow shortwave radiation coming from sun to pass through but they absorb the long wave radiation emitted by earth. So, they trap some of the heat energy radiated from the earth. The trapping of heat radiation and warming of atmosphere is somehow same as a green house and the effect is called as greenhouse effect.

MAJOR CONTRIBUTERS OF GREENHOUSE EFFECT-

1. Water vapour=36-70%
2. Carbon Dioxide=9-26%
3. Methane=4-9%
4. Ozone=3-7%

The major non-gas contributor to the earth’s greenhouse effect is cloud which also absorbs and emits I.R Radiation and thus have an effect on radiative property of atmosphere.

Strengthening of greenhouse effect through human activities is known as enhanced greenhouse effect.

CO_2 is produced by fossil fuel burning and other activities such as cement production and tropical deforestation. The concentration of CO_2 is about 313 ppm in 1960, it increases to 389ppm in 2010 and in recent it reaches 400ppm in May 2013.

GREEN HOUSE EFFECT ON CROP PRODUCTION-

It may affect-

1. Productivity in terms of quantity and quality of crops.
2. Agricultural practices through change of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers.
3. Environmental effects in particular soil erosion and reduction in crop diversity.
4. Rural space through the loss of cultivated lands.

5. Adaptation, organisms may become more or less competitive. It leads to certain varieties to adopt in the conditions which they are not familiar to lead to fill in crop production.
6. Cardinal temperature will be affected leads to misleading in crop maturity.
7. Decrease in crop yields and decrease in land availability due to starvation and malnutrition.
8. Loss of crop diversity.
9. Variable and unexpected results.
10. Wheat yield decrease by 32 to 50%.
11. Increase in CO_2 concentration lowers pH, affect nutrient availability and microbial activity.

HEAT CAPACITY-

Heat capacity of soil is the amount of heat required to raise the temperature of one cm^3 of water by 1^0C.

Heat capacity = Specific heat × soil mass

Or

Heat capacity=$\sum$(Specific heat of soil constituents)

- Heat capacity of water is 1.0 cal/ cm^3/℃.
- Most soil have heat capacity of 0.3 to 0.6 cal/cm^3/℃.

CHAPTER.6

ANIMAL CLIMATOLOGY

Stress on animal

1. Environmental stress
   a) Heat stress
   b) Cold stress
   c) High humidity

a) Heat stress-

It causes-

- Loss of production
- Loss of body gain or body weight
- Poor reproduction
- Rapid respiration (it increases from 40-50% in summer in buffalo)
- Flank region used for counting of respiration
- Increase in body temperature

Normal temperature	Animals/Birds
100.5-101.5°F	Cow, buffalo
107°F	Poultry
101-102°F	Pig

- Rapid pulse rate

55-65/min is normal in cows and buffaloes

70-80/min is abnormal or fever condition

*Buffaloes are known as seasonal breeders because they came to heat in only rainy and winter season.

*Impaction of rumen due to feeding of dry fodders without any water so the cow dung become hard to come.

Control measure of heat stress:

1. Not allowing the animal for pasture grazing in hot summer time (outside).
2. Providing shade-
    - Natural shade (trees)
    - Artificial shades (barns- kachcha and pakka types)
3. Cooling systems-
    - Fans + exhaust fans
    - Coolers
    - Fans with mist
    - A/C
    - Proper ventilation
4. Wallowing (pakka tank with proper drainage)
5. Bathing of animals (clean milk production)

b) Cold stress or chill stress-

- Body temperature may increase due to disease condition when proper care is not given during winter.
- During winter very chill, foggy weather, rain with wind causes pneumonia.

Control measures-

1. Heat is provided by fire using traditional materials.
    - Room heaters
    - Use of curtains
    - Bulbs
2. Covering the body of animals using old gunny bags or blankets.

3. Balanced diet should be provided (protein content should be more).

   Like oilseed cake, mustard cake, til cake etc.

Stress of humidity:

- More sweating (body minerals decreases)
- Serious weakness
- It is more dangerous than heat and chill stress because due to this animal loses more body minerals and sweat more.
- More fans are required with more exhaust systems.

2. **Transportation stress-**

Due to tiredness;

So, there are many transportation shelters in which animals are maintained properly with proper care in order to avoid transportation stress.

- Animal rest
- Proper grooming and massaging.

3. **Vaccination and medicinal stress-**

- Loss of appetite (which causes loss of production)
- Production loss
- Reproduction problem

Control measures-

- Avoid excess dose
- Vaccination should be done properly

4. **Excitement or nervous stress-**

   It occurs very occasionally, may be due to animals like cats, dogs etc.

Control measures of stress-

1. Always provide pleasant environment to the animals.

2. Various medicines/use of antistress medicines.
    a) Electrocare (minerals) for animals-
        - 100-200gm for adult animal.
        - 100gm per 1000 chicken with water.
        - 50-100gm per young animals.
    b) Zee tress (herbal drug)-
        - Any stress in chicken can be cured by it.
        - 5-10gm/adult animal daily
        - 1-2gm/young animal
        - 5gm/1000 chickens
    c) Stress rock (medicines)-
        - 10-15ml/1000 chickens
        - 20-25ml/animal
    d) Stress cool (it may be in liquid form or tablet form)
        - 20-25ml/animal
        - 10ml/1000 chickens

Care of pregnant cows

1. Before cowing
    - Keep the advance pregnant cow away from the herd.
    - Provide them shade or barn.

      (Cowing box or cowing pan- specific place for pregnant cow for proper care before and after cowing).
    - Provide easily digestible diet and sufficient amount of fresh and clean drinking water.
    - Protect the cow from wild animals, street dogs and wild birds.

  - Daily cleaning and disinfection of barns.
  - Avoid use of slippery floors.

2. During cowing
   - Take care of animals during cowing as mentioned above.
   - Make proper arrangement of one attendant to look after the cow during cowing.
3. After cowing

   If there is the case of retention of placenta, remove it after six hours by taking the help of veterinarian.

Effect of heat stress on production

In most tropical feeding systems, the forage is having low nutritional values during summer as compared to the winter. Initially the feed intake is depressed (decreased) under hot condition and the efficiency of nutrient metabolism and absorption of nutrients is reduced. So low nutritional quality and high environmental temperatures have various effects on reproduction. Heat stressed cows are likely to exhibit heat and often should heat at night when they are less likely to be observed. In addition, duration of estrus is shorter for cows subjected to heat stress. The time return to the activity is closely linked to blood glucose level of the cows, indicating the effect of increased heat load of feed intake and energy metabolism are very important. Increase in heat loads directly reduces utilizing hormone secretion. There are several reasons which affects reproductive performance during hot weather. Heat stress alters the follicular development pattern in cattle.

Higher intrauterine temperatures likely reduce embryo survival and also have adverse impact on consumption. One reason for greater temperature of uterus is the higher body temperature and less uterine blood flow to remove heat, because more blood is shifted to the skin to help reducing body heat.

Management strategies to optimize/minimize reproductive heat stress:

There are specific steps that can be taken to mitigate effect of heat stress on reproduction in dairy cattle.

1. **Shade**
   All animals including dry cows and pregnant cattle should have access to effective shade during the hot period of the year.
2. **Cooling**
   In severe heat stress provision of stress is some for cooling may enable the cow to maintain their normal body temperature.

*Dry cows:

The cows who stops milking and in advance pregnancy (dry period 45-60 days).

*Heat cycle:

For 21 days; cow remain in heat period for 16-22 hours.

*Lactation (milking) period- 300 days

*Gestation period- cows-280±5 days

Buffalo- 310 days

*Herd average= (milking cow + dry cow)/no. of total cows

*Milking average= Milking cow/ total cows

Adaptability

It is the ability of animal to withstand against the adverse conditions and adjusts themselves to environment in which they live.

Adaptation:

It is the process by which an animal adopts itself into new changed environmental condition. It is of 3 types as follows-

1. **Biological adaptation:**
   a) Morphological
   b) Anatomical
   c) Biochemical

d) Behavioural

Characteristics of the animal promoting its welfare and favouring its survival in a specific environment.

2. **Genetic adaptation:**

   The changes which taking place over many generations of population in a particular environment which occurs to genetic adaptation.

3. **Physiological adaptation:**

   It involves capacity and process of adjustment of animal to the external physical environment.

   Adaptability can be evaluated by the animal capability to adjust environmental conditions and climatic extremes.

   Well adapted animals are characterized by-

   1. Minimum loss in body weight when exposed to stresses like nutritional deficiency, transportation etc.
   2. Highly resistance to disease.
   3. Low mortality rate.

Acclimatization:

It is the sum of all long term complex physiological process by which animal adjust to environmental conditions.

Loss of water from the body-

- Dehydration
- Sweating
- Urine
- Major factor responsible is diarrhea.

Control –

1. Fresh water- adlibtum (as much as they can take)
2. Jaggery water
3. Rintose- 25% glucose (provide glucose to animal during water stress condition)
4. Calcium supplements
5. Mifex solution for energy.

Table 1: Effects of Ambient Temperature, Humidity and Solar Radiation on Physiological Traits of Animals (Prasad & Neeraj 2007)

	Ambient Temperature		Humidity with temperature		
Parameters	**Low**	**High**	**Low**	**High**	**Radiation**
1	2	3	4	5	6
A. **Physiological**					
1. Rectal temperature	Normal	Rise	Normal	Increase	Increase
2. Pulse rate	Normal	Increase	Normal	Increase	Increase
3. Body heat load	Less	More	Less	Increase	Increase
4. Muscular heat production	More	Decline	More	Decrease	Decrease
5. Chloride content	Normal	Increase	Normal	Increase	Increase
B. **Behavioural**					
1. Appetite	Normal or Decline		No effect	Decline	Decrease
2. Food intake	Slightly or more	Decline	Normal	Decrease	Decline
3. Water intake	Decrease	Increase	Low	Increase	Increase
4. Seeking more shade	No	Yes	No	Yes	Yes
5. Sluggishness	No	Yes	No	Yes	Yes
6. Browsing more at night	No	Yes	No	Yes	Yes
7. Grazing time	Increase	Decrease	No effect	Decrease	Decline
8. Respiration rate	Normal	Increase	Normal	Increase	Increase
C. **Productive**					
1. Growth	Better	Decline	Normal	Decrease	Decline
2. Milk yield	Increase	Decline	Normal	Decline	Decrease
3. S.N.F	Normal	Decline	Normal	Decline	Decline
4. Fat yield	Normal or increase	Decline	Normal	Decline	Decline
5. Lactose & nitrogen content	Normal	Decline	No effect	Decline	Decline
D. **Reproductive**					
1. Breeding efficiency	Better	Decline	No effect	Decrease	Decrease
2. Spermatogenesis	Normal	Decrease	Normal	Decline	Decrease
E. **Others**					
1. Body weight	Normal	Decrease	No effect	Decline	Decrease
2. Body size	Higher	Decline	No effect	Decrease	Decline
3. Belly girth	No effect	More	No effect	More	More
4. Skin burn etc.	No effect	Yes	No effect	Yes	More

CHAPTER.7

MICROMETEOROLOGY

MICROMETEOROLOGY-

Micrometeorology is the science of microclimate. This is a branch of meteorology, which deals with atmospheric phenomena over a few square kilometer areas and within a few meters of height above the ground.

