

Unit 1 - Meteorology

1.1. Introduction to meteorology

The earth is surrounded by a large envelope of gases called atmosphere. The condition of the atmosphere and the changes it undergoes influence all physical, chemical and biological activities over the earth. The study pertaining to lower atmosphere and its changes is called atmosphere physics or meteorology. In modern usage, meteorology denotes the science of weather and includes the study of atmospheric phenomena.

Definition

Meteorology can be defined as the science that deals with the study of the atmosphere.

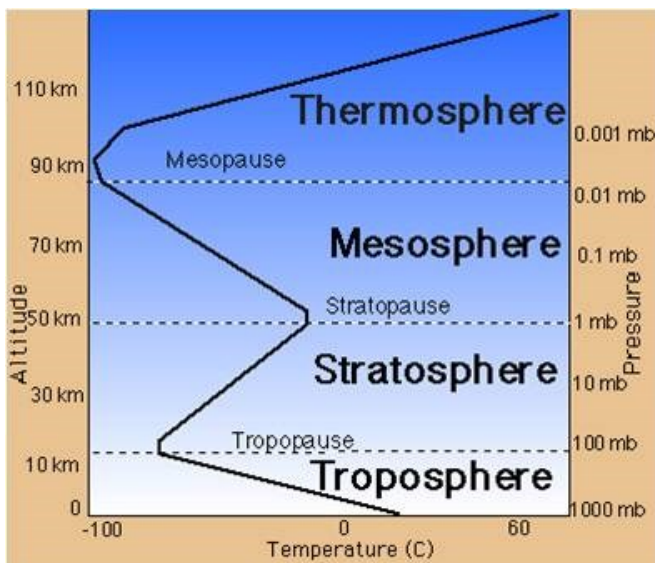
1.2. Divisions of Meteorology

- **Marine meteorology:** Meteorology pertaining to the sea and ocean is called marine meteorology.
- **Aeronomy:** The science of aeronomy investigates both the chemical and physical properties of the atmosphere and the changes that occur in these as the result of external and internal forces.
- **Bio-meteorology:** The scientific study of the interactions between living organisms and their atmospheric environment called biometeorology.

1.3. Structure of the atmosphere

The atmosphere falls into several concentric spheres on the basis of temperature (Fig) as follows:

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Exosphere



1.3.1. Troposphere

From surface towards upwards temperature decreases with altitude. This region is called troposphere. The decrease ceases at the tropopause, at a height of nearly 18km over the equator and roughly 8km over the poles.

The temperature at the tropopause is of the order of -80°C over the equator and around -56°C over the poles. The height as well as temperature of the tropopause varies with the seasons and weather situation, the lowest values occurring during the winter. The tropopause is not a continuous surface. There are breaks separating polar, extra-tropical (middle) and tropical tropopauses, sometimes one overlapping the other. These breaks facilitate the exchange of air between the tropopause and the region above. Inversions and isothermal layers can be seen in the troposphere. Nearly 75 percent of the mass of the atmosphere is in the troposphere.

1.3.2. Stratosphere

Above the troposphere is an isothermal layer followed by a region of inversion extending upto nearly 50km. This is termed as the stratosphere. Temperatures increase from around 20km becoming roughly 0°C by about 50km, which is stratopause. This rise in temperature is due to the absorption of ultraviolet radiation in the ozone layer between, say, 20 and 50km. This region sometimes gets rapidly warmed, mainly in the higher latitudes, at times by as much as 30 to 40°C in a matter of a few days. This phenomenon is termed explosive warming of the stratosphere.

1.3.3. Mesosphere

Above the stratosphere is the mesosphere extending from roughly 50 to 80km. The temperature in this region once again decreases with altitude, lowering to about -95°C at the mesopause around 80km.

1.3.4. Thermosphere

Temperatures rise rapidly above the mesopause, reaching nearly 1000°C by about 300km. This region is known as the thermosphere.

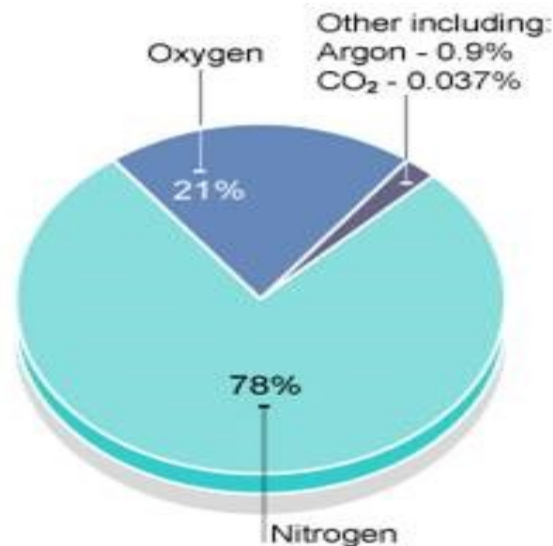
1.3.5. Exosphere

The lighter gases, hydrogen and helium, slowly become free of the earth's gravitational field and escape to space by about 600km. This region has been named as the exosphere, which gradually merges into the interplanetary space.

1.4. Composition of atmosphere

1.4.1. Gases

The atmosphere we live in is a mixture of gases composed mainly of nitrogen and oxygen. The proportion of the various gases in the atmosphere by volume is 78 percent nitrogen, 21 percent oxygen and the rest 1 percent made up of small amounts of argon, carbon dioxide, neon, helium, krypton, xenon, hydrogen and traces of ozone, methane, sulphur dioxide, nitrogen oxides etc.



The atmospheric gases are held on to the earth by the pull of gravitation. Each constituent has its own role to play in sustaining life on earth. Oxygen is essential for us to live and for combustion to take place. The role of nitrogen is also important. We cannot breathe pure oxygen. Nitrogen slows down the burning process. Carbon dioxide constitutes 0.03 percent and provides food for plants through photosynthesis, which replenishes oxygen.

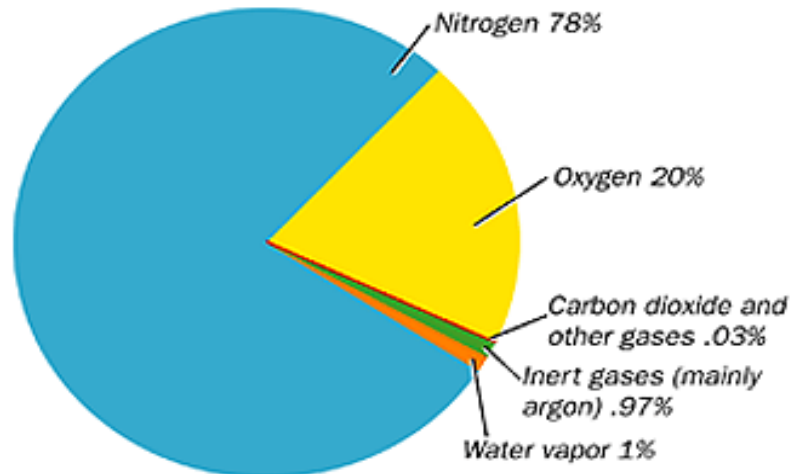
Ozone is found mostly between 20 and 50km with the maximum concentration around 25km amsl. It absorbs the ultraviolet radiation from the sun and thus filters the injurious radiation from harming us. Carbon dioxide and water vapour absorb the infrared radiation emanating from the earth and prevent excessive radiational cooling. The atmosphere acts as a protective cover to the earth by regulating the heat flow.

1.4.2. Water vapour

Water vapour is present in varying proportions. This composition remains more or less constant up to a height of 80km. The moisture content in the atmosphere varies depending on the latitude, temperature, wind and atmospheric systems. Water can be present in the vapour, liquid or solid phase, sometimes as much as 4 percent. Water and its change of phase are important in the occurrence of weather phenomena. Water vapour decreases as altitude increases.

1.4.3. Aerosols

Atmospheric aerosols are a suspension of fine solid and liquid particles in the atmosphere. These clouds of suspended matter range from dust and smoke to mists, smogs and haze. They are not always the result of pollution from human activities; some enters the atmosphere from volcanic eruptions or dust storms. Some aerosols particles are invisible to the human eyes because they are smaller than the wavelength of light.



Unit 2 - Weather and Climate

2.1. Weather

The word 'weather' refers to short period variation in the atmosphere at a given place. In other words, the physical state of the atmosphere at a given time constitutes weather. Weather at any place is defined as the momentary condition of the atmosphere. It varies from day to day and place to place. The condition of the atmosphere depends on the following variables which are called weather elements. They are 1) temperature of the air, 2) pressure, 3) humidity, 4) rainfall and 5) wind. These weather elements are closely interrelated. Among these, temperature is the most basic and fundamental. Any change in temperature causes change in the other elements. Weather influences most day-to-day activities such as farming, modes of transportation, as also clothing, etc.

2.2. Climate

The word climate refers to the condition of the atmosphere over a long period of time over a large area. In other words, the long-term average of weather is climate. The climate differs from region to region and season to season. Climate determines water potential, natural vegetation, cropping pattern, land use, housing and other infrastructure, industrial location, racial characteristics, etc. The mean value of atmospheric variables such as temperature, wind, rainfall for different areas and periods constitutes climatological data. However, extreme values as well as infrequent droughts, high winds, heat and cold waves are taken into accounts to obtain a true picture of the climate. The study of climate is climatology.

Climatic change has been attributed to both terrestrial and extra-terrestrial processes. The main factors are:

- **Astronomical:** Variations in the incoming solar radiation due to changes in the sun-earth distance arising from variation in the ellipticity of the orbit and also changes in the inclination of the axis.
- **Geological:** Changes in the disposition of oceans and continents.
- **Anthropogenetic:** Changes due to human activities in the form of deforestation, the release of greenhouse gases such as carbon dioxide into the atmosphere, etc.

2.3. Climatic control

The weather and climate are influenced by various factors. These factors are called climatic controls. They are,

- Latitudes of the place
- Altitude of the place
- Land and water surfaces

- Mountains
- Vegetation
- Winds and storms
- Ocean currents
- Semi-permanent highs and lows
- Air masses
- Cyclones

Depending on the factors, the weather elements change from place to place and season to season giving rise to varieties of weather and climates. Heating due to insolation depends on the angle of the sun's rays as well as the duration of sunlight, both of which are governed by the latitude. Altitude plays a large part in shaping weather and climate. Altitude is usually specified above the mean sea level (amsl). Pressure decreases with height. Temperature also decreases as we go up to a certain height in the atmosphere.

Mountain barriers interfere with the free flow of air and thereby modify the climate regime. The climates on the two sides of a mountain become climate divides. Rainfall increases higher up due to the forced ascent of moist air upslope and the contact of the air stream with the colder surface. Heavy clouding and rainfall are experienced on the windward side of a mountain. There is a rainshadow region on the leeward side since most of the moisture has been already taken out earlier. The air descends on the leeward side and warms up. Also, often a train of waves known as mountain waves form on the leeward side. The Himalayas and the Western Ghats are classical examples which display the influence of mountains on the climate. The Himalayas effectively prevent the cold polar air of Central Asia from penetrating into northern India in winter. Thus winters there do not become too cold. The east-west orientation of the Himalayas obstructs the flow of the moist summer monsoon of India northwards and thereby helps in its full-scale development here. The heavy rainfall of Meghalaya also is due to the Khasi Hills. Kerala, Karnataka and coastal Maharashtra would not have enjoyed the copious rainfall from the southwest monsoon if the orientation of the Western Ghats was different. Mountains give rise to peculiar local winds and small-scale circulations. Distribution of land and water acts as a major climatic control. Water takes longer to warm and cool compared to land and thereby acts as a moderating influence on temperature. Differential heating of land water results in land and sea breezes. The monsoons are also partly due to the juxtaposition of vast land and sea masses. Ocean currents and drifts also influence climate. The warm ocean currents from the equator moving towards the poles and the cold polar currents returning equatorward ameliorate the temperature of the adjoining coastal regions. The effect of the Gulf Stream on western Europe and that of the Kuroshio of Japan are well known. Semi-permanent highs and lows: The pressure pattern on the earth's surface is latitudinal or zonal in character, manifesting as east-west oriented low pressure cells or belts. These systems are the source regions of the major air masses of the world. Air masses are vast bodies of air with nearly uniform physical properties. They move, meet and interact to produce active weather systems and hence act as significant climatic controls. The genesis, movement and tracks of cyclones also are responsible for clouds, rainfall, floods etc over extensive areas of the world.

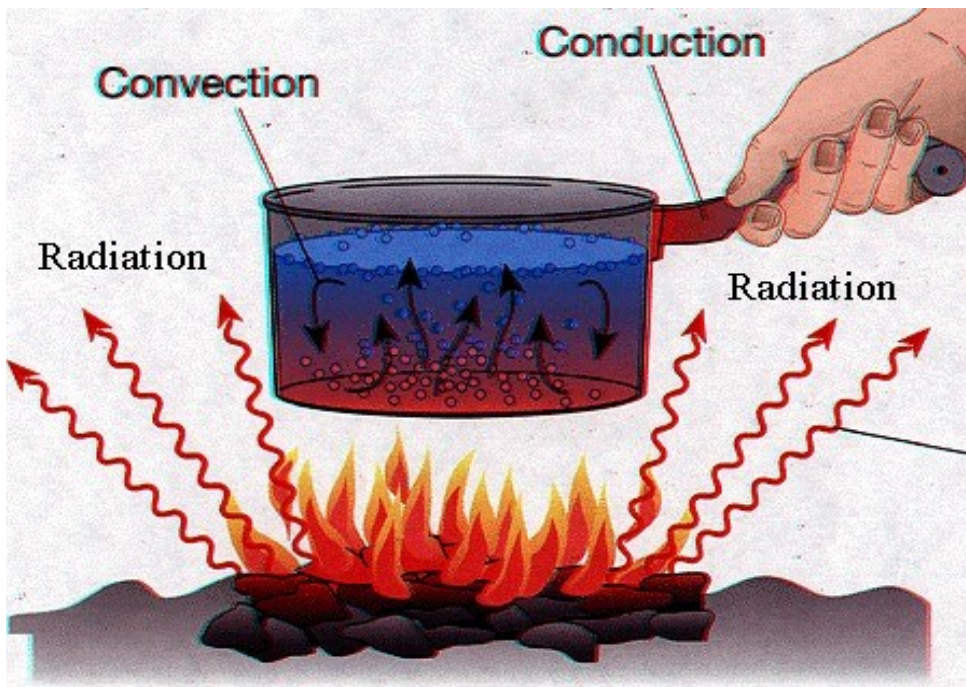


Unit 3 - Process of Heat Transmission

3.1. Process of Heat Transmission

Practically all of the energy that reaches the earth comes from the sun. Energy travels from the sun to the earth by means of electromagnetic waves. The shorter the wavelength, the higher the energy associated with it. Intercepted first by the atmosphere, a small part is directly absorbed, particularly by certain gases such as ozone and water vapour. Some energy is also reflected back to space by clouds and the earth's surface. Energy is transferred between the earth's surface and the atmosphere via conduction, convection and radiation. The processes of heating and cooling of the atmosphere are,

- conduction
- convection
- radiation and
- advection.



3.1.1. Conduction

The conduction is the process by which heat energy is transmitted through contact with neighbouring molecules. Air and water are poor conductors.

3.1.2. Convection

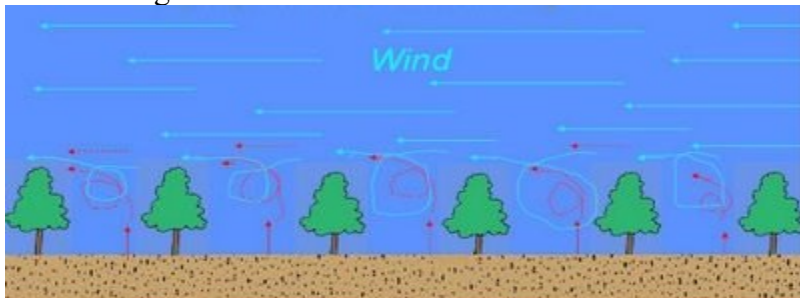
The convection transmits heat by transporting groups of molecules from place to place within a substance. Convection occurs in fluids such as water and air, which move freely. In the atmosphere convection includes large and small scale rising and sinking of air masses and smaller air parcels. These vertical motions effectively distribute heat and moisture throughout the atmospheric column and contribute to cloud and storm development (where rising motion occurs) and dissipation (where sinking motion occurs). It is through this process differential heating of the atmosphere and horizontal and vertical movement of air takes place.

3.1.3. Radiation

The radiation is the transfer of heat energy without the involvement of a physical substance in the transmission. Radiation can transmit heat through a vacuum.

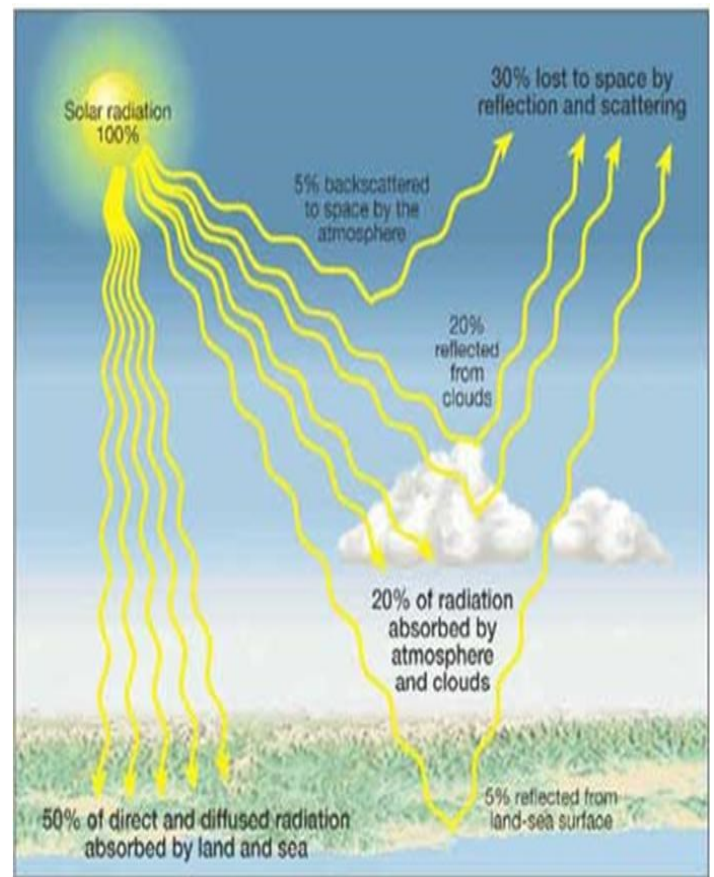
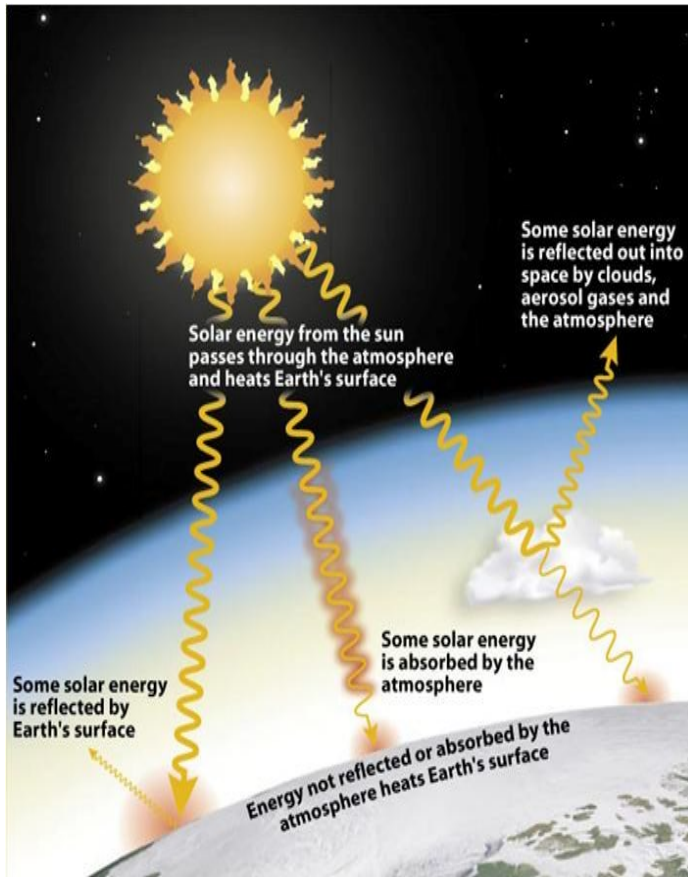
3.1.4. Advection

The process of horizontal transfer of heat by winds is called advection. Air masses in the form of winds blow from one region to another.



3.2. Heating of the atmosphere

The atmosphere does not absorb short wave radiation. Therefore, most of the radiation is transmitted to earth without heating the atmosphere. The insolation chiefly heats up the earth's surface. The heated surface of the earth reflects back the heat to atmosphere in the form of long-waves (terrestrial radiation). Insolation is received only during the day-time. But transmission of terrestrial radiation takes place all through the day and night. As a result of this phenomenon nights are cooler than the day.]



3.3. Heat budget of the earth

The average temperature of the earth generally does not change. The amount of heat reflected back by earth through terrestrial radiation equals the amounts of insolation or incoming solar radiation. In the way there is balance between insolation and terrestrial radiation. This balance is known as the heat budget of the earth.

Unit 4 - Disposal of Insolation

4.1. Insolation

The energy for all atmospheric processes is derived from the sun. The sun radiates energy at a temperature of 6000°C. Incidence of the solar radiation on the earth's surface is referred as insolation. The sun's rays suffer depletion due to absorption, scattering and reflection and by the atmospheric constituents, particulates or aerosols and clouds. Most of the ultraviolet radiation is absorbed by the ozone layer. Part of the radiation is reflected back to space by water, snow and deserts and the rest is absorbed by land and water. Nearly 19 percent of the incoming solar radiation is absorbed in the atmosphere and 34 percent scattered or reflected back to space. The rest 47 percent of the radiant energy is absorbed by the earth and transformed into heat (Fig). Heating extends to considerable depth in water due to turbulent mixing and overturning. Oceans store energy for long periods. Over land, however, the heating effect is restricted to a few centimeters. Heat is transferred upwards by conduction and eddy transfer. Large masses of heated air become buoyant and are carried upward by convection. Cooling takes place in the vertical uplift and water vapour condenses into liquid water drops, liberating latent heat.

4.2. Albedo

The term albedo denotes the reflectivity for sunlight of a rough (diffusely reflecting) surface or of an entire planet. It is defined as the ratio of diffusely reflected radiation to the incident radiation. Thus an albedo of 1 (or 100 percent) would apply to a perfectly white diffuse reflector, while an albedo of zero (or 0 percent) would apply to a perfectly black body. The average or overall albedo of a planet determines its mean temperature.

4.3. Greenhouse effect

The phenomenon called the greenhouse effect causes warming of the surface and lower atmosphere of a planet through the atmosphere's trapping of outgoing infrared radiation (long wave radiation). The trapping is affected by certain gases that act as infrared absorbers- for examples, water vapour, carbon dioxide, methane and chlorofluorocarbons (CFCs). As these gases absorb the infrared radiation being emitted by the surface, they warm the lower atmosphere and they then reradiate to the surface, warming it.

4.3.1. Greenhouse gases

Through the absorption and emission of the Earth's radiation, certain atmospheric gases contribute importantly to determine the average temperature of the planet. These are called greenhouse gases and included are such primary constituents as water vapour, carbon dioxide, ozone, methane, nitrous oxide and chlorofluorocarbons. The major constituents of the air, nitrogen and oxygen are not greenhouse gases. Some greenhouse gases are influenced by human activities, but others, such as the chlorofluorocarbons are entirely produced by human industry.

Water vapour has the largest greenhouse effect in the Earth's atmosphere, but its concentration is determined by a global balance between evaporation from the oceans and precipitation, so it is not directly affected by human activities. In general, carbon dioxide and other greenhouse gases are relatively inefficient absorbers of solar radiation; however, these gases are strong absorbers of infrared (IR) radiation (heat), the type of radiative energy emitted by the Earth.

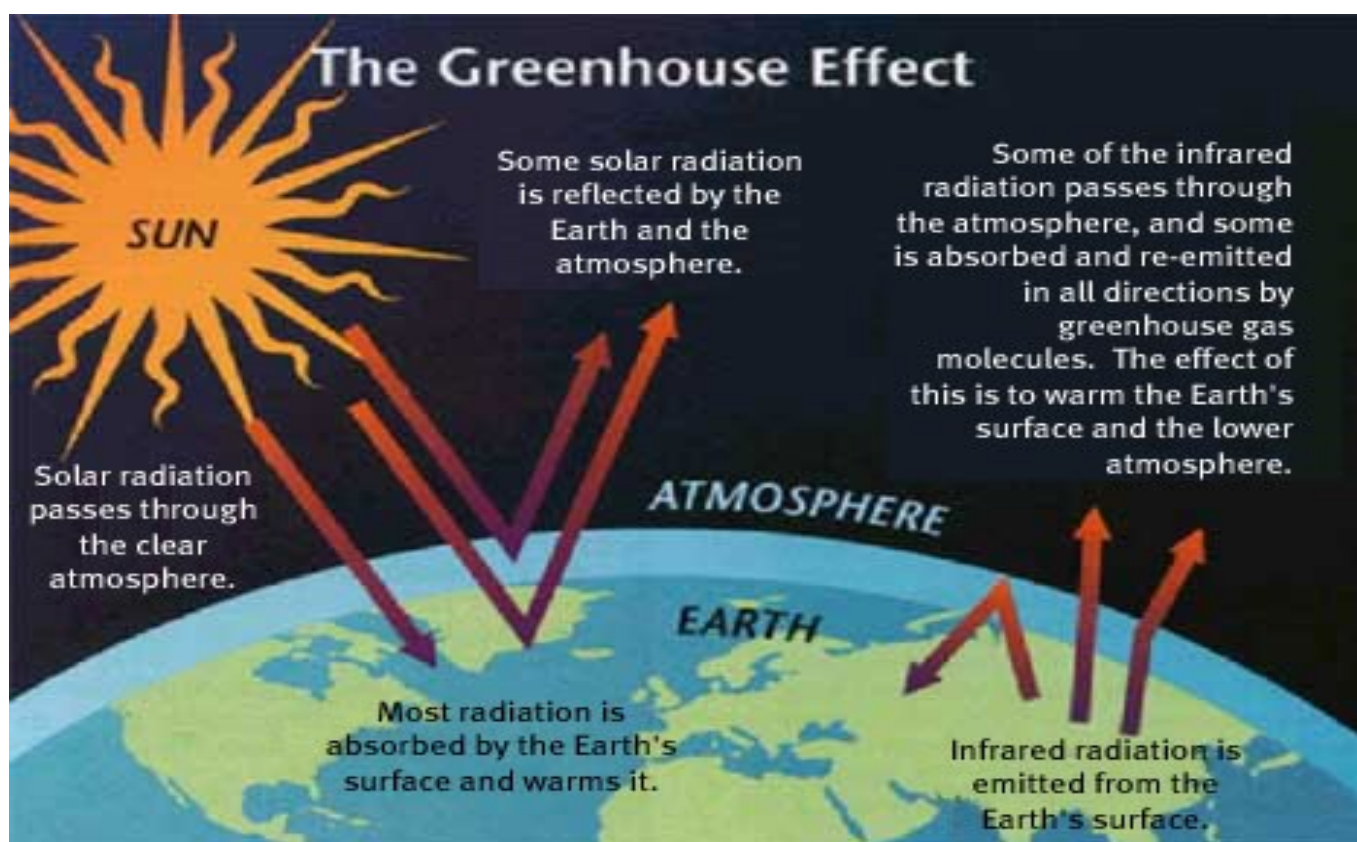
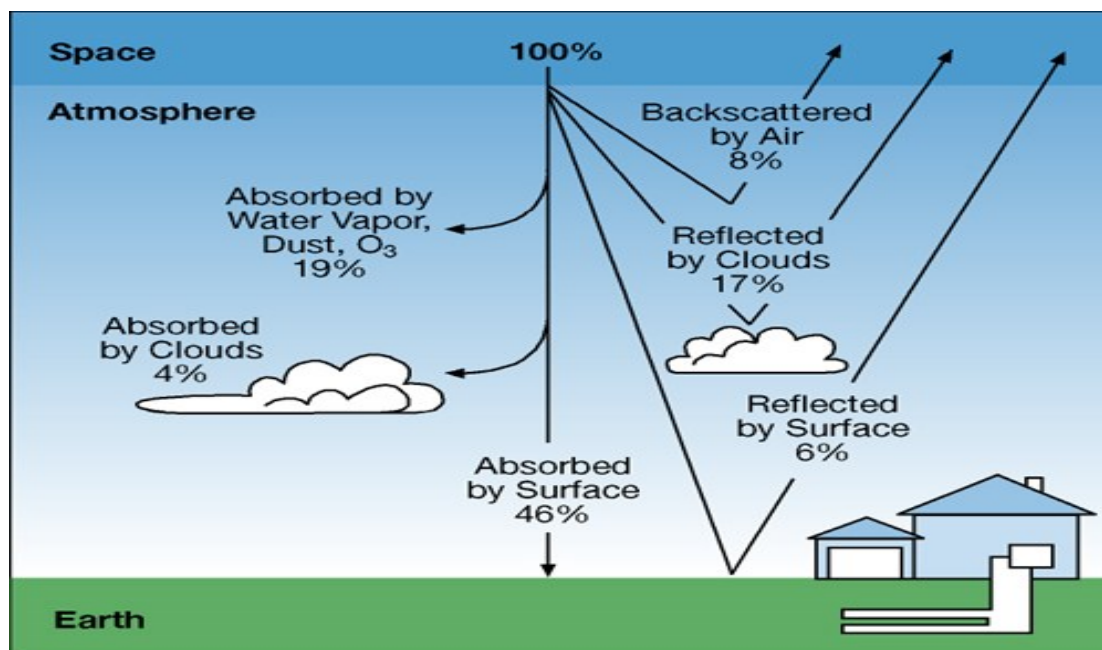
After carbon dioxide, the most important greenhouse gas is methane. Other greenhouse gases are the chlorofluorocarbons which are notorious for their effect on the ozone layer but also strong infrared absorbers, and nitrous oxide produced in soil when nitrate fertilizers are used. All the other greenhouse gases together, except for water vapour, contribute about the same to the greenhouse warming as does carbon dioxide alone.

4.4. Global warming

Globally averaged surface air temperatures during the 1980s and early 1990s have been warmer than at any other time. Many scientists believe that this global warming is the result of a concurrent increase in the levels of atmospheric greenhouse gases, specifically carbon dioxide, methane and the chlorofluorocarbons. It is also believed that the greenhouse gases have been increasing primarily because of human activities. Increasing amounts of carbon dioxide are released into the atmosphere due to the ever growing combustion of fossil fuels. Greater absorption of the outgoing long wave radiation from the earth due to the higher concentration of greenhouse gases such as carbon dioxide, methane and nitrogen oxides in the atmosphere would result in a rise in global temperatures or global warming.

Global warming may have long-term consequences such as the melting of polar ice caps which in turn would lead to flooding and submergence of low lying coastal areas. Rise in sea level would mean the wiping of the prosperous and teeming settlements of human lives as in Sunderbans, Bangladesh, Maldives, etc. The forests of the world act as global sinks which absorb the carbon dioxide emitted into the atmosphere through

the burning of fossil fuels. Depletion of our forest cover necessarily reduces their capacity to absorb carbon dioxide. Further, clearing and burning of the forests release more and more carbon dioxide into the atmosphere, thus enhancing the greenhouse effect.



UNIT 5 – AIR TEMPERATURE

5.1. Air Temperature

The temperature of the air is a fundamental and important weather element. The main source of heat for the atmosphere is the radiation emitted by the earth. The atmospheric temperature shows large variation due to irregular distribution of insolation on the surface of the earth. These variations can be classified into three types:

- Periodic temperature variation
- Horizontal temperature variation
- Vertical temperature variation

5.1.1. Periodic temperature variation

It is a common knowledge that the air temperature shows periodic variations from high to low values. These periodic variations can be classified into daily and annual changes. The daily maximum temperature occurs in the midafternoon between 1 and 4 P.M. The daily minimum temperature occurs in the early morning just before sunrise between 4 and 6 A.M. The annual variations largely follow the diurnal variations. The annual maximum temperature occurs in the end of July, a full month after summer solstice (June 21st). The annual minimum temperature occurs in the end of January, a month after winter solstice (December 22nd). These variations for the northern hemisphere only, the seasons being reverse in the southern hemisphere.

5.1.2. Horizontal temperature variation

The most fundamental horizontal temperature variation is the slow decrease in air temperature from the equator towards the poles. This is the normal effect of latitude on temperature, since the amount of insolation received on the earth's surface largely depends on the latitudes. However, the temperature at different places of same latitude will not be same because of various other factors. The irregular composition of the earth's surface has a great effect on temperature. Land areas warm and cool more rapidly than water masses (ocean). The annual temperature ranges are greater over the land than over the oceans. The temperature of the air in the first 2 or 3km above the oceans varies less between seasons and between day and night than the air above the continents. The effect is most evident in middle and high latitudes, where seasons are pronounced.

The most important reason for differences in the rates of heating and cooling is that the fluid character of water permits it to mix and as a result, the heat added to the oceans by solar radiation is distributed to over a greater depth than the heat added to a land surface. Similarly, when a water surface cools, the surface water becomes heavier and begins to sink, allowing warmer water to rise to the surface. In addition, the sun's rays penetrate water to a considerable depth, thus distributing their energy through a relatively deep layer. Water is mobile and experiences both vertical and horizontal movements which distribute the heat energy absorbed at the surface throughout its mass. On the other hand, the opaqueness of land concentrates the absorption of solar energy at the surface, causing relatively rapid and intense heating. Insolation is absorbed by land only at the surface and is transmitted slowly downward by conduction. Also of major significance is the large specific heat of water. Specific heat is the ratio of the heat addition to temperature change. Water has a specific heat of 1, while soils have a specific heat of less than 0.5. Thus, to raise the temperature of a mass of water by 1°C requires more than twice as much energy as is needed to rise the temperature of an equal mass of land by 1°C. A final important factor is that in oceanic areas more of the solar energy goes into evaporating water and thus is not available for heating the water. Because of these factors the oceans are a great stabilizer of temperature.

5.1.2.1. Isotherms

The horizontal distribution of the air temperature is shown by means of isotherms. Isotherms are the lines connecting points of equal temperature. The temperature gradually decreases from the equator towards the poles due to the effects of latitude. If the latitude is the only factor affecting temperature, then isotherm on the world map would have been straight lines. But there are other factors which influence the temperature. Hence isotherms on a world map are irregular lines. Isotherm representing highest temperature would be near the equator. A line connecting the places having highest average temperature is known as “Heat equator”. The temperature change in a direction normal to the isotherm is called horizontal temperature gradient. The lowest valid temperature registered so far is -127°F at Voslok station, Antarctica. The highest world temperature recorded is 136°F at Tripoli in North Africa.

5.1.3. Vertical temperature variation

Observation of temperatures in the upper air indicates the decrease of temperature with altitude. The regular decrease in temperature with altitude is called vertical temperature gradients. This extends up to the tropopause. There are three reasons for this decrease in temperature,

- The major source of heat for the atmosphere is the earth. So as the distance from the surface of the earth increases the temperature must decrease.
- The density of water vapour decreases with elevation, so less heat is absorbed by the air at higher latitudes.
- As the air rises to higher altitudes it expands and the temperature decreases.

5.2. Temperature inversion

Certain special conditions in the atmosphere at some altitude may produce a reversal of the normal lapse rate, so that the temperature actually increases with an increase in altitude. This is known as temperature inversion. This can occur only when a warm layer of air overlies a colder layer. The layer in which temperature increases with altitude is called inversion layer.

5.3. Actual lapse rate

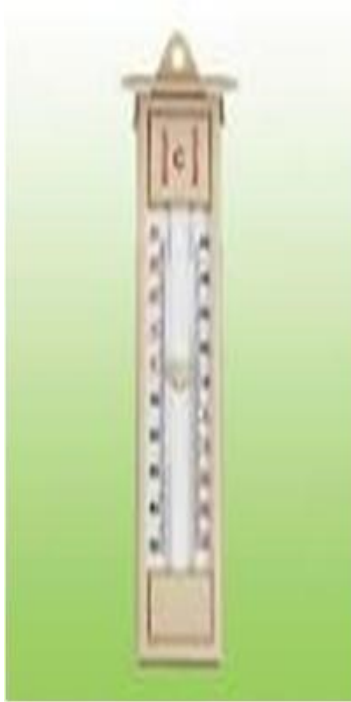
The actual decrease in temperature with elevation at a given place is called actual lapse rate. It is determined by actually observing the temperature at different elevations. It changes from place to place and time to time.

5.4. Normal lapse rate

The average rate of temperature decrease with elevation is called “Normal lapse rate”. This is determined by taking the average of the different lapse rate observed at different places and different times. Normal lapse rate is 6.5°C .

5.5.1. Maximum thermometer

Usually used at shore stations in order to record the maximum daily temperature. They are of two types, one having a constriction in the tube (as with a clinical thermometer) and the other with an index in the bore. With the later type, the mercury pushes the index up the tube when the temperature rises and when it falls the index is left in position. The maximum temperature is read at the end of the index nearest to the mercury. Mercury is used as it has a high boiling point.



5.5.2. Minimum thermometer

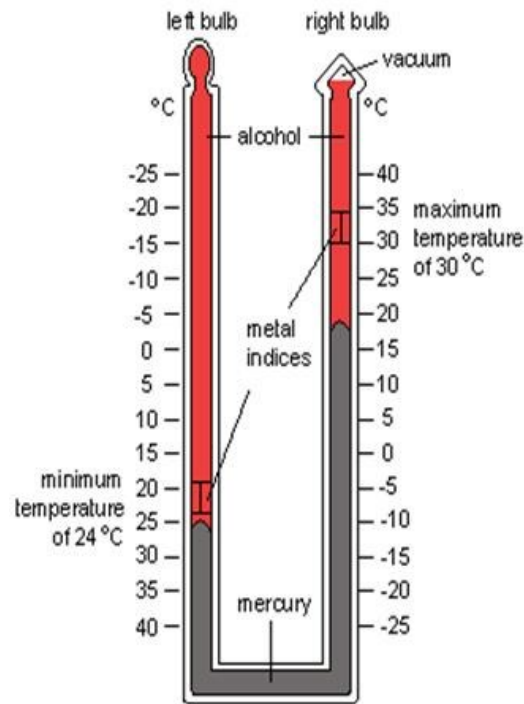
As with the maximum thermometer, this is generally used at shore stations to record the minimum daily temperature. The liquid is usually alcohol as this has a low freezing temperature. The index is immersed in the alcohol and as the temperature falls and the alcohol contracts; the surface tension of the alcohol draws the index down the tube. As the temperature increases the alcohol is free to flow past the index. The minimum temperature is read at the end of the index nearest the open end of the alcohol.



5.5.3. Sixes Thermometer

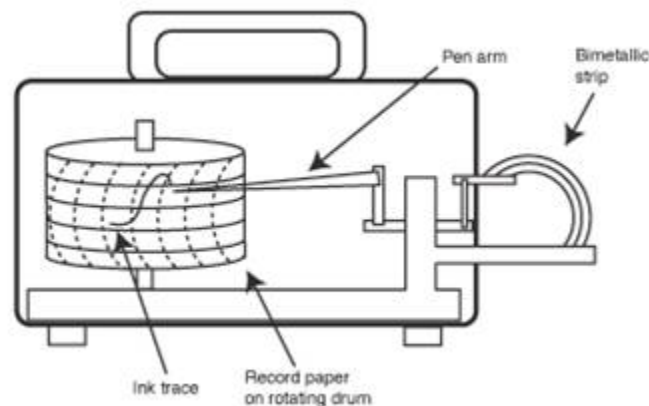
This is a useful little instrument which incorporates a maximum and minimum thermometer and is much used by gardeners. The expansion of the alcohol in the round bulb as the temperature rises, forces the

mercury round towards the pear shaped bulb and in turn, forces the index up the tube. The converse occurs when the temperature falls. The maximum and minimum temperatures are read at the ends of the indices nearest the mercury.



5.5.4. Thermograph

This recording thermometer is not often seen aboard ship. A pen, attached to a metallic coil which expands and contracts, records the temperatures on a drum moved by clockwork. A commonly used thermograph is one which uses a bimetallic strip as reactor. Two thin, curved sheets of metal of widely different thermal expansion are welded together. When the temperature changes, the two metals will expand unequally, and the curvature of the strip will change. This change is transferred through levers to a pen that traces the temperatures on the thermogram.



Unit 6 - Humidity and Water Vapour

6.1.Role and causes of water vapour in the atmosphere

The amount of water vapour in the atmosphere is called humidity. The main sources of water vapour in the lower atmosphere are evaporation from the earth's surface and transpiration by plants. The main sink (route

of loss from the atmosphere) is precipitation as rain or snow. Atmospheric water vapor accounts for only about 1 part in 10,000 of the total amount of water in the global hydrological cycle. The total volume of water in the atmosphere is about 1.3×10^{13} cubic meters; the overwhelming majority of this is in the vapor phase. For comparison, the oceans contain about 1.35×10^{18} cubic meters of water. Atmospheric water vapor is one of the most important factors in determining earth's weather and climate, because of its role as a greenhouse gas and because of the large amounts of energy involved as water changes between the gaseous (vapor) phase and the liquid and solid phase.