The small scale variations of meteorological parameters like solar radiation, temperature, wind, vapour pressure and carbon dioxide are studied in respect of their effect on the microclimate above and within plant canopy.

- Microclimate is the climate near the ground, i.e. the climate in which plants and animals live. It differs from macro climate which prevails above the first few meters over the ground.
- Microclimate just above a crop and within the canopy is known as ecoclimate. It is influenced by a particular type of crop. Very large quantities of energy are exchanged at the surface in the process of evaporation and condensation.

SCOPE-

Atmospheric motions are characterized by a variety of scales ranging from the order of a mm to as large as the circumference of the earth in the horizontal direction and the entire depth of the atmosphere in the vertical direction. Scales of motions are generally classified into 3 broad categories, namely micro, meso and macro scales. Sometimes terms such as local, regional and global are used to characterize the atmospheric scales and the phenomena associated with them.

The scope of micrometeorology is further limited to only those phenomena which originate in and are dominated by the shallow layer of frictional influence adjoining the earth’s surface, commonly known as atmospheric boundary layer (ABL) or the planetary boundary layer (PBL). Thus, some of the small-scale phenomena, such as convective clouds and tornadoes are considered outside of the scope of micro meteorology, because their dynamics are largely governed by mesoscale and macro scale weather systems.

In particular micrometeorology deals with the exchange of heat (energy), mass, momentum occurring continuously between the atmosphere and the earth’s surface including the sub surface medium. Vertical distribution of meteorological variables such as wind, temperature and humidity as well as trace gas concentrations and their roles in the energy balance near the surface also come under the scope of micrometeorology. Turbulent fluctuations are also come under scope.

MICROMETEOROLOGICAL DIVISIONS-

1. Surface
2. Skin Layer
3. Surface Boundary Layer
4. Planetary Boundary Layer
5. Frictionless Layer

IMPORTANCE-

1. SURFACE-

It is the plane separating two different media i.e., soil and air. It is an important site for energy and mass exchange and conversion. It receives energy from sun and acts as a source of heat energy.

2. SKIN LAYER-

a. This is a thin layer ranging from few mm to 1.5m.
b. The exchange of energy and mass is done through the process of molecular conduction.
c. This is the layer which is directing significant to plants, animals.
d. Surface characteristics are dominant for exchange of energy.
e. The environment is continuously changing in this layer. The factors responsible for these changes are-
    - Kind of soils
    - Types of plants
    - Sunshine
    - Wind

3. SURFACE BOUNDARY LAYER-
    a. The thickness of the layer is 50 to 100m.
    b. The exchange of mass and energy done through the process of eddies and turbulent transfer.
    c. Temperature variation during day and night observed in this layer.
    d. The wind structure is governed by surface characteristics.
    e. Total heat in this layer is more than the total at the upper layer.

f. The effect of earth’s rotation is noticeable.
g. The weather of this layer is known as micro weather.
h. These are the two layers with which all the living organism of the surface are concerned.

4. PLANETARY BOUNDARY LAYER-

a. The influence of wind is less.
b. Temperature variation is very small.
c. Air density is very small.
d. Thickness is 100 to 1000m.

5. FRICTIONLESS LAYER-

a. The effect of surface friction is absent.
b. The influence of earth’s rotation is dominant.
c. Majority of the radiant energy is absorbed, reflected and emitted.
d. The main transformation of energy i.e., from radiant to thermal, sensible to latent heat takes place. The transformation of mass i.e., from water to water vapour occurs.
e. Precipitation is intercepted.

PROFILE OF TEMPERATURE, HUMIDITY AND WIND UNDER DIFFERENT STABILITY CONDITIONS-

TEMPERATURE PROFILE-

It is a general fact that temperature decreases with height, but this statement must be modified for conditions near the ground. The expression for temperature as a function of height above the ground is called as temperature profile.

1. High temperature is typical in day time in a clear day and cooler temperature is typical in night hours.
2. Both day and night temperature extremes are found at the ground surface.
3. For a given height, greater difference in temperature is found near the surface than further above.
4. The high temperature is typical on midafternoon (about 2 pm) in a clear day and the minimum is lowest before sunshine.

The air temperature rises more rapidly in the morning then it falls during the afternoon. Rate of fall of temperature in the afternoon is smaller than the rate of rise in the morning. This is because in the morning, the heat is being dissipated by evaporation and the soil heat reservoir is being refilled. The arrival of energy from the sun is more than the rate of evaporation and the heat added to soil, so the excess heat goes into heating the air. But in afternoon soil is not right for accumulation of heat, but it supplies heat to the surface and to the air near the surface. Hence it retards the fall of temperature till the next morning.

TEMPERATURE PROFILE WITHIN CROP CANOPY-

In presence of crop, the main heat exchange center is raised to just below the top of the crop canopy.

At night, long wave radiation emitted from the crop gave rise to a temperature just below the crown, so that the temperature increases upwards in the atmosphere and downward within the vegetation.

By night, the principle site of net radiation absorption is near the canopy crown. So, this is the level of maximum heating. Hence the temperature decreases both upward and downwards and the sensible heat is carried up into the air and down into the crop. Hence during day, we feel cool and at night we feel warm under tree.

WIND PROFILE-

1. WIND PROFILE IN THE OPEN AREA-

The wind field in the boundary layer is controlled by the frictional drag imposed on the flow by the under lying surface. The drag decreases mean horizontal wind speed as the surface is approached.

- The depth of this layer increases with increasing roughness.
- The vertical gradient of mean wind speed is Au/dz.
- It is greatest over smooth surface and least over rough surface.

2. WIND PROFILE IN PLANT CANOPY-

The plant canopy and foliage stand exert a considerable influence on the position of the above surface with regard to the exchange of heat, mass and momentum.

A plot of wind speed measures at a number of levels above tall vegetation results in a profile.

a. Wind profile over short crops-

It expresses in terms of logarithmic equation-

uz= $1/K\sqrt{t}/s$ log z/z_0

Where, u=Wind velocity at height Z cm

K=Von Karman's constant (0.4)

S=Density if air

t=Shearing stress

Z_0=Roughness length/parameters

It is constant or low for short vegetation or smooth surfaces.

b. Wind profile over tall crops-

$$uz = 1/K \sqrt{t}/p \log \frac{(Z-d)}{Z_0}$$

d= Zero plane displacement

The value of 'd'

Grasses =0.66m

Crops=3.0m

Orchards=4.0m

The Value of roughness length (Z_0)-

Soil: 0.001- 0.01m

Grasses: 0.003 to 0.1m

Orchards: 0.5 to 1.0m

Agricultural crops: 0.04 to 0.2 m

HUMIDITY PROFILE-

WATER VAPOUR PRESSURE PROFILE-

1. In the morning hours the ET of surface water into the atmosphere and moisture to the lower layers, so humidity is higher.
2. By the early afternoon, evaporation is at peak so humidity drops.
3. In the late afternoon surface cooling is strong and the lowest layers become stable and hence again humidity increases.
4. Vapour pressure concentration decreases with height away from the surface by day time.
5. Vapour pressure concentration increases in the lower level because of low ET.

In the morning hours, the ET of surface water adds moisture to the lower layers and the humidity increases. By the early afternoon, evaporation is at a peak, so the humidity drops slightly in the afternoon. In the late afternoon surface cooling is strong and the lowest layers become stable and again humidity is increased. Thereafter, ET declines in the night.

MICROSCALE METEOROLOGY-

It is the study of short lived atmospheric phenomena smaller than mesoscale, about 1 km or less. These two branches of meteorology are sometimes grouped together as “mesoscale and micro scale meteorology” (MMM) and together study all the phenomena small than synoptic scale, that is they study features generally too small to be depicted on a weather map. These include small and generally fleeting cloud and other small cloud features. Microscale meteorology controls the most important mixing and dilution process in the atmosphere. Important topics in microscale meteorology includes heat transfer and gas exchange between soil, vegetation and surface water and the atmosphere caused by near ground turbulence. Measuring these transport processes involves use of micrometeorological tower. Variables often measured including net radiation, sensible heat flux, latent heat flux, ground heat storage etc.

MESOSCALE METEOROLOGY-

Mesoscale meteorology is the study of weather systems smaller than synoptic scale systems but larger than microscale and storm scale system. Horizontal dimensions generally range from around 5 km to several 100 km. Examples of mesoscale weather systems are sea breezes, squall lines and mesoscale convective complexes.

SUBCLASSES-

1. MESO-GAMMA-

2-20km, deals with phenomena like thunderstorm convection, complex terrain flows (at the edge to micro scale, also known as storm-scale.

2. MESO-BETA-

20-200 km deals with phenomena like sea breezes, lake effect and snow storms.

3. MESO-ALPHA-

200-2000 km fronts, deals with phenomena like squall lines, mesoscale convective systems (MCS) tropical cyclones at the edge of synoptic scale.

As a note, tropical and subtropical cyclones are classified by National hurricane center as synoptic scale rather than mesoscale.

MICROCLIMATE-

A microclimate is an atmospheric zone where the climate differs from the surrounding area. The term may refer to areas as small as a few square feet (for example a garden) or as large as many square miles. Microclimate exists for example near bodies of water which may cool the local atmosphere or in heavily urban areas where bricks, concrete and asphalt absorb the suns energy, heat up and reradiate that heat to the ambient air that results urban heat island is a kind of microclimate.

Another contributing factor to microclimate is the slope or aspect of an area. South facing slopes in the northern hemisphere and north facing slopes in southern hemisphere are exposed to more direct sun light than opposite slope and are therefore warmer for longer.

Tall building creates their own microclimate, both by over shadowing large area and by channeling strong winds to ground level. Wind effects around tall buildings are assessed as a part of a microclimate study.

The type of soil found in an area can also affect microclimates. For example, soil heavy in clay act like pavement moderating the near ground temperature on the other hand, if soil has many air pockets, then the heat could be trapped underneath the top soil, resulting in the increased possibility of frost at ground level.

The soil surface plays dominant roles in establishment of microclimate in different ways (1) Albedo (2) Soil physical properties (3) Kind of soil and its conditions (4) Temperature near the ground.