Air saturated when it holds the maximum possible amounts of water vapor. At that point, the rate at which water molecules enter the air by evaporation exactly balances the rate at which they leave by condensation. Specific humidity is the concentration of water vapor in a sample of moist air. Absolute humidity is the water vapor density, defined as the ratio of the mass of water vapor to the volume of associated air; it is generally expressed in grams per cubic meter. The partial pressure of water vapor in saturated air is called the saturation air pressure. Saturation vapor pressure increases rapidly with temperature; the value at 32°C is about double the value at 21°C . Relative humidity can be defined as the ratio of the actual vapor pressure to the saturation vapor pressure at a given air temperature; the result is expressed as percentage. Because the saturation vapor pressure is temperature dependent, for a given value of relative humidity, warm air has more water vapor than cooler air. When air is cooled at constant pressure and water vapor content to the saturation (or condensation) point, the air temperature at which that point is reached is the dew-point temperature. The difference between the actual temperature and to the dew-point is called the dew-point depression.

6.2. Variations in humidity

In the absence of significant changes in weather, the variations in humidity that occur over the course of a day can easily be understood. The specific humidity remains relatively constant from day to night and so the dew-point temperature does also. As the temperature cools at night, however, the saturation vapour pressure decreases, so relative humidity increases. The highest humidity values usually occur at the time of lowest temperature, before sunrise.

Seasonal humidity variations depend on two factors- seasonal changes in temperature and seasonal changes in atmospheric circulation. In temperate climate, the warmer air in summer has a higher saturation vapor pressure than does the cooler winter air. Average relative humidity values in summer and winter tend not to differ much, so the specific humidity, tends to much greater in summer. In monsoon climates, relative and specific humidity tend to increase dramatically during the monsoon season, when onshore winds carry moisture-laden air from the ocean to land areas.

6.3. Evaporation and Condensation

Humidity in the atmosphere is constantly changing. Water vapour enters and leaves the atmosphere at the surface of the earth, but it can also change phase between a liquid state (dew, rain, fog or cloud) and a solid state (snow, ice, sleet, or graupel) while remaining in the atmosphere. The fluxes of water to the atmosphere from the earth's surface and to the surface from the atmosphere (precipitation) are controlled, in part, by atmospheric humidity. Evaporation from open surfaces, like an ocean or lake can be simply estimated as proportional to the difference between the saturation vapour pressure at the water surface and the actual vapour pressure above the surface. However, higher the wind speed and the greater the turbulent mixing of the atmosphere, the greater is the evaporation. When a cold surface underlies warm, moist air, the atmospheric vapour pressure may exceed the surface saturation vapour pressure; condensation to the surface can then occur in the form of dew or rime ice (frost).

When the relative humidity is near or exceeds 100 percent, atmospheric water vapour pressure is likely to condense on nuclei to form cloud droplets or ice crystals, depending on the ambient temperature. The relative humidity required to sustain droplet growth depends on the size of the droplet and on the

concentration of dissolved solute.

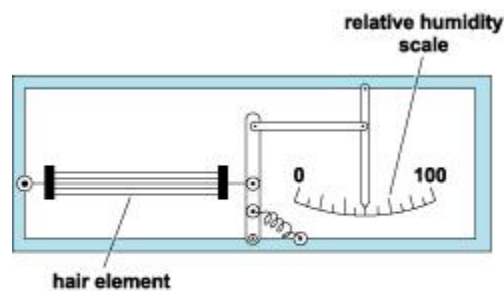
If the humidity is high enough, droplets will begin to evaporate.

If cloud droplets grow to drop size, and if the drops become sufficiently large, they fall as rain. Once outside the cloud, in air of lower relative humidity, these drops are likely to evaporate. As they evaporate, the falling drops are cooled and their temperature is close to the wet-bulb temperature. The rate of evaporation from falling drops depends of the drop size, fall speed, updraft speeds and ambient humidity. Thus water cycles among the vapour, liquid and solid phases in the atmosphere.

6.4. Humidity measuring instruments

1. Hair hygrometer

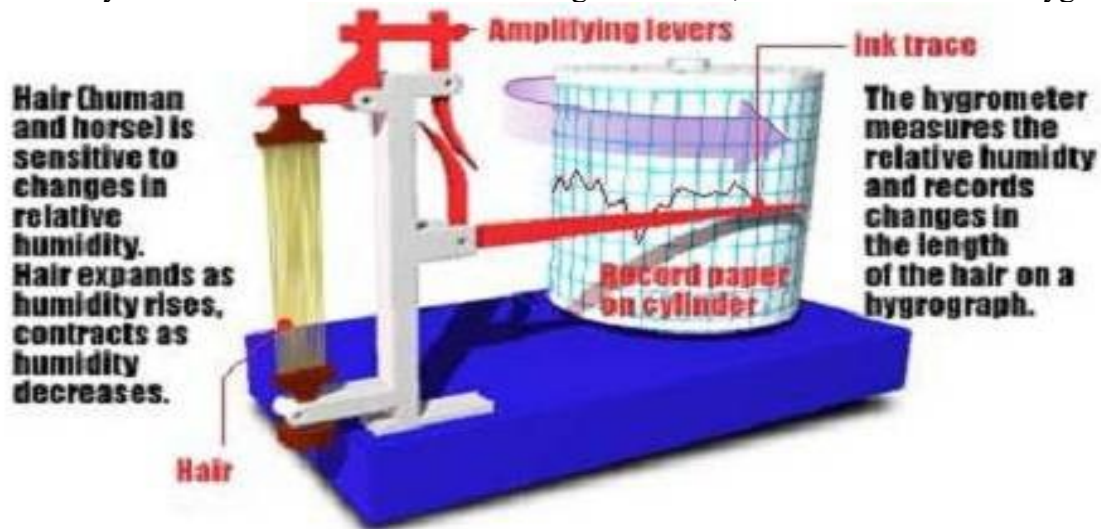
In 1783, De Saussure used human hair to measure the moisture of the air and constructed the hair hygrometer, which, with later improvements is still standard station equipment. When air is dry, the cells in the hair are close together; but when the air is humid, the space between the cells absorbs water vapour and air thickens and lengthens. It is this lengthening that is used as a measure of the moisture.



The instrument has a bundle of hairs, the upper end of which is fixed to a frame and the lower end to a weight. The weight is connected by amplifying levers to compensating cams which in turn are connected to a pointer which moves across a scale and indicates the relative humidity.

2. Hygograph

The hygrometer may be transformed into a self-recording instrument, and it is then called a hygograph.



3. Psychrometer

A Psychrometer is a simple, widely used instrument for measuring humidity. This consists of two thermometers mounted side by side in a Stevenson's screen. One is a dry bulb thermometer, the other a wet bulb thermometer. One of these is naked while the other has its bulb tightly dressed in fine muslin with a wick that draws pure water from a container thus keeping the bulb wet. Now, when air is blown fast the

bulbs, the dry thermometer shows the temperature of the air, while water evaporates from the wet bulb. Since heat is required to evaporate water, the temperature of the wet bulb thermometer sinks; it does so until a state of equilibrium is reached and then stays steady. The saturation vapour pressure at the wet bulb is then the same as that of the air and no further evaporation takes place. The temperature shown by this thermometer is called the wet-bulb temperature and we may say that this temperature is the lowest temperature to which the air can be cooled by evaporating water into it.



Now if the air is saturated initially, no evaporation would occur and the dry-bulb and wet-bulb temperatures would be the same; the relative humidity would be 100 per cent and the wet-bulb depression would be zero. The larger the saturation deficit, the more evaporation would be needed and the larger would be the wet-bulb depression. Once the air temperature and the wet-bulb temperature have been observed, the relative humidity and all other humidity measures can be obtained from tables or graphs. By entering tables with the dry-bulb temperature and the difference between the wet and dry bulbs, the dew point and relative humidity can be found.

Relative Humidity Table (wet/dry bulb method)

Dry Bulb [°C]	Wet Bulb depression [°C]															
	0	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
2	99%+	84%	68%	52%	37%	22%	8%									
4	99%+	85%	70%	56%	42%	29%	26%	3%								
6	99%+	86%	73%	60%	47%	34%	22%	11%								
8	99%+	87%	75%	63%	51%	39%	28%	18%	7%							
10	99%+	88%	76%	65%	54%	44%	33%	23%	14%	4%						
12	99%+	89%	78%	67%	57%	47%	38%	29%	20%	11%	3%					
14	99%+	89%	79%	69%	60%	51%	42%	33%	25%	17%	9%					
16	99%+	90%	80%	71%	62%	54%	45%	37%	29%	22%	14%					
18	99%+	91%	81%	73%	64%	56%	48%	41%	33%	26%	19%	6%				
20	99%+	91%	82%	74%	66%	58%	51%	44%	37%	30%	24%	11%				
22	99%+	91%	83%	75%	68%	60%	53%	46%	40%	34%	27%	16%	5%			
24	99%+	92%	84%	76%	69%	62%	55%	49%	43%	37%	31%	20%	9%			
26	99%+	92%	85%	77%	70%	64%	57%	51%	45%	39%	34%	23%	14%	4%		
28	99%+	92%	85%	78%	72%	65%	59%	53%	47%	42%	37%	26%	17%	8%		
30	99%+	93%	86%	79%	73%	67%	61%	55%	49%	44%	39%	29%	20%	12%	4%	
32	99%+	93%	86%	80%	74%	68%	62%	56%	51%	46%	41%	32%	23%	15%	8%	1%
34	99%+	93%	87%	81%	75%	69%	63%	58%	53%	48%	43%	34%	26%	18%	11%	5%
36	99%+	93%	87%	81%	75%	70%	64%	59%	54%	50%	45%	36%	28%	21%	14%	8%
38	99%+	94%	88%	82%	76%	71%	65%	60%	56%	51%	47%	38%	31%	23%	17%	11%
40	99%+	94%	88%	82%	77%	72%	66%	62%	57%	52%	48%	40%	33%	26%	19%	13%
42	99%+	94%	88%	83%	77%	72%	67%	63%	58%	54%	50%	42%	34%	28%	21%	16%
44	99%+	94%	89%	82%	78%	73%	68%	64%	59%	55%	51%	43%	36%	29%	23%	18%

Difference Between Dry Bulb and Wet Bulb Temperatures	Relative Humidity
None	100%
0.5°	96%
1.0°	93%
1.5°	89%
9.0°	44%
9.5°	42%
14.5°	19%
15.0°	17%
18.0°	5%

Unit 7 - Condensation

7.1. Condensation

The water vapour content in the atmosphere varies widely, rising at times to as much as 4 percent by volume. Nearly 85 per cent of the moisture enters the atmosphere by evaporation from the oceans, lakes, rivers, glaciers, ice caps and the rest by evapotranspiration from vegetation. Moisture can be present as vapour, droplets and ice crystals. Moisture comes out of the atmosphere by condensation and precipitation. The condensation occurs when water vapour in the atmosphere changes state from a gas to a liquid or from a liquid to a solid. This process forms fog, dew, frost and clouds, which may eventually lead to precipitation. Condensation is a major component of the hydrologic cycle because it is the mechanism by

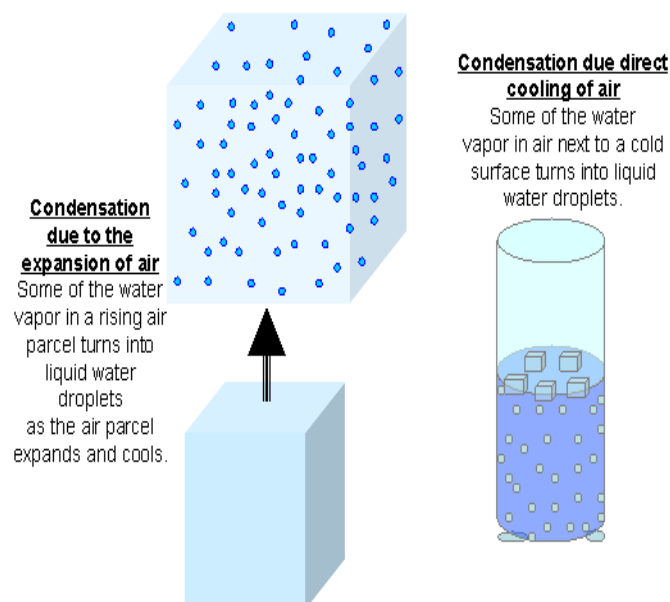
which moisture in the atmosphere is returned to the earth or ocean. Condensation of atmospheric moisture on the ground is called dew if the surface temperature is above freezing and frost if it is below freezing. Fog is simply a stratus cloud in contact with the ground.

In addition to its importance within the hydrologic cycle, condensation is also an important component of the energy balance. As the combined processes of evaporation and transpiration, store energy by changing water from a liquid to a gaseous state, this energy is again released as water condenses from a vapour to a liquid during the process of cloud formation and eventually, precipitation. This energy is removed from the surface of the earth in evapotranspiration and serves to heat the atmosphere when it is released through the condensation of water vapour.

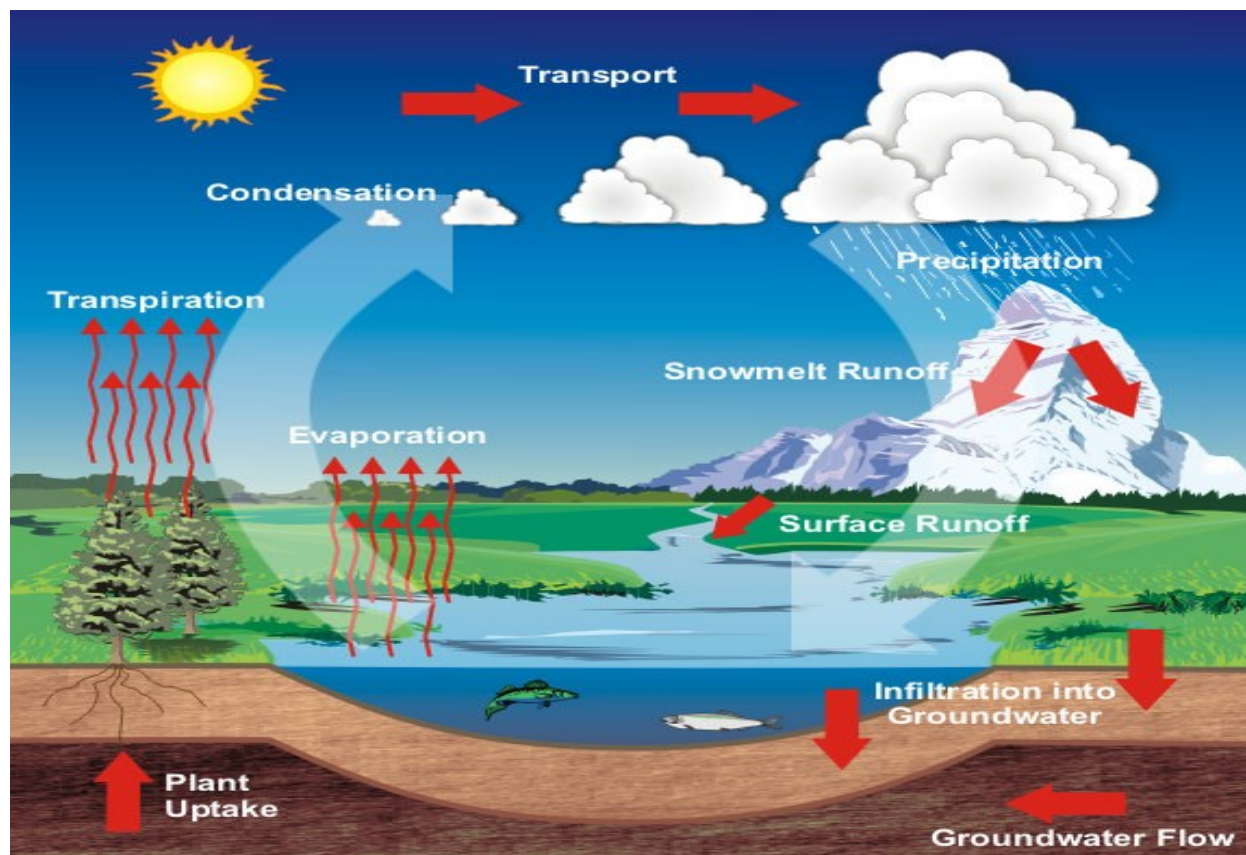
Condensation cannot begin unless the air becomes saturated with a relative humidity of 100% - that is when the partial pressure of water vapour in the atmosphere reaches the saturation vapour pressure at the ambient temperature. As the temperature of the air continues to decrease owing to rising motions, radiational cooling or contact with cooler surface, the vapour pressure exceeds the saturation vapour pressure, producing a condition called supersaturation. When air is supersaturated, the water vapour begins to condense producing extremely small water droplets.

The atmosphere contains many aerosol particles produced by blowing dust and soil, sea spray (salt), forest fires, volcanic activity and industrial pollution. Some of them are hygroscopic, i.e. they attract water. Hygroscopic particles such as sodium chloride (NaCl) act as condensation nuclei. Water vapour condenses initially on hygroscopic nuclei and changes into liquid water droplets. Once condensation is initiated, the process goes on and clouds form. Condensation can begin on condensation nuclei even when the relative humidity is less than cent percent. Water vapour can exist in the supersaturated state upto -39°C in the atmosphere. Supercooled water droplets are extremely unstable and freeze instantaneously on coming into contact with ice crystals.

Ice particles can grow large enough to produce clouds and precipitation through two processes. The first, called the Bergeron process after its discovery by Tor Bergeron in 1933, is based on the principle that when air is saturated with respect to water at temperatures below 0°C , it is supersaturated with respect to ice. Ice particles can also grow by collision with supercooled droplets (called riming) or with other ice particles (aggregation).



CONDENSATION



Unit 8 - Precipitation

8.1. Introduction

The fall of liquid water droplets or ice crystals from the clouds to the ground is termed precipitation. The fall can be in nature of drizzle, rain, shower, hail, sleet or snow. Drizzle, rain and shower are liquid water droplets, the nomenclature depending on the size of the drops and their number per unit volume. Drizzle consists of a very large number of minute droplets per unit volume. Number of drops is much less in rain and still less in showers. Snow is composed of ice crystals which exhibit a fantastic variety of forms and sizes depending upon the temperature. Sleet is a mixture of rain and snow. Ice pellets with diameters from 0.5 to 5.0 cm falling out of thunderclouds are termed hail.

Rainfall is measured as the height of water collected in an open impermeable space by direct precipitation. Any loss by absorption, evaporation or runoff is prevented. Precipitation is measured by a rain gauge or a snow gauge. There are two types of rain gauges—ordinary rain gauge and self-recording rain gauge. Rainfall is expressed in millimeters per day, month or year and denotes the total depth of water falling on the earth from all types of precipitation. Snow is measured as the water equivalent or directly as the depth of accumulation. The exposure conditions of the rain/snow gauge should conform to lay down standards so that the measurements made at various places are comparable. In India the day's rainfall is the total fall for the previous twenty-four hours ending at 0830 hrs IST (Indian Standard Time) of the day. In climatological data, a rainy day means that the day recorded 2.5mm of rain. Spatial analysis of rainfall is done by drawing isohyets which are lines connecting equal amounts of rainfall.

8.2. Rainfall in India

India is a land of wide contrasts in its weather. The Himalayas are the abode of snow and glaciers. Snowstorms and blizzards are usual in winter with temperatures going down to -45°C in Ladakh. Shifting

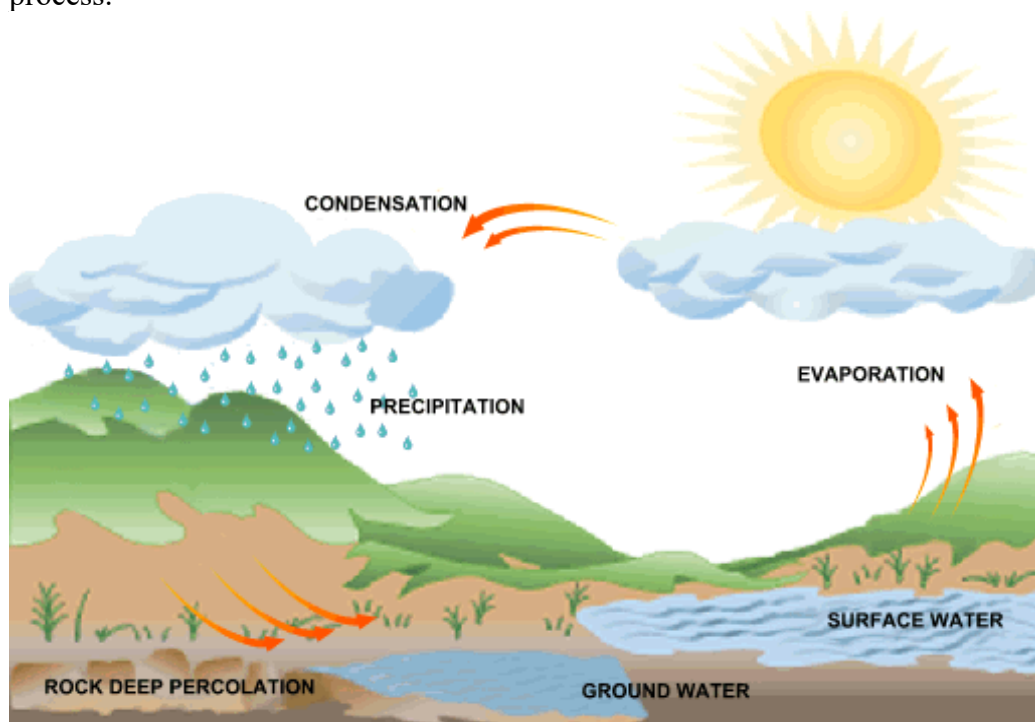
sand dunes and sand storms are ubiquitous in Rajasthan, where temperature soars up to 50°C in the summer. Pressure and wind systems over the subcontinent undergo a cyclic reversal between the summer and winter monsoons.

Orography plays a major role in the spatial distribution of rainfall. The windward slopes of Khasi and Jaintia Hills of Meghalaya receive some of the highest rainfalls in the world. The annual average rainfall at Cherrapunji is 1,102cm and at Mawsynram, 1221 cm. The highest rainfall recorded in twenty-four hours at these places is 99cm. Western Ghats are another high-rain area. The annual average rainfall of Agumbe in Karnataka is 847cm, of Mahabaleshwar in Maharashtra is 630cm and of Pirmed in Kerala is 517cm.

8.3.Precipitation process

The floating cloud droplets fall to the ground under the influence of gravity. However, they remain airborne so long as their fall speed is less than the magnitude of the upward motion in the atmosphere. The tiny droplets in the cloud grow due to aggregation or coalescence. The larger the drop, the greater is the fall or terminal velocity. When the drops grow to a size where the terminal velocity becomes greater than the updraft, they come down to the ground as precipitation. In hot or dry atmosphere, initially the drops may not reach the ground due to evaporation in the intervening layers. The rain can then be seen from a distance as downward strands from the cloud, disappearing midway. This phenomenon is termed virga.

A mechanism is required for the growth of water droplets to become large enough to attain terminal velocity high enough to come down as precipitation. Precipitation can be initiated by two different processes, depending on the temperature in the cloud. When the cloud temperature is less than 0°C either partially or wholly, initially ice crystals form in the supercooled region at the top where the temperatures are of the order of -120°C. Once formed, ice crystals draw moisture rapidly from water droplets and grow at their expense. Ice crystals in the cloud multiply by a splintering process also. A shell of ice forms on a supercooled drop. As it grows and presses inwards, the drop shatters and thousands of spikes of fine ice crystals scatter in the cloud. The ice crystals melt as they fall through cloud, liquid water drops collide with others, aggregate to form larger drops and come down to the ground as rain. If the temperature continues to be very low, snowfall occurs. This is the cold rain process.



In the tropics, in many cases, clouds do not reach the freezing level which is quite high, nearly 16 to 18km. Still rainfall occurs, though the cloud temperatures are above 0°C. In these so called warm clouds, water

droplets collide with each other, become large water drops due to coalescence and these large drops come down as rain. Initially the large drops form presumably out of giant condensation nuclei such as salt particles. Giant nuclei often arise from sprays out of large waves breaking up in the oceans. This is the warm rain process.

Unit 9 - Atmospheric Pressure

9.1.Introduction

The detectable atmosphere extends to hundreds of miles above the earth's surface which is held by gravity. The pressure exerted by the atmospheric air on the surface of the earth is called atmospheric pressure. The atmospheric pressure is expressed in terms of certain equivalent values such as mass or height of mercury column that can balance the atmospheric pressure.

9.2.Units of pressure

Pressure is measured by a barometer as the height of mercury column supported by the atmosphere and expressed as a force in millibars (mb). The unit mb is 1000dynes per sq. cm.

9.3.Periodic variation

The atmosphere is not a static body. It is a dynamic medium. Atmospheric pressure varies with time and distance, as also with altitude and weather conditions. The pressure attains the high values and the low values daily. The high values occur at 10 AM and 10 PM while the low values occur at 4 PM and 4 AM. This effect is known as solar tide. This is pronounced in tropics where the difference between maxima and minima can be of the order of 2 to 3 mb.

9.4.Vertical variation

The atmosphere is a mixture of gases held to the earth by gravity. Since gases are compressible, the overlying air compresses the lower air considerably and thereby increases the density of air near the ground. Because of this compression, pressure rapidly decreases with elevation. The rate of decrease with height is not constant. Near the ground it is approximately 1 millibar per 10 meters but at 20km, pressure decreases more slowly at about 1millibar per 130 meters. At the top of a 1000 meter mountain, pressure is about 900mb.

9.5.Horizontal variation

Atmospheric pressure is not everywhere uniform. The air over the earth's surface undergoes variety of pressure changes due to non-uniform heating of the earth's surface. The horizontal pressure field is analysed by drawing lines of equal pressure values on a map where atmospheric pressure readings reduced to mean sea level of different stations are plotted. The horizontal variations of pressure are much less than the vertical variations, but the relatively small variations are of fundamental significance in determining wind direction and speed. The horizontal pressure patterns are of two types,

- Those whose average position is roughly the same.
- Those whose position moves with the line.

Isobars

Isobars are the lines joining the points of equal pressure. Isobars are usually drawn at pressure intervals of 3, 4 or 5 millibars.

Horizontal pressure gradient

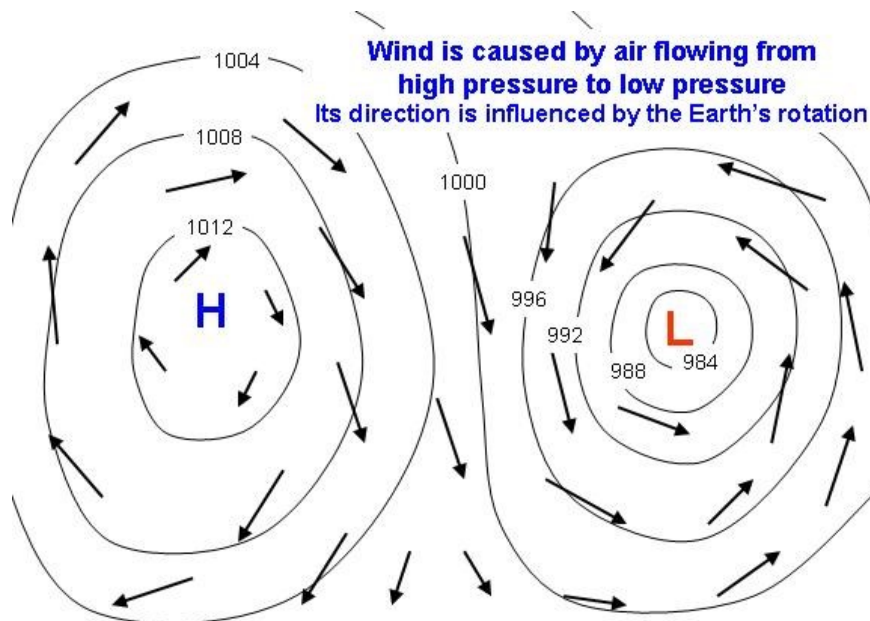
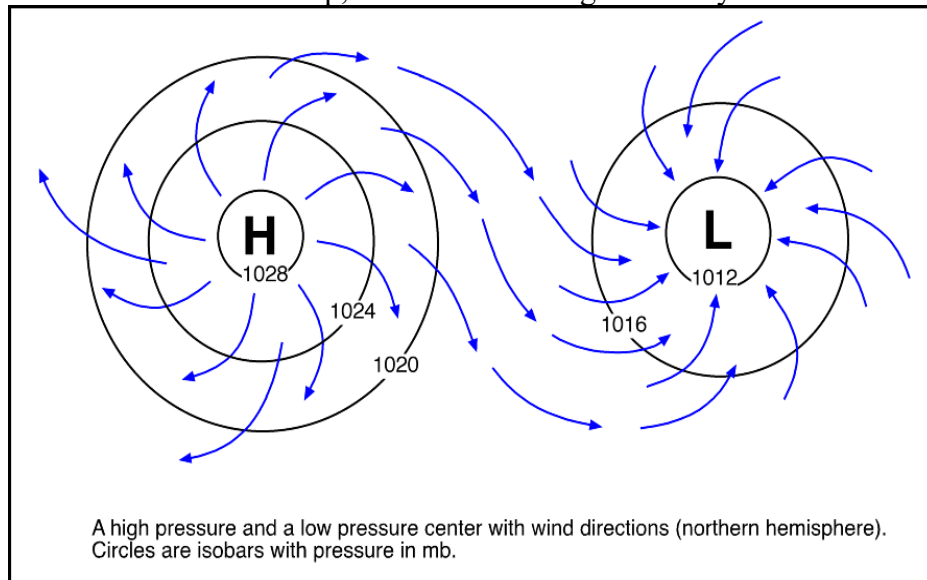
The change in pressure with horizontal distance is called pressure gradient. The pressure gradient is in a direction perpendicular to the isobars.

Isollobars

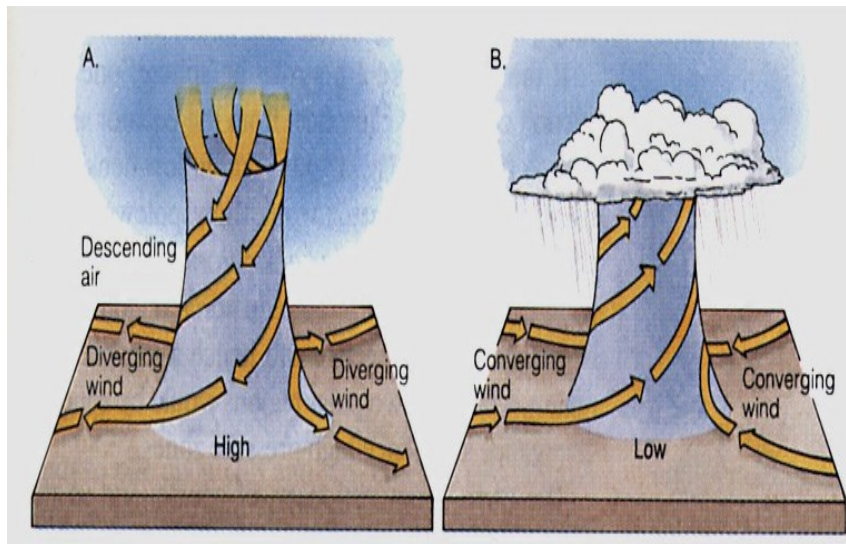
It is often important to know the magnitude of the pressure change rather than simple pressure over a particular region. The change in pressure in the hours prior to observable recording time is called pressure tendency and it is a net value. The line connecting places having equal pressure tendencies is called ' Isollobars' and constitute an important tool in weather analysis.

9.6. High and low pressure areas

An area which has low pressure than surrounding areas at the same elevation is called as low. If there is a fairly identifiable centre of low pressure on a weather map, it is referred as cyclone or depression. A region which has high pressure than surrounding areas at the same elevation is called high. If a centre of high pressure can be identified on a weather map, it is referred as high or anticyclone.



Atmospheric pressure



9.7. Pressure measuring instruments

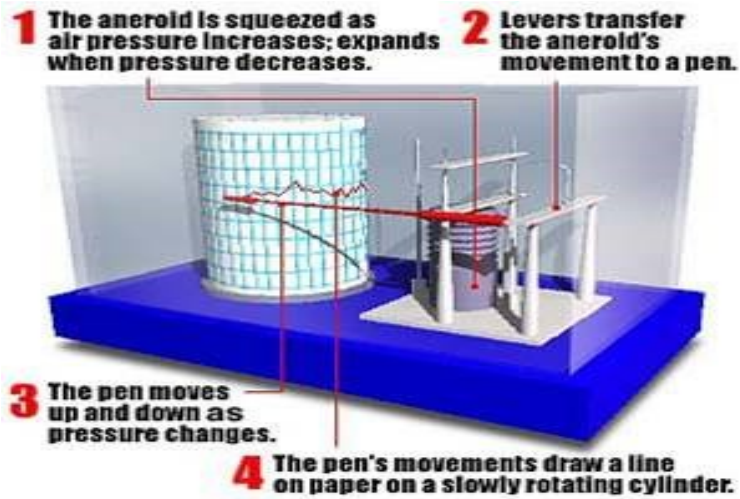
Aneroid Barometer:

A barometer which is cheap, robust and handy for home and travel is the aneroid. Essentially it consists of an air tight box from which the air has been partly evacuated. When the atmospheric pressure increases, the box will be slightly compressed and when the pressure decreases the box will expand and these motions are transferred through amplifying levers to a pointer which moves across a scale graduated in millibars or inches of mercury.



Barograph:

The aneroid barometer may be made to be self-recording so that a trace is drawn on a sheet of paper. The instrument is then called a barograph and the record paper is called a barogram.



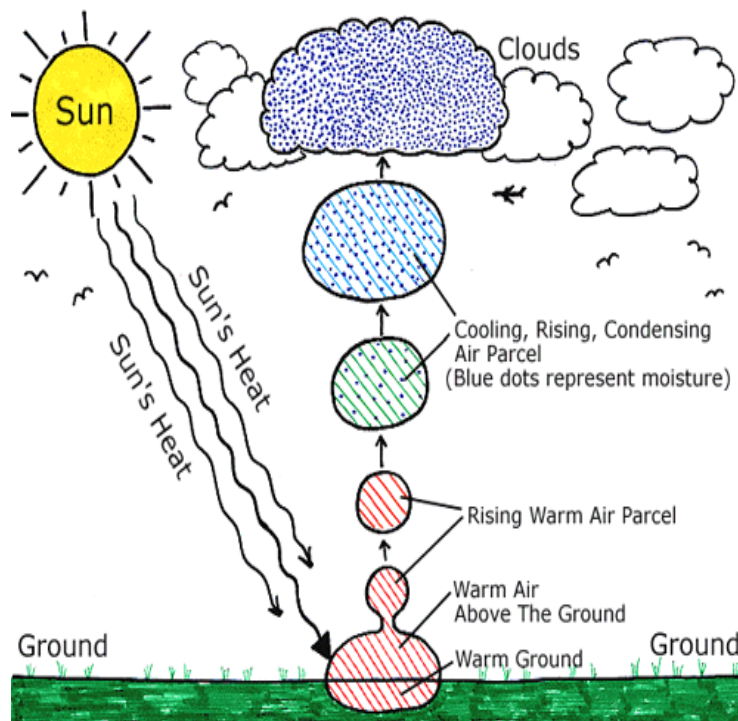
Unit 10 - Clouds

10.1.Introduction

Clouds are visible aggregates of minute water droplets or ice crystals or a mixture of both in free air. The exact composition is influenced by the temperature. Clouds are in a state of constant evolution and exhibit a fascinating variety of shapes, sizes and forms.

10.2.Cloud formation

Clouds form when the moisture content in the air exceeds the capacity of the air to hold water vapour. Water vapour then condenses to form cloud droplets or ice crystals. The processes that cause clouds to form are therefore those processes that moisten the air or reduce its water vapour holding capacity of air increases rapidly with temperature (it doubles roughly for every 10°C), processes that cool air are very effective in producing clouds. These cooling processes include ascent, which cools by expansion of air at decreasing pressure (about 10°C of cooling per kilometer of ascent); radiative cooling by emission of infrared radiation (heat) and conduction which occurs when warm air lies over a warm, moist surface, moistening of the air by evaporation from the surface also produces a different types of cloud.



10.3. Classification of clouds

Clouds with rounded tops resembling heaped cotton or cauliflower are termed cumiform while those forming as sheets in layers are referred to as stratiform. Rain bearing clouds are categorized as nimbus. Clouds with fibrous appearance like silken tufts are called cirriform clouds. Clouds are classified combining their levels of formation and appearance as follows:

Levels of formation	Cloud type
Low (ground to 2km)	Stratus (St), Stratocumulus (Sc)
Medium (Alto)(2 to 8km)	Altostratus(As), Alto cumulus (Ac)
High (Cirro)(above 8km)	Cirrus(Ci), Cirrostratus(Cs), Cirrocumulus (Cc)
Clouds with vertical development (low level to 12 to 18km)	Cumulus (Cu), Cumulonimbus (Cb)



10.4. Clouds and Climate

Clouds have two complementary effects on the climate. They cool the earth by reflecting solar radiation and they warm it by trapping thermal radiation. In order to know the net effect of clouds on climate, one must determine the properties (such as cloud optical thickness and cloud height) of the total cloud field and then calculate the cloud-radiation interactions. Using data from a suite of satellites, researchers calculated that clouds exert a warming of about 30 watts per square meter through their absorption of solar radiation and a cooling of 45 watts per square meter through their reflection of solar radiation; therefore, they have a net cooling effect on the planet of about 15 watts per square meter.

The role that the clouds will play in climatic change, such as the predicted warming of the planet caused by an increase in greenhouse gases, is a subject of intense scientific research and debate. It is argued that the cloud field has the ability either to negate or greatly to increase the predicted warming. In a scenario

predicted by several climate models, as the greenhouse gases increase and the climate warms, low clouds amounts decrease significantly while high clouds amounts increase significantly. This change would lessen the cooling due to the reflection of solar radiation by low clouds, while it would strengthen the warming due to the absorption of thermal radiation by high clouds. Such a change would result in a positive cloud feedback that would further enhance the greenhouse warming. A change of an opposite nature (an increase in low clouds or in the optical thickness of low clouds) would produce a negative cloud feedback that would reduce the greenhouse warming.

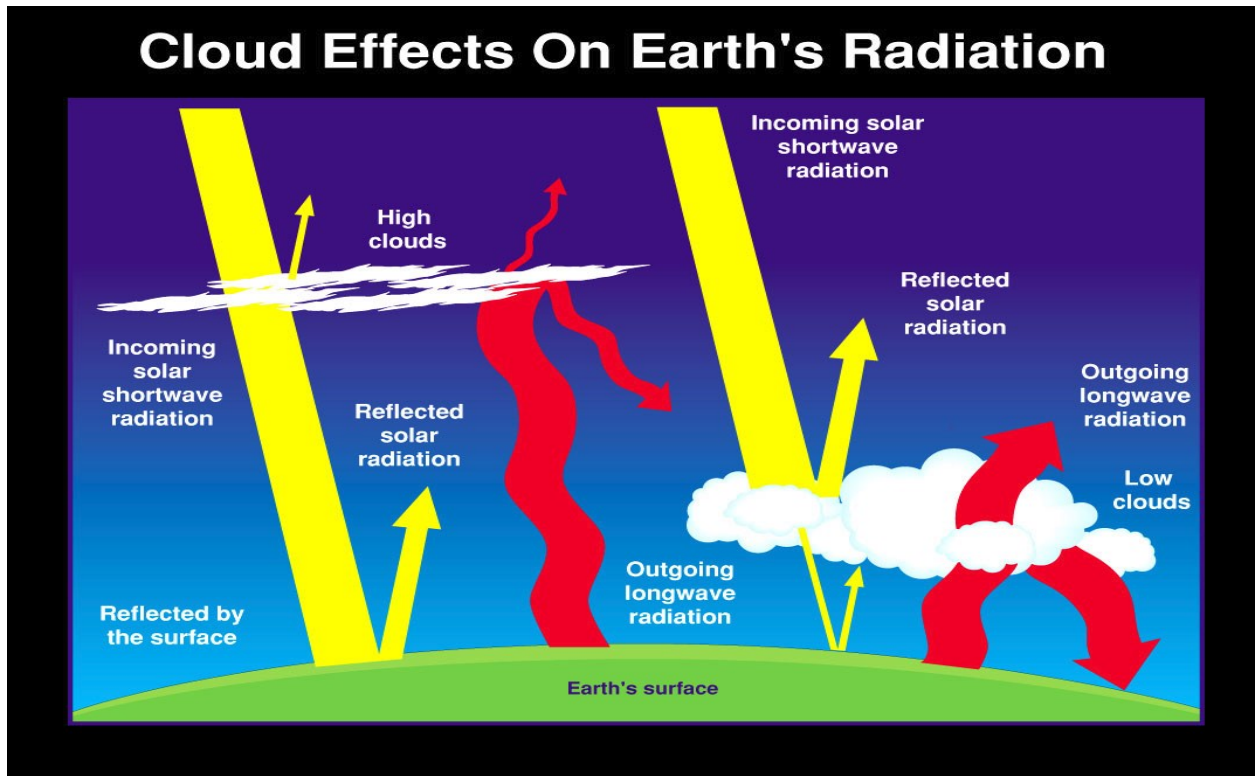
Clouds have direct impacts on the earth's heat and moisture balances and on trace gases and aerosols in the atmosphere. Clouds influence the heat balance through several mechanisms. Latent heat is released when clouds form and absorbed when they evaporate. The circulation systems associated with clouds play important roles in the vertical transport of energy in the atmosphere. Scattering, absorption and the emission of solar and infrared radiation by clouds modify the surface and planetary radiation balances. Some clouds (such as stratus and stratocumulus) exert a strong cooling effect on the planetary radiation balance, while others (such as cirrus and cirrostratus) warm the planet. Thus, cooling or warming of planet by clouds depends on the relative amounts of high and low clouds.