CHANGE OF ALBEDO-

The land is the upper most layer which receives and give off radiation. Albedo or reflectivity is the ratio of reflected radiation to incident radiation. 0.40 reflection means ground reflects 40% and absorbs 60%.

SURFACE TYPE	ALBEDO (%)
Black soil (dry)	14
Black soil (moist)	8
Gray soil(dry)	25-30
Gray soil (moist)	10-12
Green forest	5-10
Ploughed field	14-47
Desert soil	25-30
Cloud	5-85

KIND AND CONDITION OF SOIL-

It is a factor for establishing microclimate in any place.

1. Temperature near the ground governs the climate near ground to great extent. Daily heating penetrates deeply into the soil. Sandy soils heats up a higher degree in the uppermost layer than granite. But it decreases very rapidly both upwards and downwards.
2. Ploughing of soil- Alteration of soil with deep ploughing affect the heat economy of adjacent air favorable to vegetation. By ploughing, kind of soil can be changed make the soil loose so that it can contains more air, conduct heat much more poorly than any kind of soil. Tillage results in a proper heat economy.
3. Moisture content- It influences the temperature condition and its adjacent air. High conductivity corresponds to moist soil.

LAMINAR AND TURBULENT CONDITIONS-

Atmosphere is a turbulent fluid because of gases and liquids are the fluids. These are the principle constituent of atmospheric composition. It thus become obvious that loss of gases and fluids in terms of motions is also applicable in case of atmospheric motion, air circulation fluids are characterized by two types of motion or flow namely laminar flow and turbulent flow. In case of laminar flow particles moves only in one direction that is forward direction. While particles move in all directions in turbulent flow which may assume in the form of convection currents or eddies. Turbulent flow is generated because of inequality of forces as in the case of atmosphere causes due to variation. According to Newton's law of motion- "changes in the velocity of the body which is in motion is affected when acting forces changes and become unbalanced". The velocity of direction of the motion of the body remains constant so long acceleration force remain constant and in balance. In the case of the earth atmosphere air moves continuously in same direction with same velocity in straight line rather than velocity and direction frequently changes due to frequently change of temperature and pressure.

These forces include-

1. Pressure Gradient force
2. Coriolis force or the earth deflecting force
3. Frictional force
4. Rotational force

Newton's second law of motion states that the acceleration of anybody in this case, the parcel of air is directly proportional to the net force acting on it and inversely proportional to its mass.

SOME RELATIONSHIPS (Between Temperature, Humidity and wind)-

1. The higher the water surface temperature than the air temperature then higher the rate of evaporation.
   $E \propto$ Water surface temperature
2. Greater the vapour pressure of a parcel air lower the evaporation and vice versa.
3. Higher the relative humidity, lower the rate of evaporation.
4. Wind velocity is higher when evaporation is higher.
5. Relative humidity increases when temperature decreases or by adding water vapour.

CHAPTER.8.

AIR POLLUTION METEOROLOGY

AIR POLLUTION-

Air pollution is the introduction of chemicals, particulates, biological materials or other harmful materials into the earth’s atmosphere, possibly causing disease, death to human, damage to other living organisms such as food crops or the natural or built environment.

AIR POLLUTANT-

An air pollutant is a substance in the air that can have adverse effect on humans and the ecosystem. The substance can be solid particles, liquid droplets or gases. A pollutant can be of natural origin or manmade.

OCCURANCE OF AIR POLLUTANTS-

Air pollutants occurs both outdoors and indoors and can be natural or manmade.

1. OUTDOOR AIR POLLUTANTS-

It is sometimes called ambient air pollutants occur in both urban and rural areas.

2. INDOOR AIR POLLUTANTS-
   - It includes carbon monoxide (CO) and nitrogen dioxide (NO_2) from faulty gas heaters and cookers.
   - Carbon monoxide (CO) and benzene from cigarette smoke.
   - Volatile organic compounds (VOC) from synthetic furnishing vinyl flooring and plants.

CLASSIFICATION OF AIR POLLUTANTS-

Air Pollutants are generally divided into 3 categories namely origin, chemical composition and state of matters.

1. ACCORDING TO ORIGIN-

1A. Primary Pollutants (90% of the global air pollution)-

Primary pollutants are directly emitted into the atmosphere and are found as such. Ex-CO, NO_2, SO_2 and Hydrocarbons.

1B. Secondary Pollutants-

Secondary pollutants which are derived from the primary pollutants due to chemical or photo chemical reactions in the atmosphere.

Ex-Ozone, PAN, Photo Chemical Smog, Sulphuric and Nitric acid, carbonic acid etc.

2. ACCORDING TO CHEMICAL COMPOSITION-

2A. Organic Pollutants-

Ex-Hydrocarbons, Aldehydes, Ketones, Amines and Alcohols.

2B. Inorganic Pollutants-

- Carbon compounds –Ex- CO and Carbonates
- Nitrogen compounds –Ex- NO_x and NH_3
- Sulphur Compounds –Ex- H_2S, SO_2, SO_3 and H_2SO_4
- Halogen compounds-Ex- HF, HCL and Metallic fluorides
- Oxidizing Agents-Ex- Ozone (O_3)

3. ACCORDING TO STATE OF MATTER-

3A. Gaseous Pollutants-

Gaseous Pollutants which get mixed with the air and do not normally settle out. Ex- CO, NO_x and SO_2.

3B. Particulate Pollutants-

Particulate pollutants consist of finely divided solids or liquids or existing colloidal substances which include smoke, fumes, mist, fog, dust, smog etc.

AIR POLLUTANTS AND THEIR EFFECTS-

1. NITROUS DIOXIDE (NO_2)-

NO_2 is a reddish brown irritating gas that gives photochemical smog. In atmosphere, it can be concerted in to nitric acid (HNO_3).

NO_2 + Moisture→HNO_3

SOURCES-

- Combustion of fuels (Coal, Diesel, Petrol etc.)

- Industries which manufactures acids, fertilizers and explosives.
- From automobile exhausts.
- During thunder storms by electric discharge.

HEALTH EFFECTS-

- Respiratory disease
- Lung diseases
- Irritation to eyes
- Increased mortality

ENVIRONMENTAL EFFECTS-

- Acid deposition of HNO_3 can damage trees, soils and aquatic life in lakes.
- HNO_3 can corrode metals, statues and monuments.
- NO_2 can damage fabrics.

2. OXIDES OF CARBON-

A. CARBON MONOXIDE (CO)-

It is colorless, Odorless gas & is poisonous to air breathing animals.

Sources-

- Automobile exhaust
- Cigarette Smoking
- Incomplete burning of fossil fuels.
- Industrial processes

Health effects-

- Inhalation of CO leads to decrease oxygen carrying capacity of blood.
- Causes difficulty in breathing.
- Causes mental disturbance (headache), irritation to mucus membrane (visual difficulty) and paralysis.
- At high doses, it causes collapse coma and irreversible brain cell damage and finally causes death.

B. CARBON DIOXIDE (CO_2)-

It is nontoxic therefore it is not harmful to human health. CO_2 is utilized by green plants to prepare starch during photosynthesis. It is estimated that in last 100yrs 360 billion tons of CO_2 is added in atmosphere.

SOURCE-

- Burning of fuels as coal, wood, petroleum products and gaseous fuels.
- Released into the air by plants and animals through respiration.
  *CO_2 has risen by 7% in the last 30yrs.
- Increases in population implies increase in the concentration of CO_2.
- Deforestation

The fossil fuel alone releases more than 18 x 10^{12}tons of CO_2 into atmosphere each year.

HEALTH EFFECT-

- Respiratory disorders
- Suffocation

ENVIRONMENTAL EFFECT-

- Global warming
- Greenhouse effect
- Rise in sea water level

3. OXIDE OF SULPHUR-

A. SULPHUR DIOXIDE (SO_2)-

It is colorless and irritating gas in the atmosphere it can be converted to sulphuric acid (H_2SO_4).

SOURCES-

- Thermal power plants in which sulphur containing coal and diesel are burned. They are the largest source of SO_2 as they contribute 73%.
- Petroleum industry
- Oil refineries.
- Sulphuric acid manufacturing plants
- Volcanoes
- Metal extraction from ores (In processes like electroplating case hardening activities)
- Locomotives

- Leakage in chemical industries

It leads to acid rain.

$SO_2 \rightarrow SO_3 {-}{-}{-}\rightarrow H_2SO_4$

HEALTH EFFECTS-

- Causes cardiac and respiratory diseases such as asthma, bronchitis, eye irritation in human beings.
- High level of SO_2 in the atmosphere causes lung cancer.

ENVIRONMENTAL EFFECTS-

- It causes acid rain. When oxidation of SO_2 occurs in the presence of a catalyst such as NO_2 forms H_2SO_4 and thus acid rain.
- In agriculture, it causes damage to membrane, chlorophyll destruction, metabolism inhibition and growth yield reduction.

B. SULPHUR TRIOXIDE (SO_3)-

Sources-
Oxidation of sulphur dioxide under the influence of sunlight.

HEALTH EFFECT-

Cause severe breathing discomfort and irritation to respiratory tract.

ENVIRONMENTAL EFFECT- Both SO_2 and SO_3 cause acid rain.

C. HYDROGEN SULPHIDE (H_2S)-

SOURCE- Enters the atmosphere through the decomposition of sewage water or organic waste matter from various industries.

EFFECT-

- It is poisonous gas and causes corrosion of metals.
- Causes headache, nausea, collapse, coma and finally death.
- The other sources are volcanic eruption, coal pits etc.
- About 30million tons of H_2S are released by the ocean every year.

4. HYDROGEN FLUORIDE (HF)-

SOURCE-

- Phosphate fertilizer industry
- Aluminum manufacturing units
- Metallurgical process
- Brick kilns
- Industries using coal as fuel.

EFFECTS-

- It causes irritation to skin, bone, teeth and respiratory disorders.
- It also causes 'fluorosis' in cattle feeding on disease infected plants.

5. AEROSOLS (BLACK CLOUDS)-

Chemical released into the atmosphere in the form of mist and vapour.

SOURCES-

Jets and aeroplane emission in the upper atmosphere are in the form of aerosols containing SO_2, NO_2, hydrocarbons etc.

EFFECTS-

- It causes global warming.
- It promotes ozone layer destruction.
- It affects the precipitation.

6. OZONE (O_3)-

SOURCES-

- Photochemical smog.
- Complex reaction between oxides of nitrogen and hydrocarbons.

EFFECTS-

- Lining of lungs and respiratory tracts.
- Causes eye irritation.
- Ozone also damage plants, buildings and other materials.

7. HYDROCARBONS (HC)-

SOURCES-

- Fuel combustion.
- Smoke from wood fires.