Clouds influence the moisture balance of the atmosphere through condensation of water vapour and precipitation of condensed water to the surface. The circulation systems associated with clouds also transport water vapour, liquid water and ice within the atmosphere. Precipitation of liquid water and ice affects the surface balance of liquid and frozen water. Because precipitation is composed of fresh water and hence is lighter than ocean water, the distribution of precipitation from clouds influences the density and hence the circulation of the ocean.

Clouds influence concentrations of some trace gases by scattering the solar photons (elementary particles, the quanta of electromagnetic radiation) that photolyse gases and by serving as solvents for gases that react much faster in aqueous solution. For example, lightning flashes in the cumulonimbus clouds generate oxides of nitrogen that are important in the chemical balance of the troposphere.

Clouds influence aerosols (suspended particles of dust, sulfate and smoke, typically less than 1 micron in radius) by activating them as cloud condensation nuclei (CCN), by processing them in the development of droplets and by removing them from the atmosphere. Aerosols are activated as CCN when the relative humidity becomes high enough that the particle attracts condensation to form a cloud droplet. All cloud droplets form on aerosols, so that when a cloud precipitates, the aerosol is carried to the surface along with the condensed water.

Cloud Effects On Earth's Radiation



Unit 11 - Thunderstorms

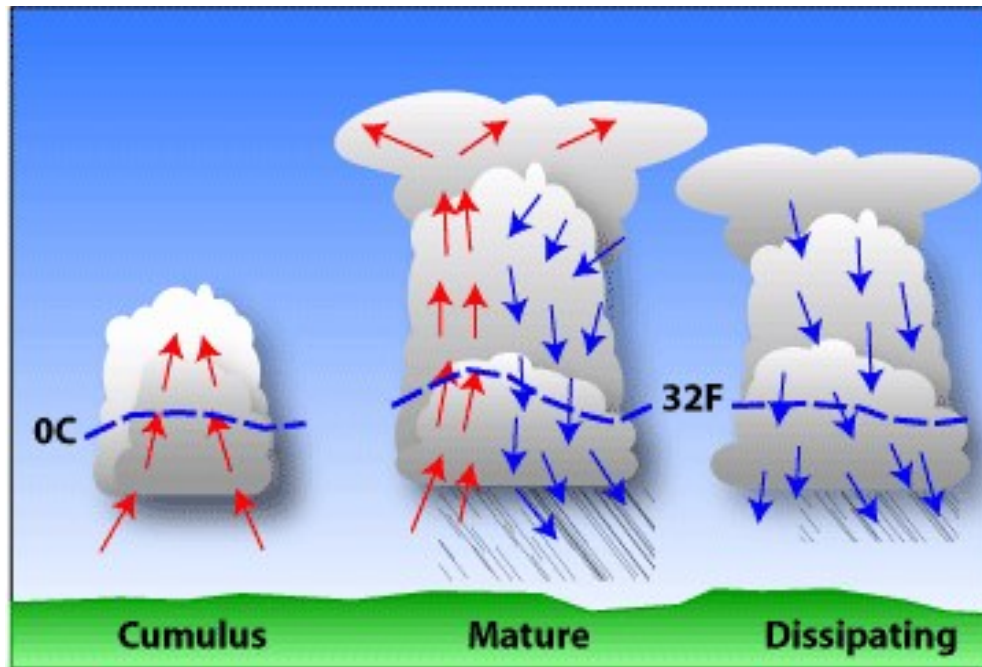
11.1. Introduction

Observations suggest that thunderstorms develop mainly in those clouds which contain large concentrations of liquid water and ice coexisting at temperatures well below -20°C . Thunderstorms are one or more convective cells in which electrical discharges are seen as lightning or heard as thunder. These cumulonimbus (Cb) clouds often give rise to squalls (a sudden increase of wind speed reaching 24kt or more and lasting a minute or more is termed a squall) and showers, at times with hail stones. The circulation in each cell is independent and 2 to 10km wide. These cells grow vertically above the freezing level reaching up to the tropopause and at times, even a kilometer or so higher. The cumulonimbus tops in the tropics can reach 18 to 20km amsl. Strong up and down currents are encountered in these convective cells. The downdrafts reach the ground as squalls of 30 to 40kt speed and sometimes even 60 to 80kt. Moderate to severe turbulence occurs in Cb clouds.

The essential conditions for the development of thunderstorms are sufficient moisture, atmospheric instability and a triggering mechanism for the uplift of moist air. Showers do not materialize when the moisture content is low. Under such circumstances, the downward squall scoops up dust or sand in arid and desert regions causing dust or sand storms.

11.2. Life cycle of a thunderstorm cell

A thunderstorm has a well-defined life cycle. The cloud is warmer than the surroundings in the initial cumulus stage. There is updraft throughout the cloud and it grows fast vertically. Ice crystals form at the top above the freezing level and an anvil takes shape. It now becomes a cumulonimbus cloud and reaches the mature stage. Down drafts commence and rain falls to the ground. Up and downdrafts coexist and both can be strong. Lightning, thunder, squalls, heavy showers and turbulence are experienced. In the third and final dissipating stage, the entire cloud becomes colder than the surroundings with downdrafts throughout. Rain ceases and the cloud breaks up. The lifetime of an individual cell is of the order of half to one hour.



11.3. Weather associated with a thunderstorm

a) Wind

The onset is sudden, sometimes violent and is shown by the rapid replacement of a wind initially flowing gently towards the developing Cb by a squally wind, with gusts perhaps exceeding 60kt, blowing outwards from the centre.

b) Temperature

The downdraft is cold, so its onset is marked by a sudden fall in temperature, changing by perhaps 10°C in as many minutes on extreme occasions.

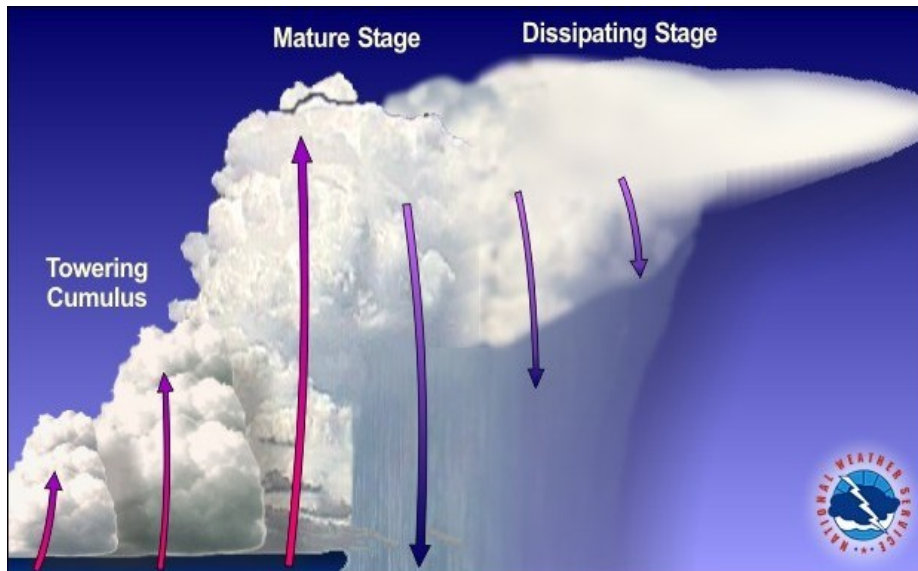
c) Precipitation

In its early stages, when the downdraft edges are still beneath the Cb cloud, the start of rain and squall are roughly coincidental, but later, when the cold air has spread well away from the precipitation area, the squall is not accompanied by precipitation.

d) Pressure

Since the downdraft is cold we would expect its greater density to produce a sudden pressure rise. This is often observed and may amount to several millibars, so that in thundery weather the barogram shows a very irregular trace.

Thunderstorms can be very destructive. Lightning strikes electrocute people, burn trees and damage buildings. Lightning is attracted to the tallest object. That is why lightning conductors are fixed on tall buildings. Thunderstorms are one of the most serious hazards to aircraft in flight. Aircraft can be tossed about in up and down currents and shattered, controls jammed and aerodynamic characteristics altered by ice accretion, hit by hail or struck by lightning. Hail stones damage crops and kill livestock. Thundersqualls uproot buildings and structures. Telecommunications are disrupted because of atmospheric and also due to the breaking up of telegraph and telephone poles and wires.



Unit 12 - Wind

12.1.Introduction

Wind is air in motion. It is produced by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly. Two factors are necessary to specify wind: speed and direction. The movement of wind is almost horizontal component. The vertical component is nearly always very small. The wind velocity is fully described by two quantities-its speed and its direction. The units of wind speed are the metre per second(m/s), mile per hour(mile/h) and the nautical mile per hour or knot(kn).

Wind direction is the direction from which the wind blows. It is well known that the wind velocity, both speed and direction, at any given place is continuously changing. Therefore, the velocity of any parcel of air as it moves over the earth's surface would also be continuously changing. The surface wind velocity is normally measured at a standard height of 10metres (33feet) above the ground.

Knowledge of winds at levels well above the ground is of the greatest importance to aircraft navigation; it is also important to the study of the development of depressions and anticyclones. Clearly, they cannot be measured by anemometers and wind vanes, except perhaps in the first 300 metres above the ground where the instruments then be mounted on a tower.

12.2.Pressure gradient force

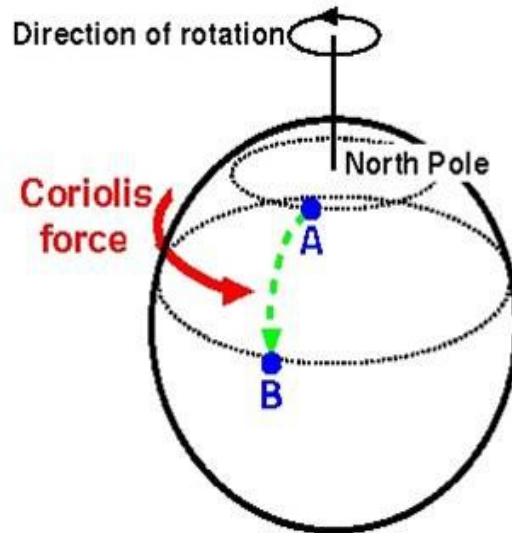
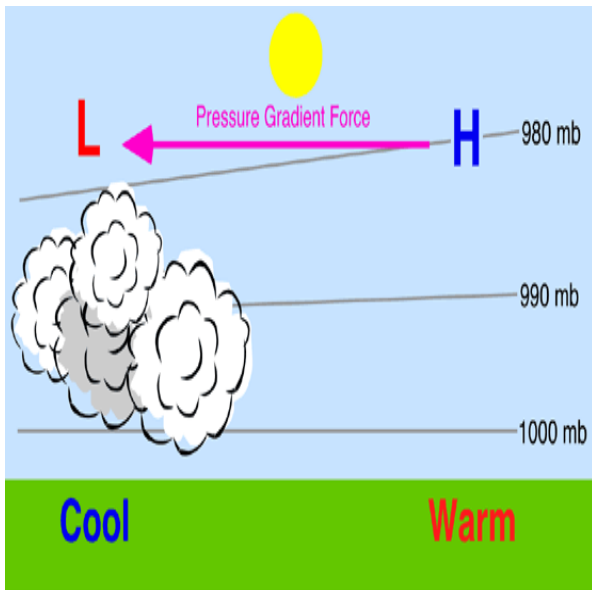
The force caused by the pressure variation is the pressure gradient force.

12.3.Isotach

A line connecting points of equal wind speed.

12.4.Coriolis force

Once air has been set in motion by the pressure gradient force, it undergoes an apparent deflection from its path, as seen by an observer on the earth. This apparent deflection is due to coriolis force that is a result of the earth's rotation. As air moves from high to low pressure in the northern hemisphere, it is deflected to the right by the coriolis force. In the southern hemisphere, air moving from high to low pressure is deflected to the left by the coriolis force. The amount of deflection the air makes is directly related to both the speed at which the air is moving and its latitude. Therefore, slowly blowing winds will be deflected a small amount, while stronger winds will be deflected more. Likewise, winds blowing closer to the poles will be deflected more than winds at the same speed closer to the equator.

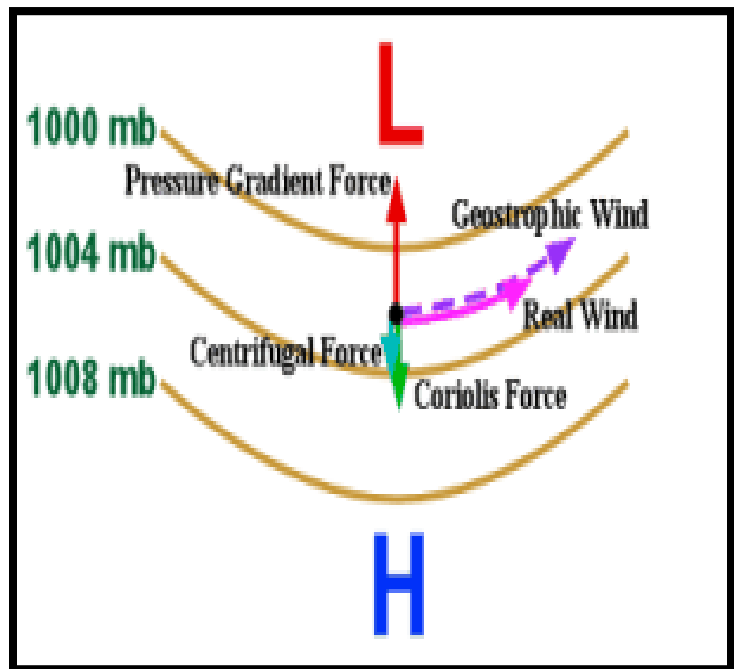
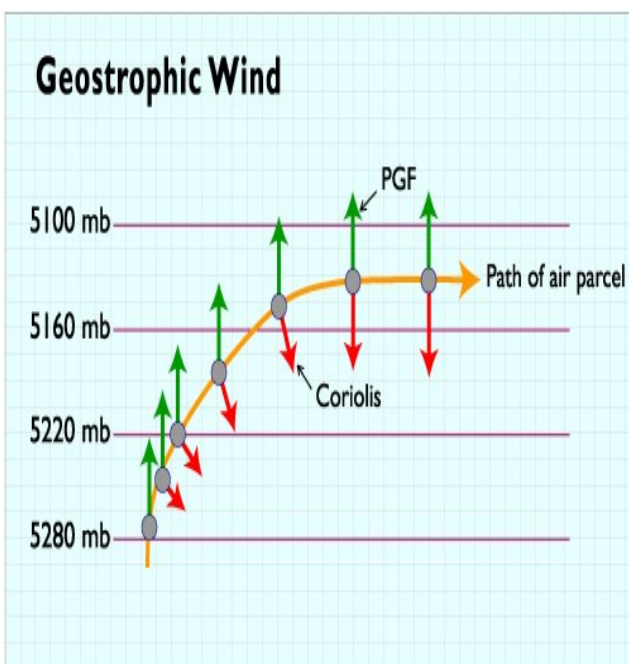


12.5. Geostrophic wind

It is a steady motion of the wind where pressure gradient force (PGF) is exactly balanced by the coriolis force.

12.6. Gradient wind

The force caused by the pressure variation is the pressure gradient force. The gradient wind is the balanced flow along a curved path under the influence of coriolis force, pressure gradient force and centrifugal force. For anticyclonic curvature, the coriolis force must be greater than the pressure gradient force, but for cyclonic curvature, the coriolis force is less than the pressure gradient force.



12.7.Surface wind flow

The diurnal variation of the surface wind is largely controlled by diurnal changes of stability of the turbulent layer near the ground. In stable air, as may be found during a clear night, mixing is inhibited and the frictional force is large; but when it is unstable, mixing is extensive and friction is reduced. Maximum speed therefore occurs in the early afternoon and the minimum in the early morning. Correspondingly, the direction is least backed in the afternoon and most in the early morning. The wind nearly always shows some gusts. These are caused by,

- Turbulence-when they are on a small scale, with extreme gust speeds approximately in excess by one-third above the mean speed.
- Convection-when they are very irregular in size and timing and there is a marked diurnal variation, as is to be expected, with the strongest gusts in the afternoon.

12.8.Squalls

A sudden increase of wind speed reaching 24kt or more and lasting a minute or more is termed a squall.

12.9.Gale

Persistent strong winds over 33kt, generally occurring with cyclones are called gales.

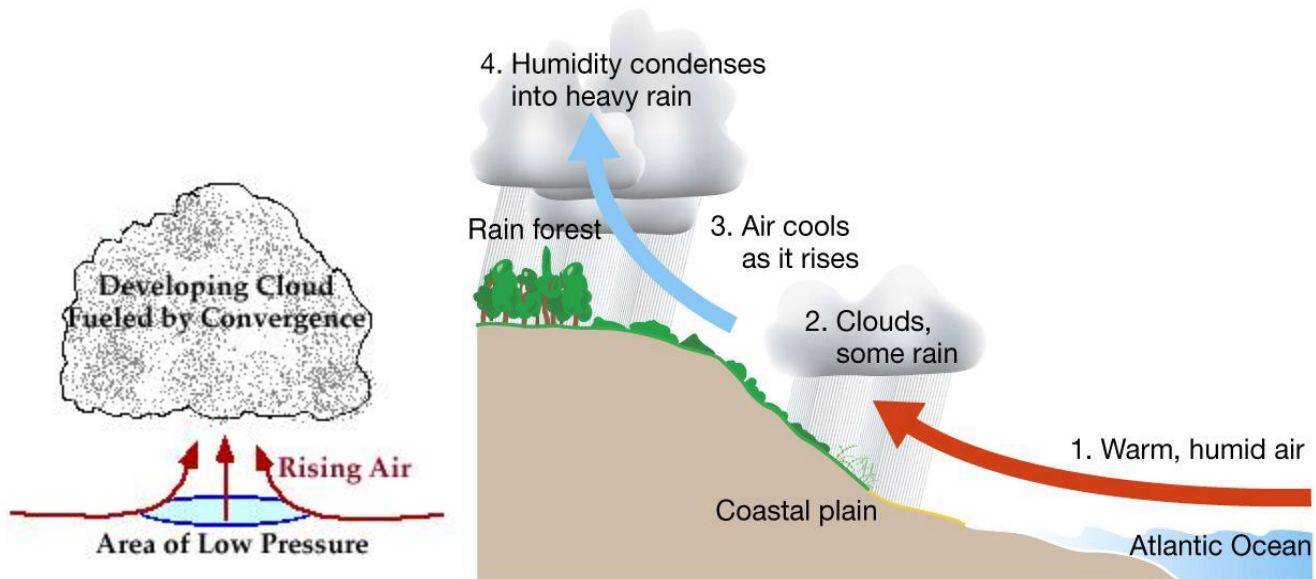
12.10.Hurricane wind

The violent winds associated with severe cyclonic storms exceeding 63kt are known as hurricane winds.

12.11.Vertical motion

Vertical motion is generally small in the atmosphere, of the order of a few centimeters per second, compared to the horizontal motion of several meters per second. In atmospheric systems such as cyclones, vertical motion occurs on a large area over a period of days. Convergence takes place when there is horizontal flow and accumulation of air over a region. Air is then transported upwards. This type of uplift of air occurs in troughs, lows depressions and cyclones, leading to cloud formation and weather development. In the ridges and highs there is downward motion or subsidence at the higher levels with net outflow of air or divergence at the lower levels and the surface. The subsided air is comparatively warm and dry giving rise to more or less settled weather.

When two air streams with marked temperature and density contrast meet, a discontinuity or front develops. The warmer and lighter air ascends along a sloping surface with the cooler air underneath. The ascent of air results in clouding and weather. When an air stream encounters a range of mountains more or less perpendicular to it, forced ascent of air takes place. Air cools during this orographic ascent and when moist, gives rise to clouding and rain or thundershowers.



Unit 13 - Planetary wind systems

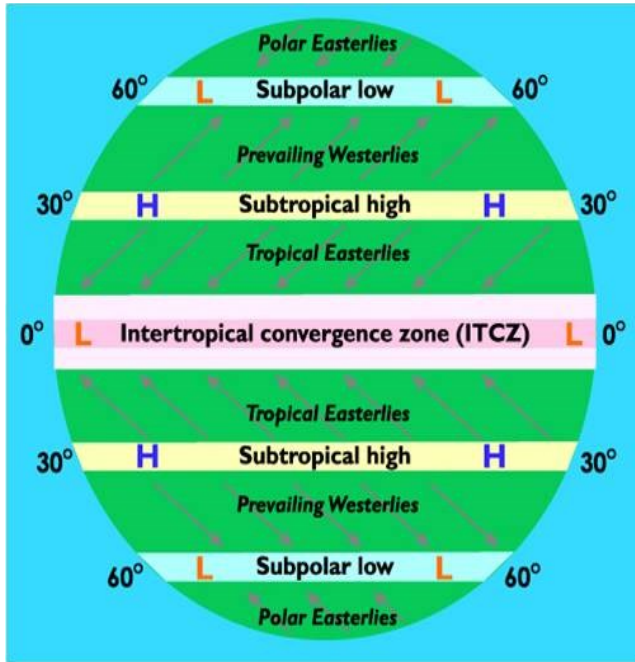
13.1. Introduction

Heating of the earth by the sun is not uniform; the equatorial regions receive much more heat than the poles. The belt of maximum insolation or the thermal equator moves north-south corresponding to the apparent movement of the sun. Heat is transported from the equator to the poles to achieve heat balance. This is done mainly through atmospheric circulation and to some extent through ocean currents. In the equatorial regions, warm air rises up and moves equatorward. Air streams and ocean waters moving north or south undergo deflection due to earth's rotation. The flow turns left or right depending on the direction of motion, rendering the stream westerly or easterly as the case may be. This is termed coriolis force and the magnitude of the coriolis deflection is governed by the latitude. The heat transport to establish global heat balance results in a definite pattern of pressure and winds.

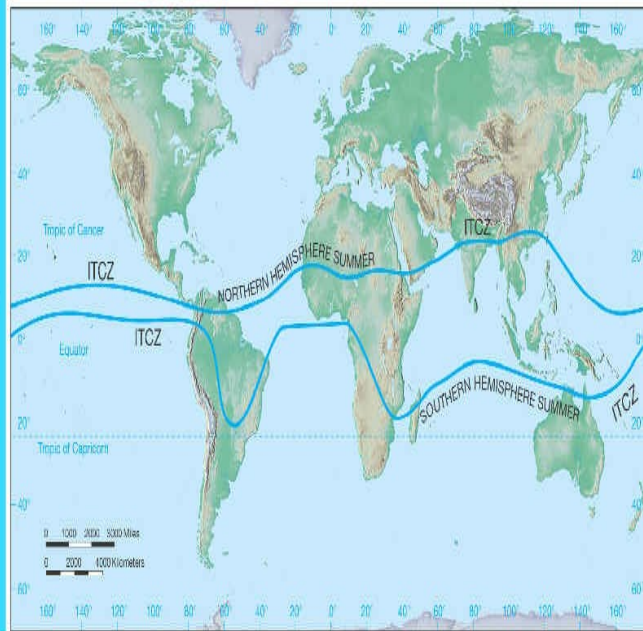
13.2. Pressure and Wind Systems

A low pressure belt covers the equatorial region, roughly between latitudes 10° north and south. This equatorial low pressure area, also known as doldrums, is characterized by weak winds and sudden storms. The doldrums is an area of calm weather. The trade winds coming from the south and the north meet near the equator. These converging trade winds produce general upward winds as they are heated so there are no steady surface winds. Air from both the hemispheres converges in this low, giving rise to the inter-tropical convergence zone (ITCZ). Warm moist air which accumulates in this zone rises up resulting in convective clouds and thundersqualls at many places along the ITCZ. The rising air moves towards the poles north and south. Part of this air sinks around latitude 30° N and S forming subtropical highs (STH) in the two hemispheres.

Air diverges at the surface from the STHs. The diverging air moves equatorward, undergoes deflection due to the earth's rotation and becomes northeast trade winds and southeast trade winds. These winds were of immense help to the sail ships of olden days to facilitate trade and that is how the name trade winds came. Part of the diverging air from the STHs moves polewards. After deflection due to coriolis force they become middle latitude westerlies. They become quite strong in the higher latitudes and are sometimes referred to as roaring forties. At the upper levels, air reaching the poles subsides and gives rise to the polar highs (PH) at the surface. Air flows and becomes polar easterlies. Middle latitude westerlies and polar easterlies, moving side by side, interact resulting in a semi permanent polar front (PF). A number of lows form on this front and move from west to east causing unsettled weather.



DOLDRUMS



ITCZ

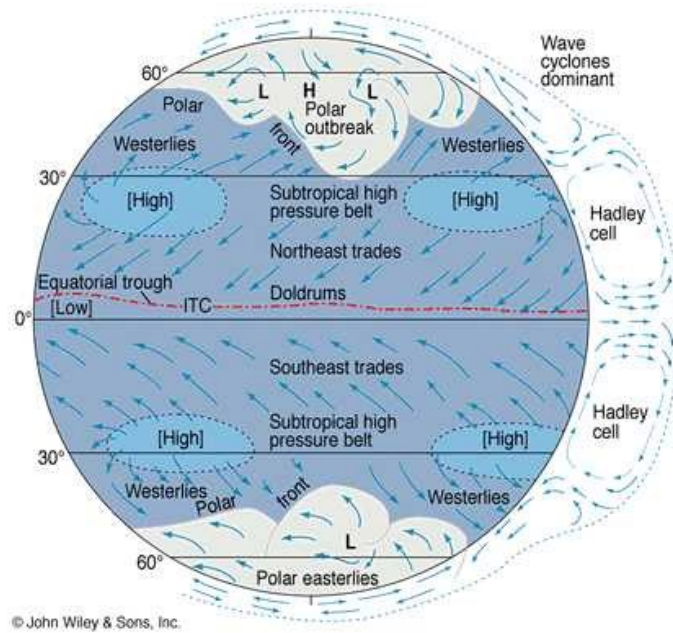
13.3.General Circulation

The long term averaged picture shows three major wind systems in the two hemispheres at the surface,

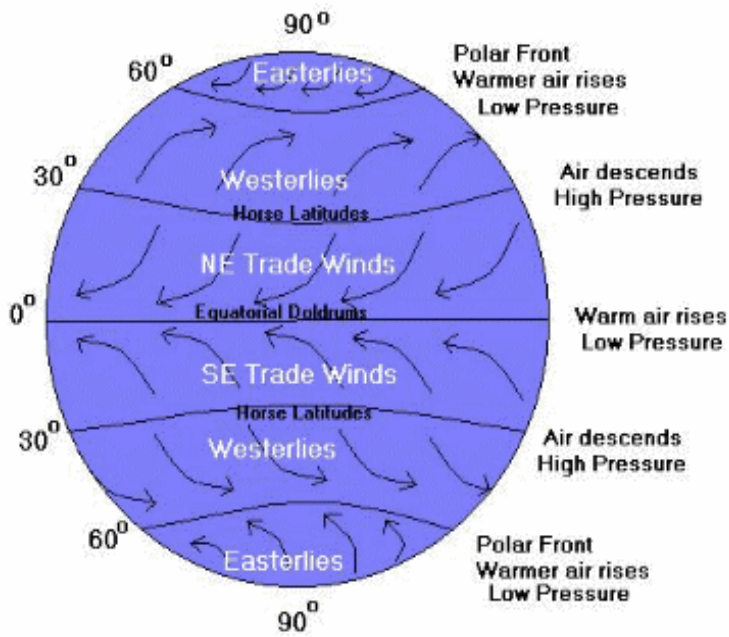
- Northeast/southeast trade winds in the tropics
- Westerlies in the middle latitudes
- Easterlies in the polar regions.

The broad latitudinal or zonal currents show wave motion and are fairly deep, extending at times up to the tropopause. These are long waves which span thousands of kilometers and have a life span of one or two weeks. There are small circulations, hundreds to thousand kilometers in extent with a life cycle of days, embedded within the long waves. These are the synoptic scale systems seen as lows, cyclones, highs, etc and constitute the actual weather-producing atmospheric systems. Within these are still smaller meso scale systems such as thunderstorms and sea breeze circulations extending over tens of kilometers and lasting some hours. Lower down the scale are still smaller micro scale circulations spanning a kilometer and down to a few centimeters, lasting several minutes. Examples are circulations and processes close to the ground such as eddies, diffusion and turbulence which modify the ecosystem and are of importance to living organisms.

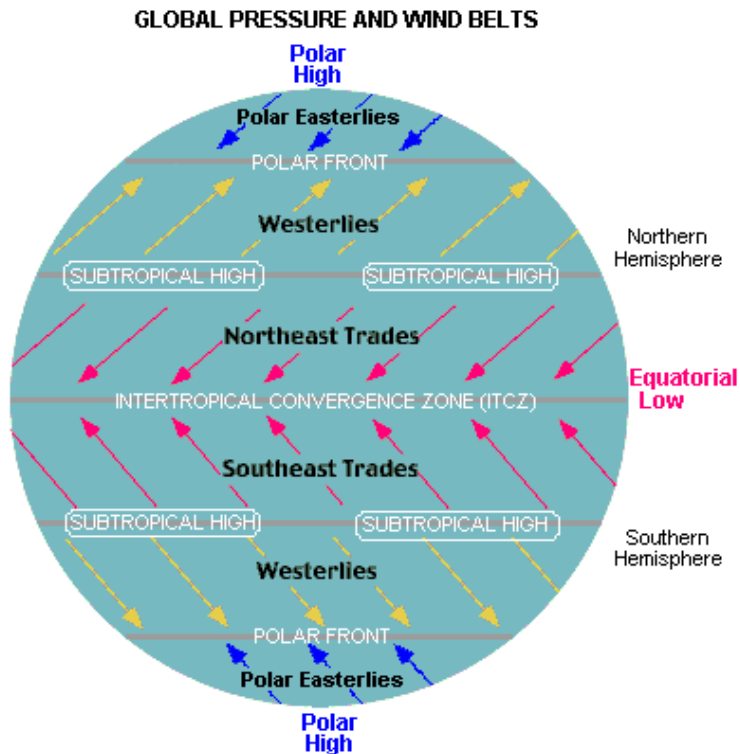
The above hierarchy of circulations, each with its own typical dimension and life cycle, constitutes the general circulation. The synoptic scale circulations are mainly responsible for the latitudinal or meridional transfer of heat from equator to poles. The zonal pressure and wind belts oscillate north and south in consonance with the seasonal movement of the sun. Simultaneously the ITCZ and PF also shift north and south.



SUB TROPICAL HIGHS or SEMI PERMANENT POLAR FRONTS



TRADE WINDS



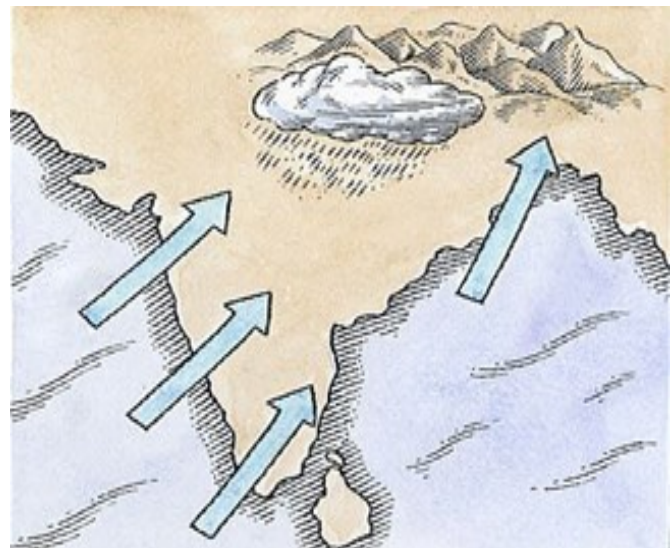
WESTERLIES AND POLAR HIGHS

13.4. Southwest and Northeast monsoon

13.4.1. Southwest Monsoon

During summer, a high pressure area lies over the Indian Ocean. Meanwhile an intense low pressure area forms over the northwest parts of the Indian subcontinent and this gradually extends as a trough across the Indo-Gangetic plains to the head of the Bay of Bengal. The air moves from high pressure area to low pressure area i.e from Indian ocean to northwest parts of Indian subcontinent, cross the equator and deflected to the right due to the earth's rotation and advance further north as a south-westerly stream. The southwesterly current reaches Kerala and the Bengal coasts by the beginning of June. This is the summer southwest monsoon. The current flows further east as the southeast monsoon of China and Japan. The entire system constitutes the Asiatic monsoon. The monsoon current is 1 to 3km deep.

The first place of onset of the southwest monsoon is south Kerala and the date of this onset is watched with great interest all over the country. Life and economy of the entire country is dependent on the behaviour of this monsoon. The actual date of onset shows wide variations from year to year. The normal date of onset over south Kerala is 1st June. The southwest monsoon current advances northwards in two branches-the Arabian Sea branch and the Bay of Bengal branch. The Himalayan range restricts its spread northward.



13.4.2. Northeast Monsoon

An intense high pressure area builds up over Central Asia by December. Meanwhile a low pressure area lies over the south Indian Ocean. The air flows from the Central Asian high towards the Indian Ocean low. Starting as the northwest monsoon of China, this air flows southwards as the northeast monsoon of South Asia. Crossing the equator, the current is deflected due to the Coriolis force and reaches Australia as the northwest monsoon there. The northeast monsoon which is the winter component of the Asiatic monsoon prevails over India from December to February.



Unit 14 - Tropical Cyclones

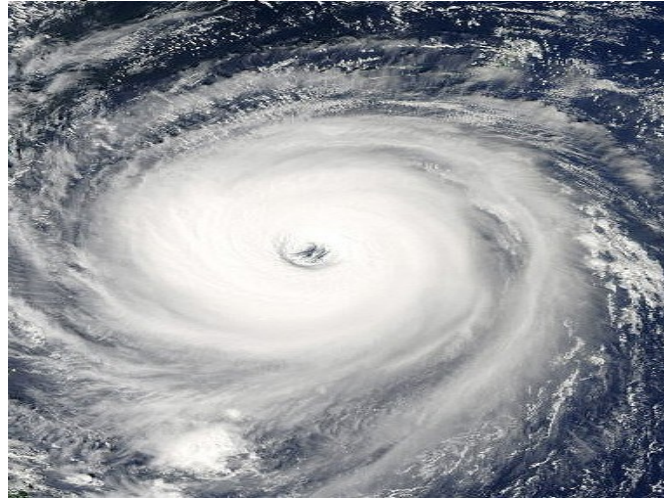
14.1. Introduction

A tropical cyclone is a relatively small, intensely developed low pressure cell that usually occurs over warm oceans. Its diameter can range between 200 and 2000km. It is characterized by a warm centre, very steep pressure gradients and strong cyclonic (clockwise in the southern hemisphere) winds near the earth's surface. Tropical cyclones with a maximum wind speed of less than 60km/h are called tropical depressions; when the maximum wind speed ranges between 60 and 110km/h, they are called tropical cyclones. In the North Atlantic and eastern North Pacific regions it is called 'hurricane', in the western North Pacific 'typhoons' and in Australia 'Willy-Willy's'.

Factors influencing formation and development of tropical cyclones

- Sufficiently large ocean areas with surface water temperature at least 26.5 oC or more (waters of this temperature cause to overlying atmosphere to be unstable (low pressure area) enough to sustain convection and thunderstorms).
- Another factor is rapid cooling with height (i.e, atmosphere must be conducive to convection), which allows the release of the heat of condensation (latent heat) that powers a tropical cyclone.
- High humidity is needed, especially in the lower- to – mid troposphere (when there is more moisture in the atmosphere, conditions are more favorable for disturbance (low pressure area) to develop).
- Low amount of wind shear are needed, as high shear is disruptive to the storm's circulation. (Wind shear is defined as amount of change in the wind's direction or speed with increasing altitude).

- Tropical cyclones generally need to form more than 555 km away from the equator (this usually happens between 5° and 20° north and south latitude). This allows the Coriolis effect to deflect winds blowing towards the low pressure center and creating a circulation. (Coriolis force causes the cyclonic systems to turn towards poles. Coriolis effect also initiates cyclonic rotation. But the driving force that brings this rotation to high speed is the heat of condensation).
- A tropical cyclone needs a pre-existing system of disturbed weather.



14.2. Factors influencing formation and development of tropical cyclones

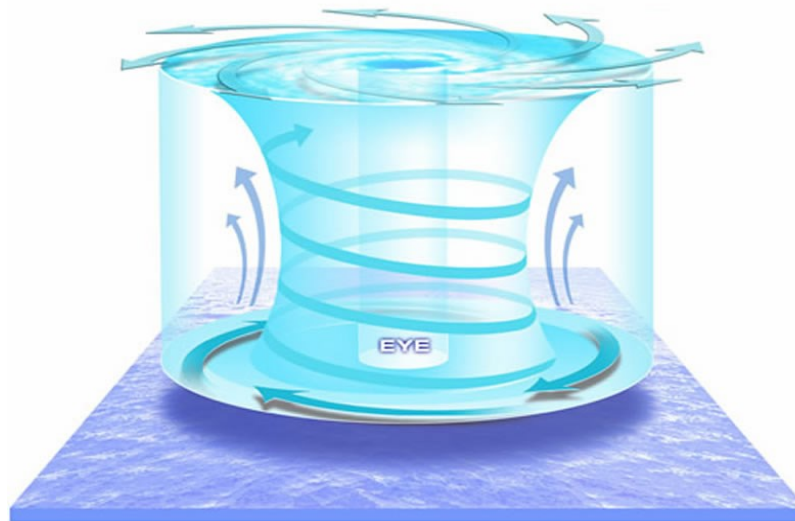
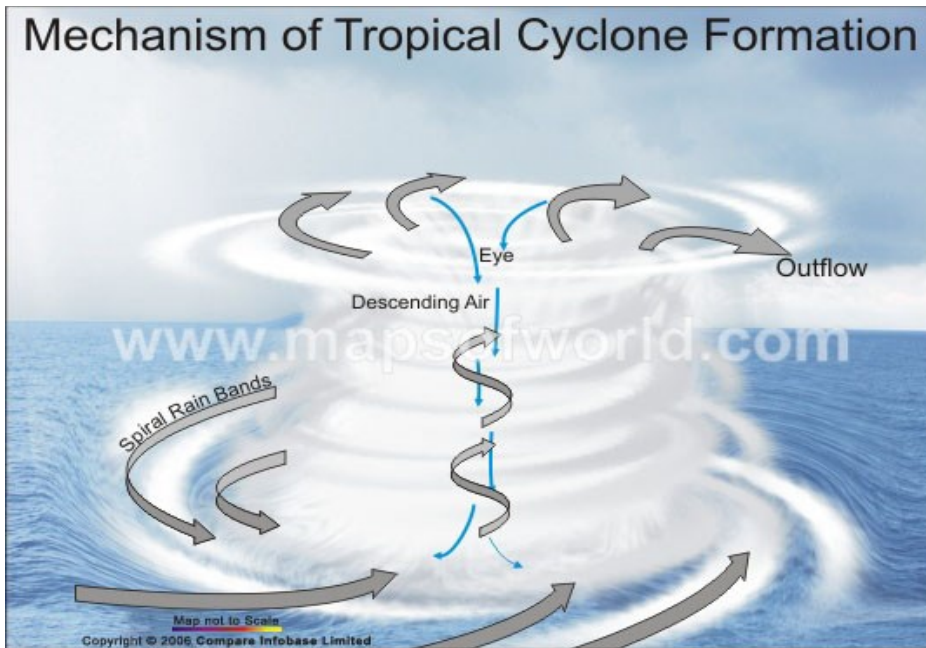
- Sufficiently large ocean areas with surface water temperature at least 26.5 °C or more (waters of this temperature cause the overlying atmosphere to be unstable (low pressure area) enough to sustain convection and thunderstorms).
- Another factor is rapid cooling with height (i.e., atmosphere must be conducive to convection), which allows the release of the heat of condensation (latent heat) that powers a tropical cyclone.
- High humidity is needed, especially in the lower- to – mid troposphere (when there is more moisture in the atmosphere, conditions are more favorable for disturbance (low pressure area) to develop).
- Low amount of wind shear are needed, as high shear is disruptive to the storm's circulation. (Wind shear is defined as amount of change in the wind's direction or speed with increasing altitude).
- Tropical cyclones generally need to form more than 555 km away from the equator (this usually happens between 5° and 20° north and south latitude). This allows the Coriolis effect to deflect winds blowing towards the low pressure center and creating a circulation. (Coriolis force causes the cyclonic systems to turn towards poles. Coriolis effect also initiates cyclonic rotation. But the driving force that brings this rotation to high speed is the heat of condensation).
- A tropical cyclone needs a pre-existing system of disturbed weather.