EFFECT-

- Headaches or Nausea
- May cause cancer
- Damage Plants

8. LEAD (Pb)-

SOURCES-

- Combustion of lead additives in motor fuels.
- Waste incineration.
- Renovation of old houses.

EFFECT-

- Lead retards development of nervous system in children.
- Lead affects almost every organ in the body whether it is inhaled or ingested. Young children are particularly susceptible.

9. PARTICLES-

SOURCES-

- Internal combustion engines (e.g., cars, trucks)
- Industries
- Burning wood
- Cigarette Smoke
- Bush fires

EFFECT-

- Lung cancer
- Asthma attack
- Heart Disease

- Lung Disease

10. CARBON DISULPHIDE (CS_2)-

It is highly dangerous gas causing mental illness like depression, anorexia, insomnia, loss of memory etc.

11. METHANE (CH_4)-

Methane has capacity to mix with blood hemoglobin to form methemoglobin which has no capacity to carry O_2 like normal hemoglobin. This reduces oxygen supply to body causing asphyxia.

SOURCES-

- Natural sources create 36% of methane emissions.
- wet lands
- Termites
- Oceans
- Landfills
- Livestock farming
- Use of fossil fuels are human related sources.

Human related sources create methane emissions accounting for 64% in total.

12. AMMONIA (NH_3)-

It is a pungent, irritant gas.

SOURCES-

- Volcanoes
- Fertilizers

EFFECT-

- Skin irritation
- Eye Irritation
- Allergies

13. CHLOROFLUOROMETHANE (CFM)-

Also called as Freon, they belong to a group called chlorofluorocarbons (CFC).

They are used as propellants in aerosols or as refrigerants in domestic refrigerators, deep freezers and air conditioners. CFC generally rises to troposphere. There they are dissociated due to ultraviolet rays to release free chlorine. This chlorine causes ozone depletion as ozone gas has strong ability to react with free chlorine gas. Thinning of ozone gas shield will allow UV-Radiations in earth's atmosphere and cause extensive damage to plants & animals.

EFFECT OF POLLUTANTS ON PLANTS-

POLLUTANTS	INJURY SYMPTOMS	SENSITIVE AGE OF LEAF	THRESHOLD (ppm)
SO_2	Chlorosis, tip and marginal necrosis, insect and chilling injury.	Middle ages most sensitive.	0.3
O_3	Necrotic spotting, pigmentation.	Oldest most sensitive.	0.3
PAN	Glazing, silvering, bronzing of lower leaf surface.	Youngest most sensitive.	0.01
HF	Tip and marginal leaf burning, dwarfing.	Youngest leaves most sensitive.	0.0001
NO_2	Irregular, white or brown spots on leaf.	Middle aged leaves most sensitive.	2.5
C_2H_4	Leaf abnormality, flower shedding, failure of proper leaf opening.	Younger leaves may recover.	0.05
NH_3	Becoming brown after drying, before it green in appearance.	Mature leaves most sensitive	10 to 20

COMPOSITION OF AIR-

CONSTITUENTS	By Volume (%)
Nitrogen	78.09
Oxygen	20.95
Argon	0.93
Carbon Dioxide	0.03

- Atmosphere is a deep blanket of gases which envelops the earth. Air is a mechanical mixture of gases and cannot be felt except when it moves as a wind. Total mass of the atmosphere has been calculated at about $56x10^{14}$t. Without the atmosphere, there could be no clouds, winds, rain or no weather. Air protects the earth from the full force of the sun during day time and prevents loss of too much of heat at night. Therefore, without atmosphere life could not exist.
- An average human requires about 12kg of air each day, which is nearly 12 to 15 times greater than the amount of food we eat. Thus, even a small concentration of pollutants in the air becomes more significant in comparison to the similar levels present in food.
- The effect of particulates ranges from soot to the carcinogenic effects (it leads to cancer) of the asbestos, dust particles and ash from industrial plants that are dispersed into the atmosphere. Repeated exposure to particulates can cause them to accumulate in the lungs and interfere with the ability of the lungs to exchange gases.

NATURAL SOURCES OF AIR POLLUTION-

- Natural fires- Smoke
- Volcanoes- Ash and acidic components
- Sea spray
- Vegetation- Volatile organic compounds
- Bacterial metabolism- Methane
- Dust- Pollen
- Viruses and Bacteria

TYPES OF PARTICULATES-

TERM	MEANING	EXAMPLES
Aerosols	General term for particulates suspended in air	Sprays from pressurized cans
Mist	Aerosol consisting of liquid droplets	Sulfuric acid mist
Dust	Aerosol consisting of solid particles that are blown into the air or are produced from large particles by grinding them down.	Dust storm
Smoke	Aerosol consisting of solid particles or a mixture of solid and liquid particles produced by chemical reactions such as fire.	Cigarette smoke, smoke from a burning garbage.

CLASSIFICATION OF ANTHROPOGENIC AIR POLLUTION SOURCES-

Source Type	Category	Important sources	Typical Pollutants
Combustion	Stationary	Power plants, industrial boilers, diesel generators, municipal or industrial incineration, refuse burning.	Oxides of sulphur, NO_x, CO, Smoke fly ash, trace metal oxides
	Mobile	Motor vehicles, air craft	CO, hydrocarbons, O_x, SO_2 Particles
Roasting & heating process	Nonferrous Metallurgical	Roasting, smelting and refining operations.	Dust, smoke, metal fumes, Cu, Pb and Zn, oxides of sulphur (SO_x)
	Ferrous Metallurgical	Materials handling, ore sintering and pelletizing, coke, oven blast furnace, steel furnaces.	Smokes, fumes, CO, Odors, H_2S, Organic vapour and fluorides
	Non-metallic Minerals	Crushed stones, gravel and sand processing, cement, glass refractories and ceramics mfr, coal cleaning.	Minerals & organic particles SO_2, NO_2, Dust fumes.
Chemical, petroleum, pulp & paper	Petroleum refining	Boilers, process heaters, catalyst regenerators, flares, reactors, storage tanks, compressor engines.	Oxides of sulphur, hydrocarbons, NO_x, particulate matter, CO, aldehydes, Ammonia, odors.
	Inorganic chemicals	Sulphuric acid plants, fertilizer manufacture, nitric acid and ammonia plants, phosphoric acid manufacture.	SO_2, HF, H_2S, NH_3, Particulate Matter, H_3PO_4 etc.
	Organic chemicals	Plastics, paints and varnish manufacture, synthetic rubber, rayon, insecticide, soap and detergent manufacture methanol, phenol etc.	Particulate matter, odours, SO_2, CO, Organic intermediates, product gases and vapors, solvent vapour etc.
	Pulp and paper (kraft process)	Digester blow system, pulp washers, recovery furnace, evaporators, oxidation towers.	Particulate matter, odourous sulphur compounds, H_2S, Methyl mercaptan, di-methyl sulphide and SO_2.
Food and	food processing	drying, preserving, packaging	Vapours, odours, dust

agriculture	Crops spraying and dusting	Pest and weed control	Organic phosphates, chlorinated HC, arsenic, lead
	Field burning	Refuse burning	Smoke, fly ash, soot

MAJOR TOXIC METALS AND THEIR EFFECTS-

ELEMENTS	SOURCES	HEALTH EFFECTS
Lead	Auto exhaust (from gasoline), paints, storage batteries, pipes.	Neurotoxin, affect blood system, behavioral disorders, death.
Cadmium	Coal, zinc mining, incineration of plastic containers, refining of metals, tobacco smoke.	Cardiovascular disease and hyper tension, interference with zinc & copper metabolism, kidney damages.
Nickel	Combustion of coal, diesel and residual oils, tobacco, smoke, chemicals and catalysts, steel and nonferrous alloys Manufacture.	Respiratory symptoms, lung cancer (as nickel carbonyl)
Mercury	Combustion of fossil fuels, evaporation from ore mining, exhausts from metal smelters, chloralkali cells, paints pharmaceuticals.	Nerve and train damages, kidney damage.

AIR POLLUTION CONTROL-

1. Reducing Production-

i. Particulate Removal-

Remove particles physically by trapping them in a porous mesh which allows air to pass through but hold back solids.

ii. Sulfur Removal-

Switch from soft coal with a high sulphur content to low sulphur coal.

iii. Nitrogen oxide-

Best method is to prevent creation.

- Staged burners
- Selective catalysts

ACID RAIN-

Acid rain is rain or any other form of precipitation that is unusually acidic, meaning that it possesses elevated levels of hydrogen ions (low pH). It can have harmful effects on plants, aquatic animals and infrastructure. Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which reacts with water molecules in the atmosphere to produce acids. Governments have made efforts since the 1970s to reduce the release of sulfur dioxide into the atmosphere with positive results. Nitrogen oxides can also be produced naturally by lightning strikes and sulfur dioxide is produced by volcanic eruption. The chemicals in acid rain cause paint to peel, corrosion of steel structure such as bridges and erosion of stone statues.

Acid rain is a popular term referring to the deposition of wet (rain, snow, sleet, fog, cloud water and dew) and dry (acidifying particles and gases) acidic components. Distilled water once carbon dioxide is removed has a neutral pH of 7. Liquids with a pH less than 7 are acidic, and those with a pH greater than 7 is alkaline 'clean' or unpolluted rain has an acidic pH, but usually no lower than 5.7, because carbon dioxide and water in the air react together to form carbonic acid, a weak acid according to the following reaction.

$H_2O(l) + CO_2(g) = H_2CO_3(aq)$

The term 'acid rain' was coined in 1872 by Robert Angus Smith.

EMISSIONS OF CHEMICALS LEADING TO ACIDIFICATION-

NATURAL PHENOMENA-

- The principal natural phenomena that contribute acid producing gases to the atmosphere are emissions from volcanoes. The volcanoes create extremely high amounts of acid rain and fog with acidity as high as pH of 2.
- Acid producing gases are also created by biological processes that occurs on the land in wet lands and in oceans. The major biological source of sulfur containing compounds is dimethyl sulfide.

- Nitric acid in rain water is an important source of fixed nitrogen for plant life and is also produced by electrical activity in the atmosphere such as lightning.

HUMAN ACTIVITY-

- The principle cause of acid rain is sulfur and Nitrogen compounds (SO_x and NO_x) from human sources, such as electricity generation factories and motor vehicles.
- Electric power complex utilizing coal are among the greatest contributors to gaseous pollution that are responsible for acidic rain. The gases are carried hundreds of kilometers in the atmosphere before they are converted to acids and deposited.
- In the past, factories had short funnels to let out smoke but this caused many problems locally thus factories now have taller smoke funnels. However, dispersal from these taller stacks cause pollutants to be carried further causing widespread ecological damage.