14.3. Formation

The process by which a disturbance in the pressure pattern forms and subsequently strengthens into a tropical cyclone depends on at least three conditions:

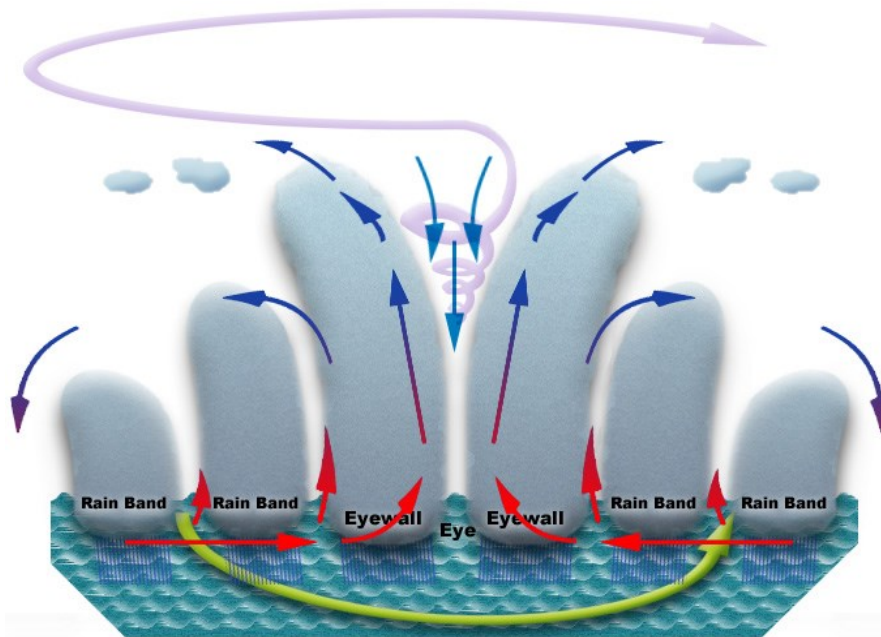
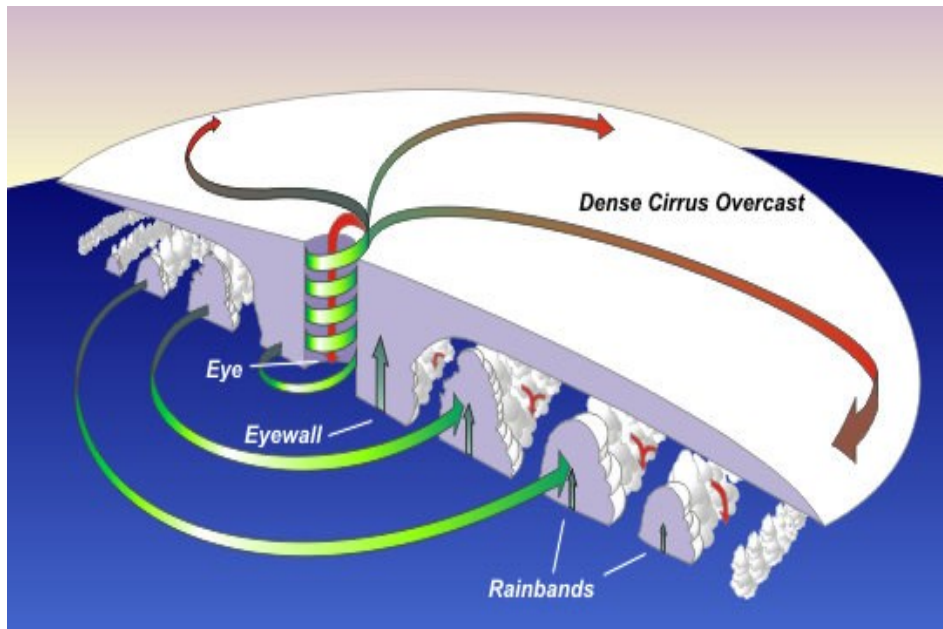
- Developing tropical cyclones gather heat and energy through contact with warm ocean waters. This usually happens between 5° and 20° North and South.
- The addition of moisture by evaporation of sea water from the sea surface powers them like giant heat engines, i.e. it draws its energy from, the evaporation of sea water under the storm.
- A wind pattern near the ocean surface that spirals air inward is also necessary.

The net result of these processes is a towering column of spiraling air with an intense low pressure in its centre. Bands of thunderstorm form, allowing the air to warm further and rise higher into the atmosphere.



14.4. Structure of the storm centre

The centre or eye of a tropical cyclone is relatively calm and warm. The eye itself is clear, mainly because of gently subsiding air within it. The eye is extremely warm near the top of the storm circulation reaching temperatures as much as 10°C greater than that of the undisturbed environment at the same altitude. Near the sea surface the air has virtually the same temperature through the storm. A spectacular wall of cloud (mainly cumulonimbus) rings the edge of the eye from sea level to heights of over 15km. This ring of cloud called the eyewall, may be tens of kilometers thick, while a dense cirrus and altostratus overcast may extend outward several hundred kilometers from the eyewall. The most violent activity takes place in the eyewall. At the top of the eyewall, most of the air is propelled outward, increasing the air's upward motion.



14.5. Life time

Once a mature tropical cyclone forms, it can last while the atmospheric and oceanic conditions remain favorable- duration of one week is typical. Tropical cyclones decay when they move over land (called landfall) or cold ocean water- more rapidly over land, particularly if the terrain is rough.

14.6. Hurricane warning

A hurricane warning is issued when a hurricane with sustained winds of 74mph (118km/h) or higher is expected in a specified coastal area in 24 hours or less. Maritime flags indicate this with two square red flags with a black square in the middle of each. A hurricane warning can remain in effect when dangerously high water and exceptionally high waves continue, even though the winds may have subsided below hurricane intensity. When the intensity or track of a forecast cyclone is uncertain, a Tropical Storm Warning and a Hurricane Watch are often in effect on parts of the coast. Maritime flags indicate this with two square red flags with a black square in the middle on only one of them.

14.7. Effects of tropical cyclone

The main destructive effects of tropical cyclones include heavy rain, strong wind, large storm surges, landfall and tornadoes. How devastating a tropical cyclone depends mainly on its intensity, how big it is and its location. Tropical cyclones act to remove forest canopy as well as change the landscape near coastal areas, by moving and reshaping sand dunes and causing extensive erosion along the coast. Even well inland, heavy rainfall can lead to mudslides and landslides in mountainous areas. The cyclone's passage is marked with destruction: plantations are leveled up, big trees are uprooted, settlements are utterly destroyed and the loss of life is heavy. After the cyclone has passed, devastation continues. Standing water can cause the spread of disease and transportation or communications infrastructure may have been destroyed, hampering clean-up and rescue efforts. Nearly two million people have died globally due to tropical cyclones. Despite their devastating effects, tropical cyclones are also beneficial by potentially bringing rain to dry areas and moving heat from the tropics to poleward. Strong winds can damage or destroy vehicles, buildings, bridges and other outside objects. Tropical cyclones often destroy key bridges, overpasses and roads, complicating efforts to transport food, clean water and medicine to the areas that need it.

In the Northern hemisphere, cyclones are common from August to October; south of the equator, the period of cyclonic activity is in February and March. The areas more affected by cyclones are the Caribbean and South China seas. The Indian Ocean is often visited by cyclones during the period of the retreating monsoon. Bangladesh and the eastern coast of India mainly in Andhra and Orissa suffer heavy damage every year.

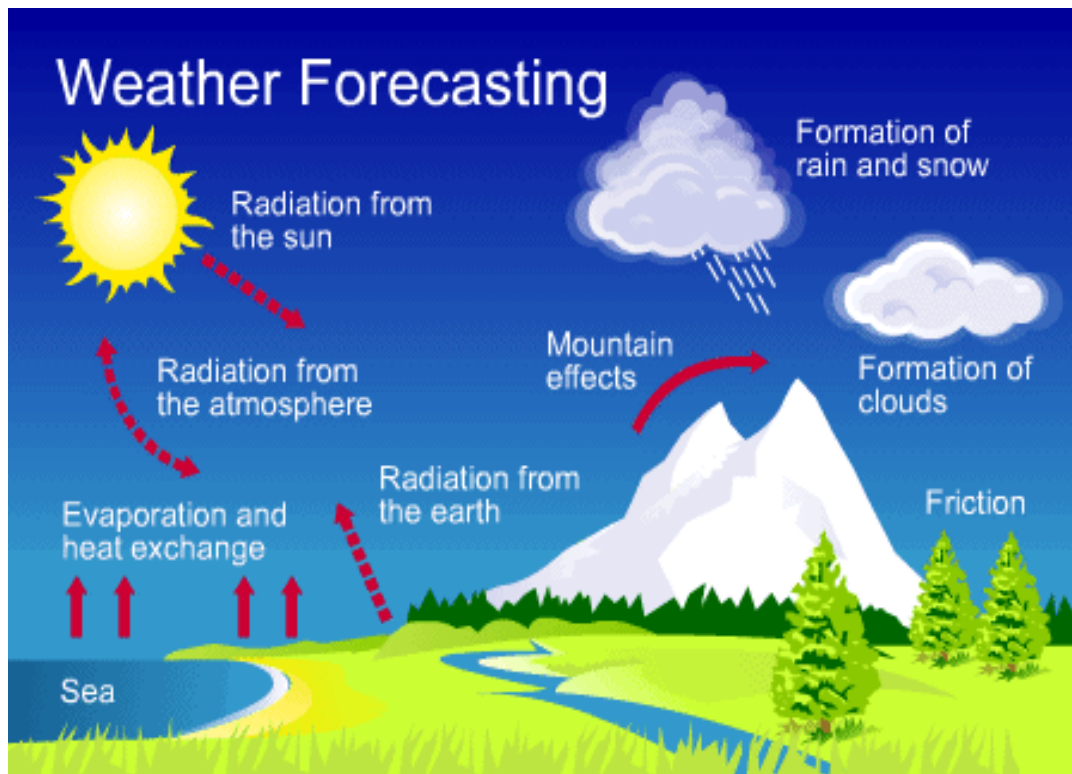
Category	Strongest Gust (km/h)	Typical Effects (indicative only)
1 (Tropical Cyclone)	Less than 125 (Gales)	Negligible house damage. Damage to some crops, trees and caravans. Craft may drag moorings.
2 (Tropical Cyclone)	125-169 (Destructive winds)	Minor house damage. Significant damage to signs, trees and caravans. Heavy damage to some crops. Risk of power failure. Small craft may break moorings.
3 (Severe Tropical Cyclone eg. <i>Roma</i>)	170-224 (Very destructive winds)	Some roof and structural damage. Some caravans destroyed. Power failure likely.
4 (Severe Tropical Cyclone eg. <i>Tracy</i>)	225-279 (Very destructive winds)	Significant roofing loss and structural damage. Many caravans destroyed and blown away. Dangerous airborne debris. Widespread power failures.
5 (Severe Tropical Cyclone eg. <i>Vance</i>)	More than 280 (Very destructive winds)	Extremely dangerous with widespread destruction.

Unit 15 - Weather Forecasting

15.1. Weather Forecasting

Weather affects nearly every one every day. Weather forecasts are issued to save lives, reduce property damage, reduce crop damage, to let the general public know what to expect. It is essential for especially for

fishermen and farmers. Weather forecasting of what the weather will be like in an hour, tomorrow, next week or during a season. Surface observations of temperature, humidity, pressure, wind, visibility, clouds etc. are obtained by installing properly exposed instruments. Observations at various levels in the atmosphere are made by optical or radio/radar tracking of hydrogen-filled balloons carrying appropriate sensors. Radio sounding (radiosonde) and radiowind (RAWIN) observations provide measurements of pressure, temperature, humidity and winds at various levels such as also of atmospheric constituents such as ozone and carbon dioxide.



15.2. Synoptic Observations

Simultaneous observations of the atmosphere at the surface and in the upper air are made at a large number of locations several times a day at specified hours all over the world. These observations are known as synoptic observations, are made by observers who scan the skies, read the instruments and faithfully record the observations. Surface observations are made every three hours and upper air observations, every six hours. Over and above these, various types of routine and special weather observations are made at different times to meet the specific requirements of various interests such as aviation, shipping, agriculture, hydrology etc. The data are fed into the sophisticated computers to interpret the weather conditions.

15.3. Organization

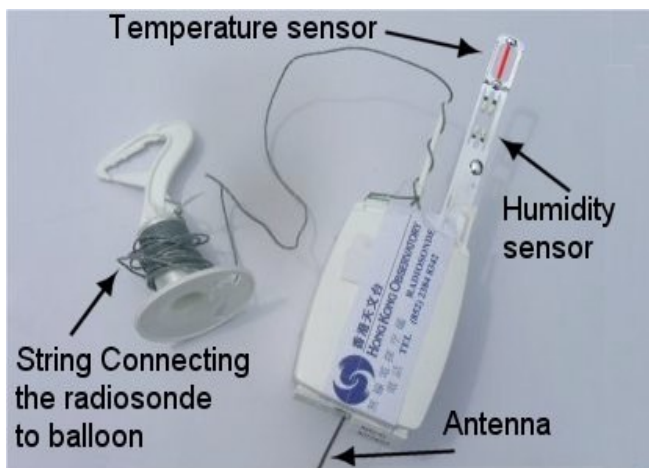
The meteorological observations of all countries must be strictly comparable, so that they can be used and analysed together. For this, standardization of instruments, observational procedures and data processing have to be ensured by international cooperation and agreement. This is made possible by the World Meteorological Organization (WMO) which is a specialized agency of the United Nations Organization. In India the Meteorological Department (IMD) provides climatological, weather forecasting and warning services for all interests, as also training and research facilities in respect of atmospheric sciences. IMD has forecasting offices at its 6 Regional Meteorological Centers and Metrological Centers at the State capitals. In addition it has two major forecasting centers at New Delhi and Pune. IMD maintains a countywide network of observational stations from where weather reports are received at Pune through the Regional Telecommunication Hub based at New Delhi. With the help of these reports and other observations from the globe, the Pune office issues the All India Daily Weather Bulletin and Weather Forecasts for the entire country.

15.4.Synoptic Charts

A large volume of data is received at a weather office. These data have to be presented in an easily assimilable form. For this, the observations are plotted on a map and this map shows at a glance the weather conditions over a large geographical area at a specified time. Such a map is known as a synoptic chart. Charts are plotted for each synoptic hour for the surface and various standard levels in the atmosphere. Elements such as pressure, temperature, etc are plotted as symbols at fixed positions around a circle representing the observing station. Wind is plotted as an arrow coming to the station from the direction it blows. The synoptic chart is carefully analysed and the pattern of distribution of various parameters brought out. Different atmospheric systems such as lows, highs, depressions and cyclones are clearly delineated on the analysed chart.

15.5.Forecasts

Weather forecasts provide valuable guidance for forward planning, economic benefit as well as safety of men and materials. A forecast is a statement of weather conditions expected over a place or an area during a specified period of time in the future. Short range forecasts are valid upto forty-eight hours and give details of various weather elements and their variations expected during that period. Examples are the usual forecasts issued to the media and route forecasts issued to aircraft. Medium range forecasts are valid from two to seven days and are often tagged on to short range forecasts as further look out. Long range forecasts pertain to weeks, months or a season ahead and indicate the expected mean conditions of certain selected elements such as rainfall or temperature. The seasonal monsoon forecast issued by the India Meteorological Department before the southwest monsoon commences is a typical example.



FORECASTING INSTRUMENT

15.6.Predictability

Future weather is governed by the birth, growth and decay of various atmospheric systems, as also by their interaction and transformation in space and time. It is not always possible to identify and track all the individual systems for the entire course of their life cycles. This introduces an inherent limitation in the predictability of weather forecasts as the period of validity increases. Thus shorter the range, the higher is the degree of accuracy of forecasts.

15.7.Uses of forecasts

Accurate weather data, forecasts and warnings disseminated through the newspapers and over the radio and enable millions of people to make decisions for effective resource management and safety of life and property. The period of validity and accuracy of weather forecasting have improved with advent of sophisticated observing systems, remote sensing, real time telecommunications, atmospheric modeling and superfast computing capabilities.

Unit 16 - Geography

16.1. Introduction to Geography

Till a few decades back, the study of Geography implied only a catalogue of names and a student of Geography felt quite satisfied if he could commit to memory such facts as the names of continents and oceans, the depths of seas and bays, the length of rivers and the height of mountains. Geography was recognized as a description of the world and its inhabitants. But the Geography of today is not merely a description or interpretation of the regions of the world. It is an enquiry, a study of the causes, an attempt to find out the why and how of all those facts and factors that go to influence the life of man on this planet.

Modern Geography studies earth as the home of man. It attempts to find out the relationship between man and his environment. It depicts the geographical conditions under which man lives and works. In other words, it studies man's adaptation to the environment in which he lives and works.

16.2. Definition of Geography

Characteristic definitions of Geography.

- Geography is the study of the earth as the home of people(Yi-Fu Tuan, 1991)
- Geography is the study of variations in phenomena from place to place(Holt-Jensen, 1980)

16.3. Physical Geography

Physical Geography is the study of physical features of the earth. This includes study of landforms, drainage forms, water bodies and shorelines, minerals, soils, climate, natural vegetation and life of animals.

16.4. Human Geography

Human Geography studies the man-made features of the earth. This includes cultural elements such as the density and pattern of population, the utilization of land, the types of and materials for the buildings and the means of transportation and communication.

Human Geography is further divided into

- Passive or static human geography: It deals with the action of nature upon man.
- Active or dynamic human geography: It deals with the reaction or action of man upon nature.

16.5. Factors which go to influence, determine and condition the distribution and activities of man

The physical features, climate, vegetation and animal life all go to determine the life and activities of man in the different areas of the world. Of these main factors, the physical features and the climate are the most important and they exert the determining influence on the occupation and settlement of man in the different areas of the world. The type of vegetation in any region is controlled to a very great extent by the configuration of land and the climatic condition.

16.5.1. Physical features

These include the configuration of land, its various formations, the drainage systems, mineral content of the rocks and the soils. Man's habitats, occupations, his mode of living and his capacity for work are primarily and directly influenced by the physical features of a particular area.

16.5.2. Climate

Climate is an extremely powerful factor so far as the occupancy of an area by man is concerned. The working

capacity of man and his capacity to produce economic wealth is also determined by factors like temperature, rainfall and winds which are included in the climate of an area.

16.5.3. Vegetation

The vegetation depends upon both the physical features and the climate. The growth of plants and trees is determined by the texture of soil, the range of temperature and the amount of moisture supply.

16.5.4. Animal Life

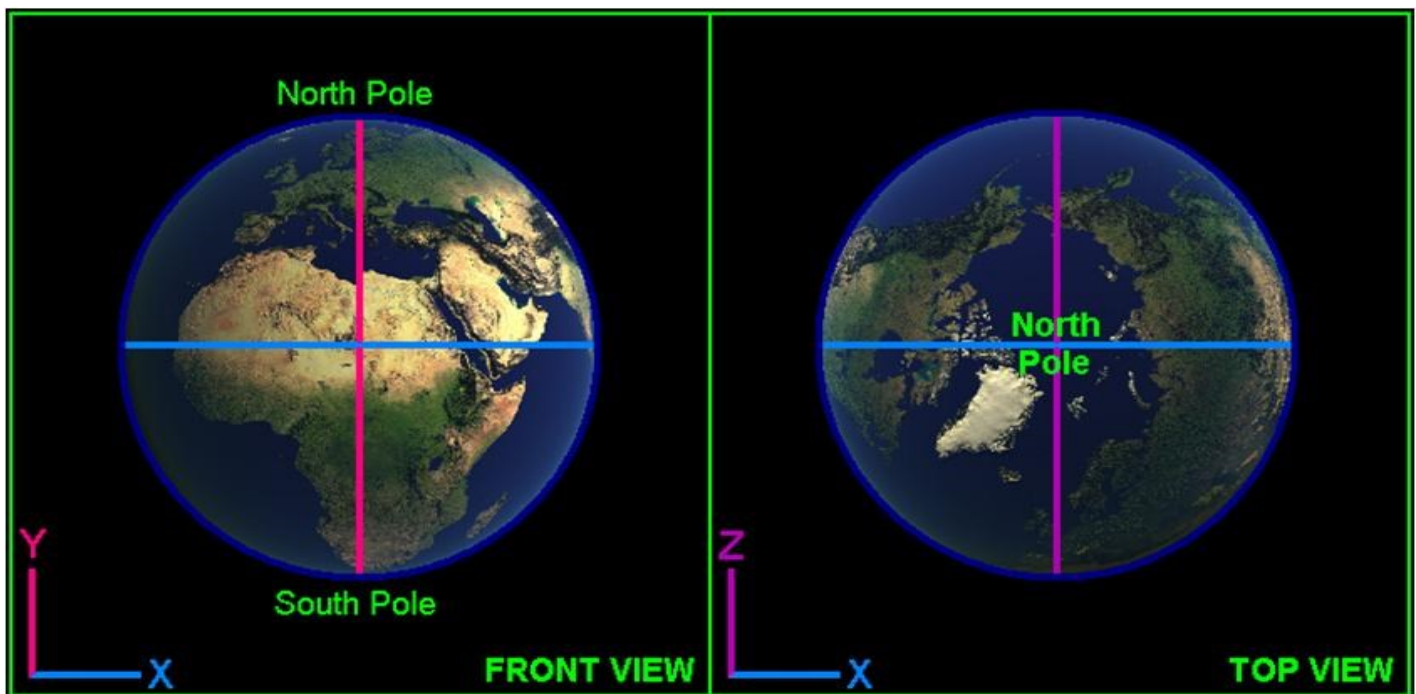
The animal life is determined directly and apparently by the vegetation cover but the primary influence is that of climate and physical features.