CHEMICAL REACTIONS INVOLVED-

- SO_3 (g)+H_2O---H_2SO_4 (Sulfuric acid)
- SO_2(g)+H_2O---H_2SO_3 (Sulfurous acid)
- CO_2(g)+H_2O---H_2CO_3 (Carbonic acid)
- $3NO_2$(g)+H_2O—NO+$2HNO_3$ (Nitric acid)
- 4NO(g)+O_2+$2H_2O$---$4HNO_2$ (Nitrous acid)

ACID DEPOSITIONS-

WET DEPOSITION- In the form of precipitation.

DRY DEPOSITION-

Acid deposition also occurs via dry deposition in the absence of precipitation. This can be responsible for as much as 20 to 60% of total acid deposition. This occurs when particles and gases stick to the ground, plants or other surfaces.

ADVERSE EFFECTS-

- Causes damage to fish and other aquatic animals. At pH lower than 5 most fish eggs will not hatch and lower pH can kill adult fish.

  - According to United States environmental protection agency (EPA) of the lakes and streams surveyed, acid rain caused acidity in 75% of the acidic lakes and about 50% of the acidic streams.
  - Microbes in soil are unable to tolerate changes to low pH and are killed. The enzymes of these microbes are denatured (in shape so they no longer function) by the acid.
  - Forest areas also affected.
  - Ocean acidification
  - Human health effects (Lung and heart problems including asthma and bronchitis)
  - Monumental damage

PREVENTION METHODS-

- Many coal firing power stations use flue gas desulfurization (FGD) to remove sulfur containing gases from their stack gases. FGD gases removes 95% or more of the SO_2 in the flue gases. An example of FGD is wet scrubber.
- Fluidized bed combustion also reduces the amount of sulfur emit by power production.
- Vehicle emission control reduces emission of nitrogen oxides from motor vehicle.

Emission control equipment may be classified into two general types-

1. Particulate control type
2. Gases and odors control type

The basic mechanisms of removing particulate matter from gas streams may be classified as-

1. Gravitational settling
2. Centrifugal impaction
3. Inertial impaction
4. Direct interception
5. Diffusion
6. Electrostatic precipitation

Equipment presently available which make use of one or more of the above mechanisms fall into the following five broad categories-

1. Gravitational settling chambers
2. Cyclone separators
3. Fabric filters
4. Electrostatic precipitators

5. Wet collectors (scrubbers)

1. GRAVITATIONAL SETTLING CHAMBERS-

Generally used to remove large abrasive particles (usually >50µm) from gas streams. They offer low pressure drop and require simple maintenance but their efficiencies are quite low for particles smaller than 50µm.

Setting chambers use the force of gravity to remove solid particles. The gas stream enters a chamber where the velocity of the gas is reduced. Large particles drop out of the gas and are recollected in hoppers.

2. CYCLONE SEPARATORS-

- Cyclone separators utilize a centrifugal force generated by a spinning gas stream to separate the particulate matter from the carrier gas. The centrifugal force on particles in a spinning gas stream is much greater than gravity.
- Cyclones are effective in the removal of much smaller particles than gravitational settling chambers and require much less space to handle the same gas volumes.
- The general principle is that particulate laden gas is forced to change direction. As gas changes direction, the inertia of the particles uses them to continue in the original direction and hence separated from the gas stream.

3. ELECTROSTATIC PRECIPITATORS (ESP)-

- Removals of fly ash from electric utility boiler emissions.
- The dust laden gas is passed between oppositely charged conductors and it becomes ionized as the voltage applied between the conductors is sufficiently large (30,000 to 60,000 volts dependent on electrode spacing).
- As the dust laden gas is passed through these highly charged electrodes both negative and positive ions are formed the latter being as high as 80%. The ionized gas further passed through the collecting unit which consists of a set of vertical metal plates. Alternate plates are positively charged and earthed.
- The dust removed from the plates with the help of shaking motion is collected in the dust hoppers.

4. WET COLLECTOR (SCRUBBER)-

PRINCIPLE-

- Wet scrubbers are used for removal of particles which have a diameter of 0.2 mm or higher.
- Wet scrubber work by spraying a stream of fine liquid droplets on the incoming stream.
- The droplets capture the particles.
- The liquid is subsequently removed for treatment.

The wet scrubber consists of rectangular or circular chamber in which nozzles are mounted. The nozzle sprays a stream of droplets on the incoming gas stream. The droplets contact the particulate matter and the particles are soaked by stream. Then the polluted spray is collected. Particle are settled or removed from the liquid.

In general, in wet scrubber the polluted gas stream is brought into contact with the scrubbing liquid by spraying it with the liquid, by forcing it to a pool of liquid to remove pollutants. It collects both particulates and gas in a single system.

ADVANTAGES-

- Wet Scrubber have the ability to handle high temperature and moisture.
- Wet gas scrubber can remove both gases and particulate matter.
- It can neutralize corrosive gases.
- Small space requirements.

DISADVANTAGES-

- High potential to corrosive problems.
- High power requirements.
- Scrubbing liquid poses a water pollution problem.

5. FABRIC FILTERS-

Commonly known as bag houses, fabric filters used for filtration to separate dust particles from dusty gases. They are one of the most efficient and cost-effective types of dust collectors available and can achieve a collection efficiency of more than 99% for very fine particulates.

PRINCIPLE-

When the dirty air with contaminated dust particle flows through the inlet some of the smaller particles are retained due to interception and diffusion.

ADVANTAGES-

- Very high collection efficiency.
- The pressure drops are reasonably low.

DIS ADVANTAGES-

- It requires a large floor area.
- The fabric will be damage at high temperature.
- Ordinary fabric cannot handle corrosive gases.
- Fabric filters cannot handle moist gas streams.

Q. The surface temperature is 15℃ at the surface of earth. What is the temperature at 5510.5m?

(Lapse rate- 6.49℃/km)

Sol-5510.5m=5.5105km

For each km the atmosphere decreases 6.49^0C temperature so the temperature decreases.

5.5105 x 6.49=35.76℃

Original temperature was 15^0C so temperature at 5.5105km

$=15^0-35.76^0= -20.76^0$C

GENERAL CHARACTERSTICS OF STACK PLUMES-

A. DISPERSION OF POLLUTANTS-

1. Wind

Carries pollution downstream (forward) from source.

2. Atmospheric Turbulence

Causes pollutants to fluctuate from main stream in vertical and cross wind direction.

B. Mechanical and atmospheric heating both present at same time but in varying ratios.

C. Affect plume dispersion differently.

SIX CLASSES OF PLUME BEHAVIOUR-

1. LOOPING-
    - High degree of convective turbulence.
    - Super adiabatic lapse rate: strong instabilities.
    - Associated with clear day time conditions accompanied by strong solar heating and light winds.

2. CONING-
    - Occurs under neutral conditions.
    - Stable with small scale turbulence.
    - Associated with overcast moderate to strong winds.
    - Roughly 10^0 cone.
    - Pollutants travels fairly long distance before reaching ground level in significant amounts.

3. FANNING-
    - Occurs under large negative lapse rate.
    - Strong inversion of a considerable distance above the stack.
    - Extremely stable atmosphere.
    - Little turbulence.
    - If plume density is similar to air, travels downwind (moves forward) at approximately same elevation.

4. FUMIGATION-
    - Stable layer of air lies at short distance above release point with unstable air beneath.
    - Usually early morning after an evening with a stable inversion.
    - Significant ground level concentrations may be reached.

5. LOFTING-
    - Opposite condition of fumigation
    - Inversion layer below with unstable layer through and above.
    - Pollutants are dispersed downwind without significant ground level concentration.

6. TRAPPING-
    - Inversion above and below stack.
    - Diffusion of pollutant is limited to layer between inversion.

INVERSION-

Exchange of wind energy between the layers on ground level or above ground level is called as inversion.

Inversion is influenced by-

- Time of year
- Topography
- Presence of water or lakes
- Time of day- Horizontal and vertical dispersal of pollutants are hampered.

AIR QUANTITY MODELING (AQM)-

- Perfect pollutant concentration at various locations around the source.
- Identify source contribution to air quality problems.
- Access source impact and design control strategies.
- Perfect future pollutant concentration from sources after implementation of new regulatory programs.

Mathematical and Numerical techniques used to stimulate the dispersion of air pollutants.

1. Modeling of the dispersion of the pollutants-

a. Toxic and odouring substances
b. Single or multiple points
c. Point, area or volume sources.

Input data require for AQM-

a. Source Characteristics

b. Meteorological Conditions

c. Site and surrounding conditions

Ambient air concentration modeling-

Types of pollutant sources-

Point sources	Area sources	Volume sources
Stacks, vents	Landfills, ponds, storage piles	Conveyors, structure with multiple vents

FACTORS AFFECTING DISPERATION OF POLLUTANTS IN ATMOSPHERE-

1. Source characteristics-
    a. Emission rate of pollutants
    b. Stack height
    c. Exit velocity of the gas
    d. Exit temperature of the gas
    e. Stack diameter
2. Meteorological Conditions-
    a. Wind velocity
    b. Wind Direction
    c. Ambient temperature
    d. Atmospheric stability

AIR POLLUTATION MODELLING-

A. GAUSSIAN MODEL-

Advantages-

- Produce results that match closely with experimental data.
- In corporate turbulence in an adopt manner.
- Simple in their mathematics.
- Quicker than numerical model.
- Do not require super computer.

Disadvantages-

- Not suitable if the pollution is reactive in nature.
- Fair to incorporate turbulence is comprehensive sense.
- Unable to predict concentration beyond the radius of approx. 20kms.

- For greater distance, wind variation, mixing depth and temperature variations become predominant.

SOURCE OF ERROR IN GAUSSIAN MODEL-

A. Emission data-

- Source strength
- Time variation of flume
- Flume rises after emission
- Location of source

B. Meteorological data-

- Wind speed
- Dispersion parameters
- Wind direction
- Mixing temperature

C. Physical Deficiency-

- Real source is not point source.
- Actual spread is not Gaussian.
- Meteorological parameter varies by time and place.
- Uncertainty in transportation and removal process.
- Terrain effect
- Uncertainty about multiple source.
- Diffusivity coefficient independent of height.

Numerical Solution-

- Solving the system of partial differential equation.
- Equation mathematically represent the fate of pollutant and downwind concentration.
- Number of unknown parameters must be equal to number of equation.
- System of equation is written in numerical form with appropriate numerical scheme and solved using computer source.

Classes of numerical model-

A. 3D-Equation (K theory model)

B. Higher order closer model

Source of error in numerical model based on K-theory-

A. Emission data-

- Source Strength
- Time variation of flume
- Flume rise
- Rate of loss or gain of pollutant due to reaction of pollutant absorption rate.

B. Meteorological data-

- Wind speed
- Wind Direction
- Mixing Depth
- Specification of A-profile (Turbulent mass flux)

C. Physical deficiency-

- Realism of theory
- Deficiency in the theoretical basis of C-D equation.
- Uncertainty in transportation and removal process.
- Complex terrain effect.

D. Computational problem-

False or numerical difference due to grid size limitation.

EFFECTIVE HEIGHT OF STACK-

$H=h+\Delta h$

Where, H= Effective stack height (m)

h= Actual height of stack (m)

$\Delta h =$ Plume height (m)

Value of H is used in equation is the effective height of stack (chimney) and not its actual height. This effective height consists of actual height (h) + the height of Δh to which the plume rise above the stack before leveling out.

There are exists several equations for calculating plume height (Δh), out of which Holland equation is often used.

$$\Delta h = Vs \times D/u[1.5 + 2.66 \times 10^{-3} \text{P} \times D(Ts - \frac{Ta}{Ts})]$$

Where, Δh=rise of plume above the stack (in m)

Vs=Stack gas velocity (m/s)

D=Inside existing diameter of stack (m)

u=Wind speed or velocity (m/s)

P=Atmospheric pressure (mb)

Ts=Stack gas temperature (^{0}k)

Ta=Air temperature (^{0}k)

Question:-Determine the effective height of stack with given data.

a. Physical stack =180m tall with 0.95m inside diameter
b. Wind velocity =2.75m/s
c. Air temperature=20^{0}C
d. Barometric pressure=1000mb
e. Stack gas velocity=11.12 m/s
f. Stack gas temperature=160^{0}C

Sol:-Given that

h=180m, D=0.95, u=2.7m/s Vs=11.12m/s

Ta=20^{0}C =20+273=293^{0}k, Ts=160+273=433^{0}k

P=1000mb

$$\Delta h = Vs \times D/u[1.5 + 2.66 \times 10^{-3} \text{P} \times D(Ts - \frac{Ta}{Ts})]$$

By putting the values

$=11.12\times0.95/2.75\ [1.5+2.66\times10^{-3}\times1000\times0.95(433-293/433)]$

$=10.564/2.75\ [1.5+2.66\times0.95(140/433)]$

$=3.84\ [1.5+2.66\times 0.95(0.323)]$

$=3.84\ [1.5+2.66\times 0.31]$

$=3.84\times 2.3246$

=8.926m

Δh=8.926m

h=180m

So, H=h+Δh

=180+8.926

=188.926m

=188.93m

QUESTIONS FOR COMPETITIVE EXAMINATIONS.

One Word and Fill in the Blanks

Q.1. Layer of Ozone is present in ………… Ans: Stratosphere.

Q.2. Number of Agro climatic Zones in Uttar Pradesh are ………… Ans: 7.

Q.3 According to Planning Commission agroclimatic region of the whole country has been divided into ………… Ans: 15.

Q.4. Movement of air occurs in the atmosphere up to height of ……… Ans: 10km

Q.5. Vertical temperature decrease is called Lapse rate and the normal lapse rate is………

Ans: 6.5℃km.

Q.6. The Process by which a cloud droplet first forms is …………… Ans: Condensation.

Q.7. Clouds are classified and named according to their latitude and ………… Ans: form or appearance.

Q.8. A Cumulus cloud is recognized mainly by its …………… Ans: Obvious vertical dimension.

Q.9. The approximate lifetime of a wave cyclone is ……………… Ans: a few days to a week.

Q.10. A tornado is a small, very intense example of the …………… Ans: Cyclone.

Q.11. Tornadoes most often move toward what direction? Ans: North East.

Q.12. What type of cloud is most common in a hurricane? Ans: Cumulonimbus.

Q.13. What causes the winds of a hurricane to be so fast? Ans: very strong pressure gradient force.

Q.14. The vertical motions that occur when the air is unstable are termed as ………

Ans: Convection.

Q.15. The Stability of an air layer refers to its tendency to either sustain or suppress ……….

Ans: vertical motions.

Q.16. High clouds tops generally are limited by the height of the ……… Ans: Tropopause.

Q.17. The term “Latent” means ……… Ans: Hidden.

Q.18. Energy of motion is also known as …………… Ans: Kinetic Energy.

Q.19. An increase in albedo would be accompanied by……….. in radiative equilibrium temperature. Ans: Decrease.

Q.20. Charged particles from the sun that travel through space at high speeds are called ………. Ans: Solar Wind

Q.21. Sunlight passes through a thicker portion of the atmosphere at ……… Ans: Both sunrise and sunset.

Q.22. The percentage of water vapor present in the air compared to that required for saturation is the ………… Ans: Relative Humidity.

Q.23. The Name given to a liquid drop of dew that freezes when the air temperature drops below freezing is ……………… Ans: Frozen dew.

Q.24. A dim, “Watery” sun visible through a gray sheet like cloud layer is often a good indication of ………… Clouds. Ans: Altostratus

Q.25. The unit of pressure most commonly found on a surface weather map is ……………… Ans: Millibars (mb) or hectopascals.

Q.26. The transfer of heat by molecule to molecule contact is …………… Ans: Conduction.

Q.27. The Combined albedo of the earth and the atmosphere is approximately …… percent.

Ans: 30

Q.28. Which cloud type would most likely from in absolutely stable air? Ans: Stratus

Q.29. Which cloud type would most likely form in an unstable atmosphere?

Ans: Cumulonimbus.

Q.30. If rain falls on one side of a street and not on the other side, the rain most likely fell from a …………… Ans: Cumulonimbus cloud.

Q.31. The rate of the earth’s rotation determines the strength of the ……… Ans: Coriolis force.

Q.32. The first meteorological satellite was launched in the year ……… Ans: 1960.

Q.33. Unit of wind is ………. Ans: Knot.

Q.34. Unit of pressure is ……… Ans: Millibar.

Q.35. The cup anemometer rotates ………… Ans: West to East

Q.36. Quantum sensors used to measure …………… Ans: PAR (Photo synthetically active radiation).

Q.37. Evapotranspiration is measured using ………… Ans: Lysimeter.

Q.38. The line joining the places having equal temperature is called as ………… Ans: Isotherm.

Q.39. The line joining the places having equal atmospheric pressure is called as ………

Ans: Isobar.

Q.40. The line joining the place having equal amount of rain fall is called as …………… Ans: Isohyet.

Q.41. Evaporation is measured by…………… Ans: USWB open pan Evaporimeter.

Q.42. USWB stands for ……………… Ans: United States Weather Bureau.

Q.43. Hair hygrograph is an instrument used for measurement of ……… Ans: Relative Humidity (RH).

Q.44. Sensor used in Quantum sensor is …………… Ans: Photodiode.

Q.45. Sensor used in Albedometer is ………… Ans: Thermopile.

Q.46. NCMRWE Stands for …………… Ans: National Center for Medium Range Weather Forecasting.

Q.47. IMD Stands for …………… Ans: India Meteorological Department.

Q.48. IMD was established in ……………… Ans: 1875.

Q.49. WMO Stands for …………….. Ans: World Meteorological Organization.

Q.50. WMO was formed in ………… Ans: 1950.

Q.51. India Standard time (IST) is calculated from the longitude of ……… Ans: Allahabad.

Q.52. Longitude of Allahabad is ………… Ans: 82.5^0E.

Q.53. Local time is also called as …………… Ans: Solar time.

Q.54. …………… is called as Umbrella of the earth. Ans: Ozonosphere.

Q.55. The Ozone layer was discovered in 1913 by the French physicists …………………. & ……………. Ans: Charles Fabry & Henri Buisson.

Q.56. Total mass of atmosphere has been calculated as about …………… Ans: 56 x 10^{14}t.

Q.57. Water Vapor controls…………… of the atmosphere. Ans: Temperature.

Q.58. Blue color of the sky is due to …………… Ans: Rayleigh scattering.

Q.59. The structure of earth is …………… Ans: Oblate ellipsoid.

Q.60. The rotational speed of earth is maximum at ………… Ans: Equator.

Q.61. The longest day of northern hemisphere is ………… Ans: 21st June.

Q.62. The shortest day of northern hemisphere is ………… Ans: 22nd December.

Q.63. The incoming solar radiation is known as ……………… Ans: Insolation.

Q.64. The imaginary line joining the places having equal duration of sunshine hour is known as ………… Ans: Isohel.

Q.65. The value of solar constant is …………… Ans: 1398 watt/m^2.

Q.66. The radiation which lies in wavelength ranges from 0.4 to 0.7µm of solar spectrum is known as …………. Ans: Visible Radiation or Visible Light.

Q.67. Albedo of Desert is …………… Ans: 28%.

Q.68. Albedo of fresh snow is …………… Ans: 80-85%.

Q.69. Albedo of water is …………… Ans: 6-9%.

Q.70. The instrument used for measurement of long wave radiation is ……… Ans: Pyrgeometer.

Q.71. Pyranometer is used for the measurement of …………. Ans: Short wave radiation.

Q.72. The instrument used for measurement of light intensity is ………. Ans: Lux meter.

Q.73. ITCZ stands for …………………… Ans: Inter tropical Convergence Zone.

Q.74. Horizontal movement of air is called as …………… Ans: Wind.

Q.75. Vertical movement of air is called as …………… Ans: Air Current.

Q.76. The trade wind belts lie between …… to …… latitude in both hemispheres. Ans: 5^0 to 30^0.

Q.77. The belt of westerlies between …… to …….. latitude in each hemisphere. Ans: 30^0 to 60^0.

Q.78. The pressure distribution between two high pressure areas and two low pressure areas is called as……… Ans: Col.

Q.79…………………… is called as valley of low pressure. Ans: Trough.

Q.80. The direction of winds depends upon the direction of ………… Ans: Pressure Gradient.

Q.81. Both wind speed and wind direction is measured using ………….. Ans: Aero vane.

Q.82. The line on weather map which joins the places having equal wind speed is known as ……… Ans: Isotach.

Q.83………… state is called as gateway of India monsoon. Ans: Kerala

Q.84…………… state receives most rainfall during N-E Monsoon. Ans: Tamilinadu

Q.85. The present level of CO_2 is …………… Ans: 350 ppm.

Q.86. The term 'Acid rain' was coined in 1872 by ………… Ans: Robert Angus smith

Q.87. The specific heat of water is …………… Ans: 1.0cal/gm/℃

Q.88. Dry adiabatic lapse rate per kilometer is …………… Ans: 10^0C.

Q.89. Wet adiabatic lapse rate of temperature per kilometer is …………… Ans: 5^0C.

Q.90. Summer monsoon over India is known as …………… Ans: South west monsoon.

Q.91. The optimum temperature for germination of most of the crops is …… Ans: 10^0C-27^0C.

Q.92. Relative humidity is expressed is ………… Ans: Percentage (%).

Q.93. The mean height of the cirrus cloud is …………… Ans: 4-6km.

Q.94. Specific humidity is maximum at the …………… Ans: Equator.

Q.95. Temperature inversion is found in ………… season. Ans: Winter.

Q.96. For a white body, the emissivity and absorptivity is …… Ans: 0.

Q.97. Frost occurs when the dew point is below……… ^{0}C. Ans: 0.

Q.98. Visible range of photosynthetically active radiation extends between ……… Ans: 400-700nm.

Q.99. Specific heat of water is ……………… Ans: 4.2×10^3 J/Kg/^{0}C.

Q.100. Average weather condition of a particular region is called as ……… Ans: Climate.

Q.101. Condensation of water vapor over the surface is called as ……… Ans: Fog.

Q.102. The germination of seed is induced by the light of …… color. Ans: Red.

Q.103. Instantaneous physical state of atmosphere is called as ………. Ans: Weather.

Q.104. The base temperature for wheat is …… Ans: 4.4^{0}C.

Q.105. Which layer is known as region of mixing? Ans: Troposphere.

Q.106. The surface temperature of the sun is estimated between …… ^{0}C to ….. ^{0}C.

Ans- 5500^{0}C to 6100^{0}C.

Q.107……. gram calorie is the amount of heat to raise the temperature of 1gm water by 1^{0}C.

Ans- One gram.

Q.108. The total amount of insolation received at the equator is roughly about …… times that received at either of the poles. Ans: Four.

Q.109. Albedo of earth and its atmosphere is …………%. Ans: 35%.

Q.110. Albedo of sand is …… %. Ans: 20-30%.

Q.111. The decrease of temperature with increasing altitudes in the atmosphere is called as ……………… Ans: Vertical temperature gradient.

Q.112. 1 mb = ………… Hectopascal. Ans: 1.

Q.113. Total mass of the atmosphere has been calculated as about ……… tons. Ans: 56×10^{14}.

Q.114. The mean value of solar constant is ………… Ans: 1.98cal/cm^2/minute.

Q.115. The sensor used in quantum sensor is ………. Ans: Silicon Photo diode.

Q.116 ……… is used for measurement of light intensity. Ans: Lux meter.

Q.117. The belt of westerlies lies between …………. to …… latitude in both hemispheres.

Ans- 30^0 to 60^0.

Q.118. Hadley cell is also called as ………… cell. Ans: Tropical.

Q.119. The surface wind in Hadley cells are ……… winds. Ans: Trade.

Q.120. The surface winds in ferrel cells are ………… Ans: Westerlies.

Q.121. The surface winds in polar cells are ……… Ans: Easterlies.

Q.122. Coriolis force affects the………… distribution over the globe. Ans: Pressure.

Q.123. Pressure depends on the ……… of air. Ans: Density.

Q.124. The mean rate of decrease in pressure with height is ……… per 100m. Ans: 1cm.

Q.125. Dry adiabatic lapse rate of atmosphere is ……… Ans: 10^0C/km.

Q.126. Wet adiabatic lapse rate is ……. Ans: 5^0C/km.

Q.127. For transferring 1 gm of water into vapour about ………… calories are required.

Ans: 600.

Q.128…………… of two air masses is responsible for change in weather. Ans: Interaction.

Q.129. The wind in a cyclone rotate ……… in northern hemisphere. Ans: Anticlockwise.

Q.130. For formation of tropical cyclone, the sea surface temperature should be >…… ^{0}C.

Ans: 27.

Q.131……… force makes the air to bend. Ans: Coriolis force.

Q.132. In a tropical cyclone, the eye has a diameter of …... km. Ans: 40km.

Q.133. Highest Coriolis force always at ………… and minimum at ………. Ans: Poles, Equator.

Q.134……… fronts are responsible for development of temperate cyclone. Ans: Polar.

Q.135. Dew is not formed in ……… night. Ans: Windy.

Q.136. The black frost is also called as ……… frost. Ans: Advection.

Q.137. Clouds at lower or ground surface is called as ……… Ans: Fog.

Q.138. The process associated with formation of new fronts is called as ………..

Ans: Frontogenesis.

Q.139. The destruction of fronts is called ……………… Ans: Frontolysis.

Q.140. Which front is formed when cold front overtakes warm front and warm air is completely displaced from the ground surface? Ans: Occluded front.

Q.141. A low pressure with wind speed < 34 knots, the system is called as ……………

Ans: Depression.

Q.142. If wind speed>34 knots, then it is called as …………… Ans: Cyclone.

Q.143……………. is called as valley of low pressure. Ans: Trough.

Q.144…………… is an extension of an anticyclone. Ans: Ridge.

Q.145. The pressure distribution between two high pressure areas and two low pressure areas is called as ………… Ans: Col.

Q.146. Horizontal flow of air takes place along the ………… Ans: Pressure Gradient.

Q.147. The direction of wind mainly decided by direction of …… Ans: Pressure Gradient.

Q.148……… force causes air movement in the direction of low pressure. Ans: Pressure Gradient.

Q.149…………… force reduces wind velocity. Ans: Frictional.

Q.150……… measures both wind speed and wind direction. Ans: Aero vane.

Q.151. The temperature at which condensation of water vapour starts is called as…..... Ans: Dew point.

Q.152. Visible aggregate of liquid water droplets and ice crystals suspended in the air is called as …………. Ans: Cloud.

Q153………………. clouds generally do not give precipitation. Ans: Cirrus.

Q.154……………… clouds have rounded tops like dome or cauliflower with flat base.

Ans: Cumulus.

Q.155. If any cloud associated with rain fall then we prefix ……… to its form. Ans: Nimbus.

Q.156……….. cloud produces halo phenomena around sun and moon which is resulted from refraction of light. Ans: Cirrostratus.

Q157………….. clouds responsible for corona phenomena around sun and moon due to diffraction of light by water droplets. Ans: Altostratus.

Q.158……… clouds sometimes referred as sheep clouds or wool pack clouds. Ans: Alto cumulus.

Q.159. Streaks of water or snow falling from Nimbostratus clouds but not reaching the ground are called ……….. Ans: Virga.

Q.160……….. clouds are formed due to flattening of cumulus clouds. Ans: Stratocumulus.

Q.161. Specific heat of water is ……….. Ans: 1cal/cm^3.

Q.162. Specific heat of soil is …………… Ans.0.34 cal/cm^3.

Q.163……….. state receives most rainfall in N-E Monsoon. Ans: Tamilnadu.

Q.164. During south west monsoon, India receives……… % of annual rainfall. Ans: 70-80.

Q.165……… state is called as gateway of Indian monsoon. Ans: Kerala.

Q.166. Drainage is measured with……….. Ans: Lysimeter.

Q.167……….. light is the most effective inhibitor of flowing in the case of long day plants. Ans: Red.

Q.168 ……….. light helps mature apples to turn red. Ans: Red.

Q.169. Stem elongation is promoted by exposure to ……… wave lengths. Ans: Far red.

Q.170. PAR (Photo Synthetically Active Radiation) is measured by ……….. Ans: Silicon photovoltaic detector.

Q.171. The Optimum temperature for plants are between ……… Ans: 18.3^0C to 23.9^0C.

Q.172. Cotton is a …………… day plant. Ans: Short.

Q.173. Barley is a ………… day plant. Ans: Long.

Q.174. Rice is a …………… day plant. Ans: Short.

Q.175. Tomatoes grows faster when the temperature is …… ^{0}C by day and …… ^{0}C by night.

Ans: 26 and 17.

Q.176. Threshold temperature for wheat is …… Ans: 4.4^0C.

Q.177. Threshold temperature for rice is ………… Ans: $10\text{-}12^0$C.

Q.178. Threshold temperature for tobacco is ……… Ans: $13\text{-}14^0$C.

Q.179. The global renewable water supply is about ………… m^3 per person per year. Ans: 7000.

Q.180 ……… is a substance that has crystal properties similar to those of ice.

Ans: AgI(Silver Iodide).

Q.181. NCMRWF Stands for ………………

Ans: National Centre for Medium Range Weather Forecasting.

Q.182. Wind velocity is higher when ………… is higher. Ans: Evaporation.

Q.183. Higher the relative humidity, lower the rate of ………… Ans-Evaporation

Q.184 ………… gas causes chlorosis is plants. Ans: SO_2.

Q.185. An average human requires about ……… kg of air each day. Ans: 12.

Q.186. Particulates suspended in air is called as …………… Ans: Aerosols.

Q.187. Aerosol consisting of liquid droplets is called as ……… Ans: Mist.

Q.188. Wind speed is a ……… quantity. Ans: Scalar.

Q.189. Wind velocity is a ………… quantity. Ans: Vector.

Q.190. Instantaneous physical state of atmosphere is called as ……… Ans: Weather.

Q.191. Generalized physical state of atmosphere is called as …… Ans: Climate.

Q.192. AICRPAM Stands for …………….

Ans: All India Coordinated Research Project on Agrometeorology.

Q.193. 1^0 = …… minutes. Ans: 4.

Q.194. Accuracy of ordinary rain gauge is …………… Ans: ±0.2mm.

Q.195……… is used to measure reflected solar radiation from crop and other surfaces.

Ans: Albedo meter.

Q.196. Sensor used in albedometer is ………… Ans: Thermopile.

Q.197……… is used to measure global diffuse and direct radiation. Ans: Pyrheliometer.

Q.198 ……… is used to measure overall net radiation. Ans: Net radiometer.

Q.199 ………… is used to measure heat conducted inside the soil. Ans: Soil heat flux plate.

Q.200. Sensor used in quantum sensor is …………… Ans: Photodiode.

Q.201……… is used to measure depth of water table. Ans: Piezometer.

Q.202 …………. is used to measure water stress in soil. Ans: Tensiometer.

Q.203. Coriolis force is zero over ………… Ans: Equator.

Q.204. The atmosphere after absorbing the long wave radiation also radiates some portion of it back to the earth is called ……… Ans: Counter Radiation.

Q.205. At what height atmospheric pressure is half the sea level value? Ans: 12 km.

Q.206. Wind direction is deflected from its normal course due to ………… Ans: Coriolis force.

Q.207. The speed of storm is ……… km/h. Ans: 100-120.

Q.208. On which date day is longest in northern hemisphere? Ans: 21stJune.

Q.209. On which date night is longest in northern hemisphere? Ans: 22nd December.

Q.210. The height of the low cloud extends up to ……… Ans: <2km.

Q.211. The ultra violet radiation is strongly absorbed by ……… Ans: Ozone (O_3).

Q.212. The short-range forecasting is valid for ………… days. Ans: 1-3.

Q.213. The medium range forecast is valid for ……… Ans: 3-10days.

Q.214. Moisture availability index was first introduced by ……… Ans: Hargreaves.

Q.215. The ratio between water deficit and water need is known as ……. Ans: Aridity Index.

Q.216. Most of the tropical plants are ……… day plants. Ans: Short.

Q.217. The vapour pressure is higher during ……… Ans: Morning.

Q.218. Heat transfer through mass motion is known as ……… Ans: Convection.

Q.219. GDD is an index of …………. Ans: Thermal requirement.

Q.220. Meteorological drought is mainly classified on the basis of ……….. Ans: Rainfall.

Q.221. Bowen ratio (β) is the ratio of …………… Ans: Sensible heat to latent heat.

Q.222. Surface boundary layer extends up to a height of ………… Ans-50 to 100m.

Q.223. The wind structure of surface boundary layer is governing by …………….

Ans: Surface characteristics.

Q.224. The weather of surface boundary layer is known as ……….. Ans: Micro weather.

Q.225. The thickness of planetary boundary layer is ……… Ans: 100 to 1000m.

Q.226. SDD stands for …………… Ans: Stress Degree Day.

Q.227. The productivity of wheat crop increases with ……… Ans: Latitude.

Q.228. In general the % conversion of solar energy into dry matter in case of wheat crop is………

Ans: 1%.

Q.229. The point at which respiration rate is equal to the photo synthesis rate is …………..

Ans: Compensation point.

Q.230. About how much of water in needed to produce 1 kg of wheat? Ans: 1000kg.

Q.231. The type of weather forecasting mainly useful for agricultural operations is ……………

Ans: Medium Range.

Q.232. Unit of heat use efficiency is ………… Ans: kg/ha/degree day.

Q.233. The microclimate just above a crop and within the canopy is known as …………

Ans: Eco Climate.

Q.234. Most of the temperate crops are ………… day plants. Ans: Long.

Q.235. Climate Classification was first done by ……… Ans: Decandole.

Q.236. Infrared thermometer is used to measure …………… Ans: Canopy Temperature.

Q.237. The instrument used to measure altitude of various points is ………… Ans: Hypsometer.

Q.238. The space tool used for detecting tropical cyclone is ………. Ans: Radar.

Q.239. Steady state porometer is used to measure ……… Ans: Transpiration.

Q.240. Leaf area meter measures …………. Ans: Leaf Area Index (LAI).

Q.241. The cup of anemometer rotates …………… Ans: West to east.

Q.242. Cup counter anemometer is used for measuring ………… Ans: Horizontal wind speed.

Q.243. Human hair is most sensitive to ………… Ans: Humidity.

Q.244. When dry bulb and wet bulb temperature are equal, relative humidity is ……………

Ans: 100%.

Q.245. During winter which type of cards are used in sunshine recorder? Ans: Short curved cards.

Q.246. The first meteorological satellites were launched in the year ………….. Ans: 1960.

Q.247. Who first measured the velocity of Light? Ans: Romer.

Q.248. World meteorological day is celebrated on …… Ans: 23 march.

Q.249. World environment day is celebrated on ……… Ans: 5th June.

Q.250. The space application centre (SAC) is located at ……….. Ans: Ahmedabad.

Q.251. According to NARP, the number of agro climatic zones in India are ……. Ans: 127.

Q.252. According to IMD, the number of meteorological sub division in India are …………….. Ans: 35.

Q.253. Who was discovered the concept of potential evapotranspiration? Ans: C.W Thornthwaite.

Q.254. ICRISAT was started during the year ………… Ans: 1975.

Q.255. The Indian institute of tropical meteorology (IITM) is located at ………… Ans: New Delhi.

Q.256. Father of agro climatology is ……….. Ans: Koppen.

Q.257. The mean surface temperature of the earth is ……… Ans: 300^0k.

Q.258. The radiation from sun scattered by the air and dust molecules is known as ……….

Ans: Sky radiation.

Q.259. A remote sensing sensor records which energy?

Ans: Reflected energy.

Q.260. The remote sensing systems which provide their own source of illumination are known as …………. Ans: Active sensors.

Q.261. The sensors which measure the naturally available energy are called as …………

Ans: Passive Sensors.

Q.262. The study of upper part of the atmosphere is known as ……… Ans: Aeronomy.

Q.263………… gas influences atmospheric temperature. Ans: CO_2.

Q264. …………. are the agents for reflection and scattering in the atmosphere. Ans: Dust particles.

Q.265. Most of the weather phenomena occurs in ………… layer of atmosphere.

Ans: Troposphere.

Q.266. The temperature is almost constant in …………. space. Ans: Stratosphere.

Q.267. The transition zone between troposphere and stratosphere is known as ………..

Ans: Tropopause.

Q.268. The transition zone between stratosphere and mesosphere is known as ……..

Ans: Stratopause.

Q.269. Thetransition zone between mesosphere and thermosphere is known as ……………

Ans: Mesopause.

Q.270. In …… sphere the temperature increases rapidly with height. Ans: Thermosphere.

Q.271. The day and night are caused due to …….. of the earth. Ans: Rotation.

Q.272. The earth is closest to the sun on ……… every year is known as ………

Ans: Jan 3, Perihelion.

Q.273. The equinoxes falls on ………… and ………… every year on earth.

Ans: Sept-23rd and March 21st.

Q.274. The solstices falls on ……… and ……… every year on earth.

Ans: Dec22nd and June 21st.

Q.275. The equatorial region is a …… pressure area. Ans: Low.

Q.276. Polar region is a ………… pressure area. Ans: High.

Q.277……… has two maxima and two minima. Ans: Pressure.

Q.278. The thickness of skin layer is ……… Ans: Few mm to 1.5mm.

Q.279 ……… of the leaf is directly related to its chlorophyll content. Ans: Transmissibility.

Q.280 ………… is the most important factor affecting crop production and distribution.

Ans: Rainfall.

TRUE OR FALSE-

Q.281. Ozone is the predominant gas in the atmosphere. (F)

Correct Answer-Nitrogen.

Q.282. The distance between the sun and the earth is farthest on about January 4. (False)

Correct Answer-July 4.

Q.283. The position of earth nearest to the sun is described as Aphelion. (F)

Correct Answer-Perihelion.

Q.284. Topography influences the temperature on local scale. (T)

Q.285. Albedo affects vertical temperature at the surface. (T)

Q.286. Stable air masses are extremely cold in middle latitude. (T)

Q.287. Coriolis force reduces the speed of the wind. (F)

Correct Answer-Frictional force.

Q.288. Gujarat state receives rains due to south west monsoon only. (T)

Q289. Latent heat in water vapour is important for the circulation in the atmosphere.(T)

Q.290. Dew is the source of water in arid region. (T)

Q.291. Frost is a form of condensation. (F)

Correct Answer-Sublimation.

Q.292. Line joining places of equal cloud over a map is known as isobar. (F)

Correct Answer-Isoneph.

Q.293. The annual rainfall over semi-arid regions range from 1000 to 1500 mm. (F)

Correct Answer- 250-500mm.

Q.294. Local forecasts are most useful to aviation services. (T)

Q.295. Duration of light accelerates the flowering of cryophytes. (T)

Q.296. High maximum temperature decreases the saturation deficit of the plants. (F)

Correct Answer-Increases

Q, 297. Presence of radiation is essential to maintain turgidity in plant. (F)

Correct Answer-Water

Q.298. High winds causes lodging of plants. (T)

Q.299. Net radiation is negative during day time. (F)

Correct Answer-Night Time

Q.300. Albedo affects the solar radiation leaving the surface. (T)

REFERENCES

Brunt, D. (1952). Physical and Dynamical Meteorology, Cambridge University Press.pp 1-428.

Byers, H. R. (1974). General Meteorology, McGraw-Hill, New York.pp 1-461.

Lal, D. S. (2014). Climatology, Sharda PustakBhawan, Allahabad.pp 1-448.

Mavi, H. S. (2010). Introduction to Agrometeorology, Oxford & IBH Publishing Co. pp 1-286.

Mote, B. M and Sahu, D. D. (2014). Principles of Agricultural Meteorology, Scientific Publishers, India.pp 1-197.

Murthy, V. R. K. (1996). Basic Principles of Agricultural Meteorology, Shri Venkateswar Publishers, Hyderabad.pp 1-261.

Purohit, S. S. and Ranjan, R. (2003). Ecology, Environment and Pollution, Agrobios, Jodhpur, India.pp 223-308.

Siddhartha, K. (2013). Atmosphere, Weather & Climate, Kisalaya Publications Pvt. Limited, New Delhi, India. pp 1-547.

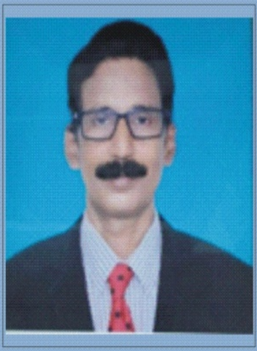
ABOUT AUTHORS

Mr. SITANSHU SEKHAR PATRA is presently pursuing PhD Meteorology and Oceanography at Department of Meteorology and Oceanography, Andhra University, Vishakhapatnam. He has completed his B.Sc. Agriculture (Dr.B.R. Ambedkar University, Agra) and M.Sc. Agrometeorology (SHUATS, Allahabad) securing 1st rank in M.Sc. He has been awarded Merit Scholarship during his M.Sc from Government of Odisha and DST Inspire Fellowship in Ph.D. He has 10 research papers to his credits which were published in various peer reviewed national and International Journals.

Mr. SANDEEP ROUT is presently Ph.D Forestry Scholar at College of Forestry, SHUATS, Allahabad, he has completed his B.Sc Forestry and M.Sc Forestry in Forest Products from OUAT, Bhubaneswar securing 1st rank in M.Sc. He has been awarded University Merit Scholarship during his M.Sc. and DST Inspire Fellowship in Ph.D. He has 15 research papers to his credits which were published in various peer reviewed national and International Journals.

Dr. NEELAM KHARE is an Assistant Professor (Sr. Scale) working at College of Forestry, SHUATS, Allahabad. She is engaged in professional Forestry teaching and research. She has guided 14 M.Sc and 02 Ph.D students. She has 25 research papers published in various peer reviewed national and International Journals.

Prof. (Dr.) PREMA NARAYAN JAGADEV is currently Dean of Research, Orissa University of Agriculture and Technology, Bhubaneswar. He is engaged in professional Agriculture teaching and research. He has guided 55 M.Sc and 01 Ph.D students. He has 67 research papers published in various peer reviewed national and International Journals.



Mr. DHARANIDHAR PATRA is presently Deputy Director of Horticulture, Mayurbhanj, Government of Odisha, India. He has a vast experience in the field of Horticulture