16.6. Size and shape of the earth

There are several evidences for spherical shape of the earth

- The edge of shadow of the earth on the moon during eclipse.
- Possibility of circum-navigation.
- The horizon appearing as a clear marked circle.

From the satellite picture it is proved beyond doubt that the earth is in oblate spheroid or ellipsoid shape. It has a shorter polar radius (3950 miles) and a longer equatorial radius (3963 miles). The earth sphere has a mean or average radius of 3959 miles. The earth is slightly bulged at equator and flattened at poles. The diameter at equator is 7927 miles and diameter at poles 7000 miles. The polar circumference is 24,818 miles and equatorial circumference is 24,860 miles.



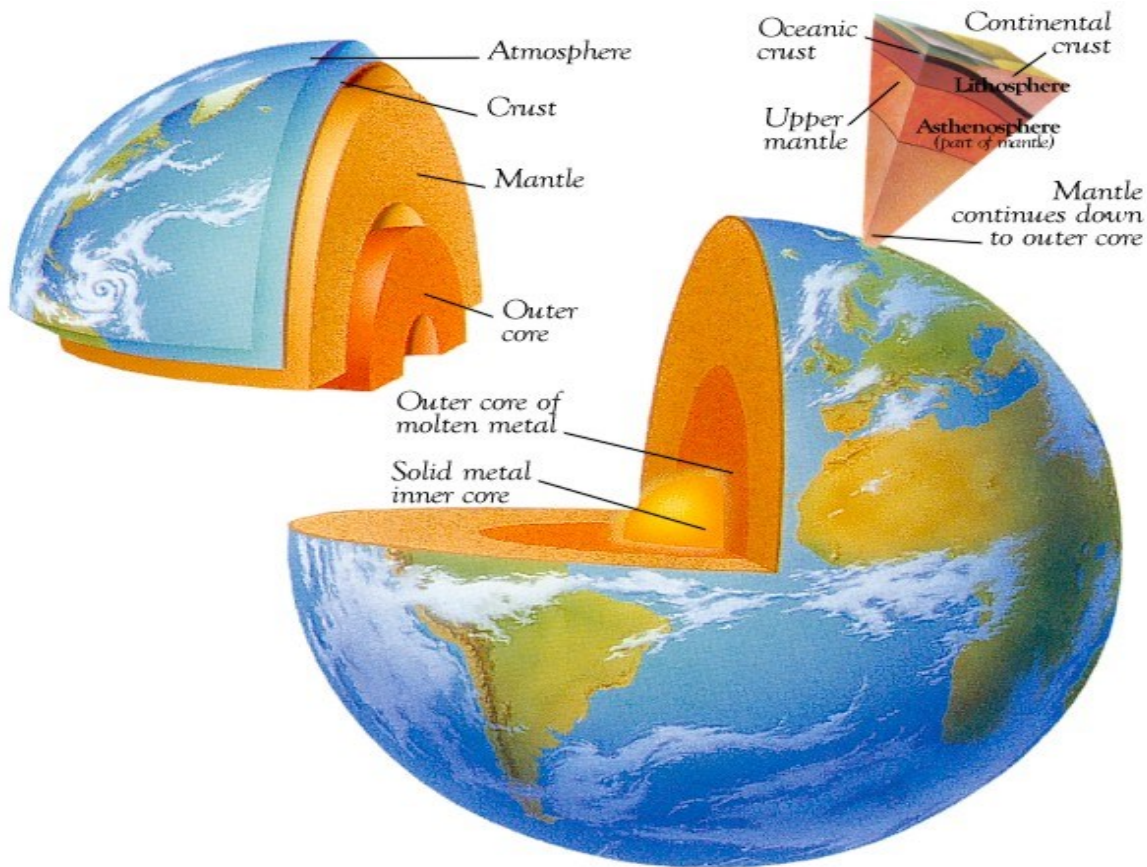
16.7. Structure of the earth

At the earth's center is an inner core, its radius 1070km. It is solid and very dense because it exists under extremely high pressure; it is also magnetized, rich in iron and nickel and very hot (5000° C). The inner core is surrounded by a transition zone about 700km thick which is in turn surrounded by a 1700km thick layer of liquid material, together they form outer core. The liquid material of the outer core is similar in composition to the inner core but cooler (4000° C). The next largest mass of material of any of the layers (about 70% of the earth's volume). This layer is 2835km thick; it is less dense than the core, still cooler (1500-3000° C) and composed of magnesium-iron silicates. The outer part of the mantle is thought to be rigid, while the inner

region is deformable and flows slowly over the deeper mantle. The earth's outermost layer is the cold, rigid; thin (10-65km), that is the crust. The crust divided into SIAL and SIMA layers. The SIAL is the upper layer contains mainly silicon and aluminium elements. SIMA is the lower layer dominates silicon and magnesium elements. SIMA layer forms the bottom of the ocean and is known as pyrosphere.

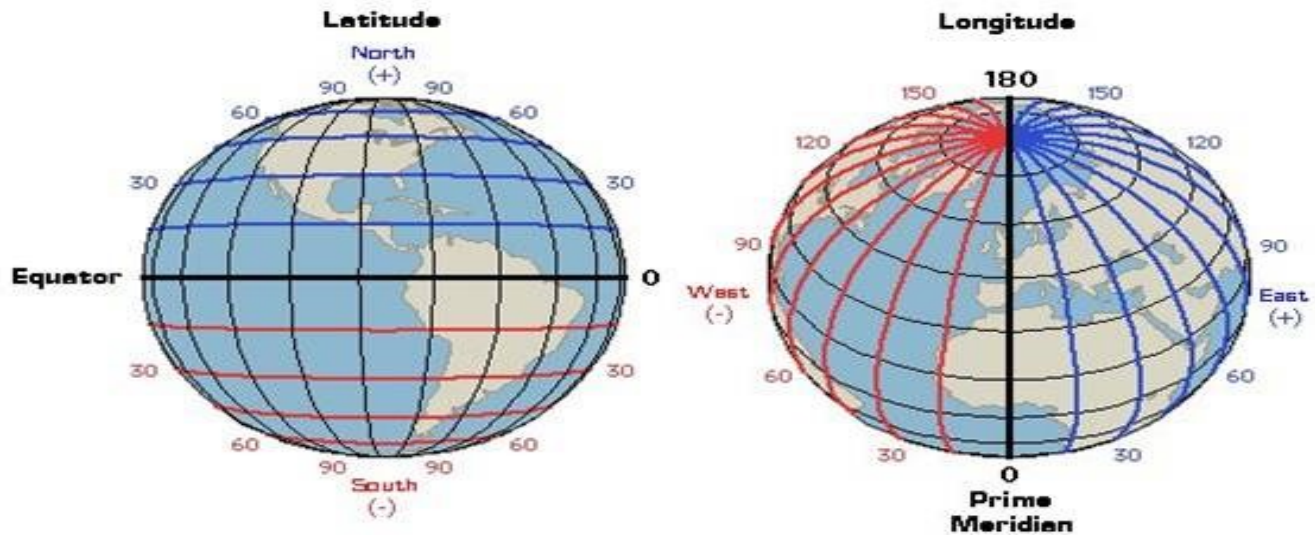
The boundary between the crust and the mantle is the Mohorovic discontinuity named for its discover and usually called the Moho. The Moho is a boundary at which there is sudden change in the chemical composition and the speed of seismic waves. The mantle just below the crust is rigid, solidified, basalt-type rock, fused to the crust but at the same time separated from it by the Moho. This rigid layer of crust and upper mantle is the lithosphere. The subregion of the mantle extending about 250km below the lithosphere is the asthenosphere. The lithosphere is less dense than the asthenosphere, both continental and oceanic lithosphere float on the asthenosphere.

There is a fundamental difference between the crust under the land and under the ocean both in thickness and composition. The continental crust averages about 35km in thickness and the ocean crust averages about 11km including the overlying water. The main rock type of the continents is granite while that of the oceanic crust is gabbro. Granites and gabbros are both rocks that have formed from the cooling of magma. Continental crust has a density of 2.8g/cm^3 and oceanic crust has a density of 3.0g/cm^3 .



16.8. Latitude and Longitude

To determine the location of a position on the earth's surface, we use a grid of reference lines that are superimposed on the earth's surface and cross at right angles. These grid lines are called lines of latitude and longitude. Some lines of latitude and longitude have great significance in geographical studies.

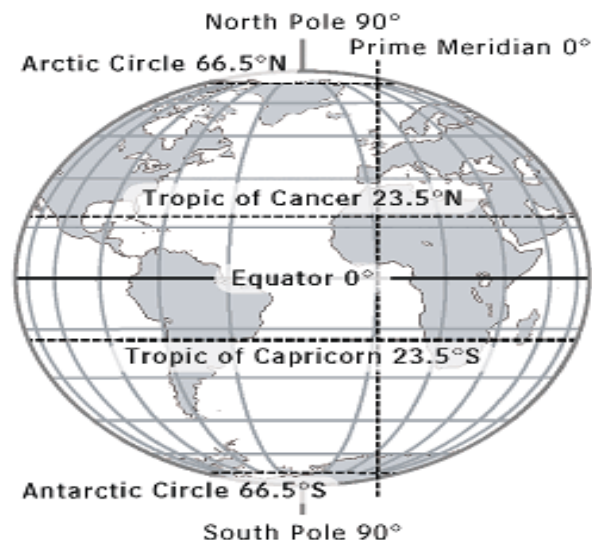


16.8.1.Latitude

The angular distance of any place north or the south of the equator is called the latitude of that place. The lines of latitude are called parallels. The equator is marked at 0° latitude and other latitude lines are drawn around the earth parallel to the equator, northward to 90° N or the North Pole and southward to 90° S or the South Pole. The parallel of 0° is called the equator; those of 23.5° N and S are known as the tropics of Cancer and Capricorn respectively and the 66.5° N and S are known as the Arctic and Antarctic circles respectively.

Characteristics of latitude

- Latitudes are parallel to one another and hence are called parallels.
- They always remain equal distance apart and along true east-west.
- All parallels except the equator are small circles.
- The latitudes are expressed in degrees, minutes and seconds, e.g. 23° 5' 23".



16.8.2.Longitude

The angular distance of any place east or west of the Prime Meridian is called the longitude of that place. Lines of the longitude are called meridians. Among the longitudes, the 0° or the meridian of Greenwich is known as the prime meridian and the opposite it on the globe i.e. the 180° longitude is called the International Date Line. It passes through the central Pacific Ocean. All longitude lines form great circles. Only the equator is a great circle of latitude. Any circle at the earth's surface with its center at the earth's center is a great circle.

Characteristics of Longitudes

- All meridians run in a true north-south direction.
- Meridians spaced farthest apart at the equator and converge at the poles.
- All longitude lines form great circle.

16.9. Distribution of continents and oceans

Continents are the largest unit of landmasses on the earth. The continents include Europe, Asia, North America, South America, Australia and Antarctica. All continents together constitute less than one-third of the earth's surface that means more than two-thirds of the earth's surface are covered with water. Two-third of the continental land mass is located in the Northern Hemisphere. Less than 35% of the total land is found south of the equator, and between 50 and 65 S there is essentially no land at all. In this area oceans are essentially connected.

Generally, the continents are antipodal to the ocean basins (i.e. ocean basins are found on the opposite side of the earth from continental masses). For example, there is an antipodal relationship between the continental Antarctic region and the Arctic Ocean and the Pacific Ocean lies opposite of Africa and Europe. The continental areas above sea level comprise about 29% of the earth's surface. However, from a geological point of view, a submerged continental shelf is also part of a continent. Inclusion of the shelf area increases the extent of the continents to 35% of the globe. The earth's average land elevation is 820m above sea level; the highest point is the summit of Mt .Everest (8,850) and the lowest point is the shore of the Dead Sea at 410m below sea level.

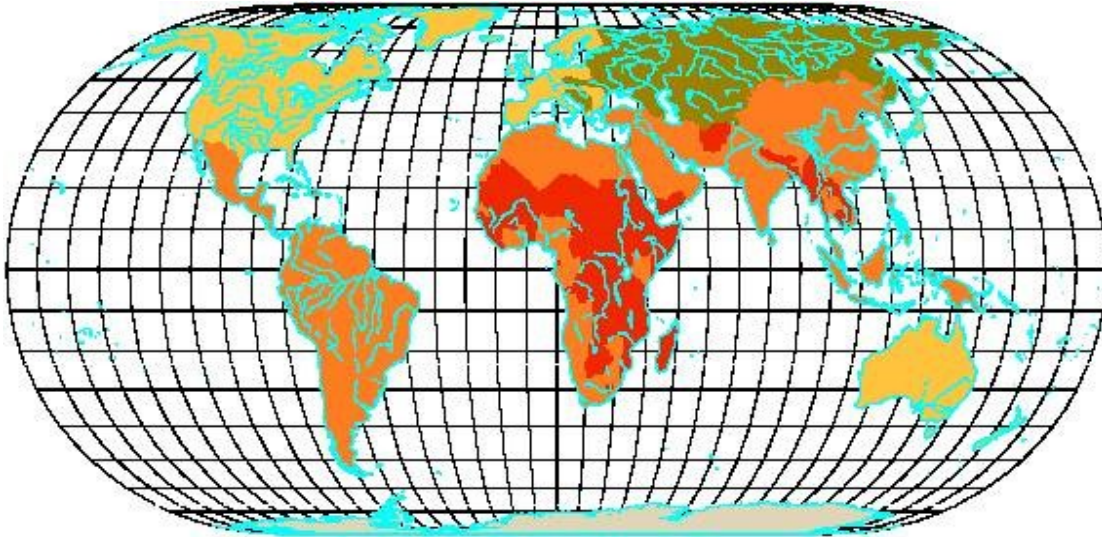
Seas and oceans account for 71% of the total area of the earth's surface. The ocean basins also have an uneven distribution on the earth's surface. They are not evenly distributed and most of them are found in the Southern Hemisphere. The 4 largest oceans of the world are: Pacific Ocean, Atlantic Ocean, Indian Ocean and Arctic Ocean. The total volume of the ocean is about 1350 million cubic kilometers. The average depth of the ocean is 3729m. The ocean floor can be subdivided into two major divisions called the continental margin and the ocean basin or deep sea. The Pacific Ocean is the largest ocean, having an area and volume greater than the Atlantic and Indian Ocean. The Atlantic Ocean is a relatively narrow ocean. The surrounding continents are Africa, South America, Europe and North America. The Indian Ocean, somewhat triangular in shape is situated mainly south of the equator. The Arctic Ocean is somewhat circular in shape and is considerably shallower than the other oceans.



Unit 17 - Map projection

17.1.Introduction

A map projection is a way to represent the curved surface of the earth on the flat surface of a map. A good globe can provide the most accurate representation of the earth. However, a globe is not practical for many of the functions for which we require maps. The need for map projections arises from the very fact that an ordinary globe is rendered useless for reference to a small country. Map projections allow us to represent some or the earth's entire surface, at a wide variety of scales, on a flat, easily transportable surface such as a sheet of paper. Map projections also apply to digital map data, which can be presented on a computer screen.



17.2.Classification of Map Projections

There are hundreds of different map projections. The process of transferring information from the earth to a map causes every projection to distort at least one aspect of the real world-shape, area, distance or direction. Each map projection has advantages and disadvantages; the appropriate projection for a map depends on the scale of the map, and on the purposes for which it will be used. The properties of a map projection may also influence some of the design feature of the map. Some projections are good for small areas, some are good for mapping areas with a large east-west extent and some are better for mapping areas with a large north-south extent. Map projection varies with the size and location of different areas on the earth's surface. While conical and zenithal projections are commonly used for mid-latitudes and polar regions, cylindrical projections are referred for equatorial lands. Projections also vary with the purpose of the map. While transferring the globe on a plane surface, the following facts should be kept in view- preservation of area, preservation of shape and preservation of bearing i.e. direction and distance.

It is, however, very difficult to make such a projection even for a small country in which all the above qualities may be well preserved. Any one quality may be thoroughly achieved by a certain map projection only at the cost of others.

17.3.Based on Quality

So the following groups of projections have been made according to the quality they preserve,

- Equal area or homographical projections
- Correct shape or orthomorphic projections
- True bearing or azimuthal projections.

17.4.Based on different bases

Following classifications may be suggested depending on different bases;

A. Based on the method of constructions

- Perspective
- Non-perspective

B. Based on the developable surface used

- Conical
- Cylindrical
- Azimuthal or zenithal
- Conventional

C. Based on the preserved qualities

- Homolographic or equal area.
- Orthomorphic
- Azimuthal or true bearing projections.

D. Based on the position of tangent surfaces

- Polar
- Equatorial or Normal
- Oblique

E. Based on the position of view point or light

- Gnomonic
- Stereographic
- Orthographic
- Others

F. Based on Geometric shape

- Rectangular
- Circular
- Elliptical
- Butterfly shape
- Others

17.5.Zenithal Projection

A projection that maintains accurate directions(and therefore angular relationships) from a given central point is called an azimuthal or zenithal projection. In this map projection, the direction from a given central point to any other point is shown correctly. These projections are used for aeronautical charts and other maps where directional relationships are important.

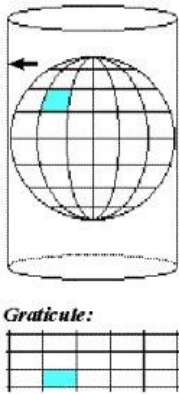
17.6.Conical Projection

A conical projection projects information from the spherical earth to a cone that is either tangent to the earth at a single parallel or that is secant(cutting the sphere or spheroid along a line or lines) at two standard parallels. Once the projection is complete, the cone is unwrapped to form a flat surface. The lines where the cone is tangent or secant are the places with the least distortion.

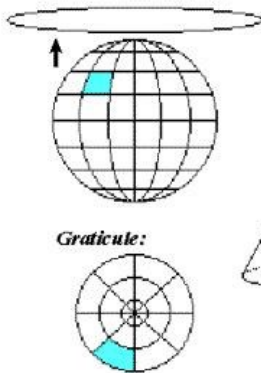
17.7.Cylindrical Projection

A cylindrical projection projects information from the spherical earth to a cylinder. The cylinder may be either tangent to the earth along a selected lines or may be secant(intersect the earth) along two lines. Imagine that once the earth's surface is projected, the cylinder is unwrapped to form a flat surface. The lines where the cylinder is tangent or secant are the places with the least distortion. A Mercator projection is created using a cylinder tangent at the equator. Mercator projection is better for navigation because compass courses are easy to determine.

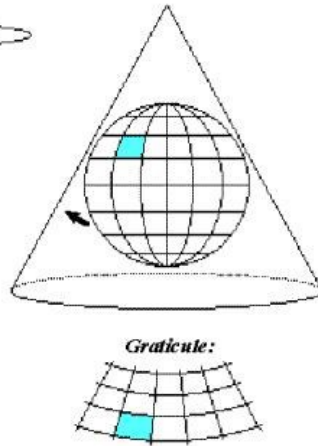
CYLINDRICAL



AZIMUTHAL



CONIC



Conical



Cylindrical



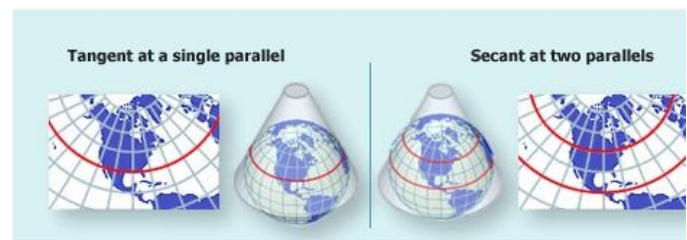
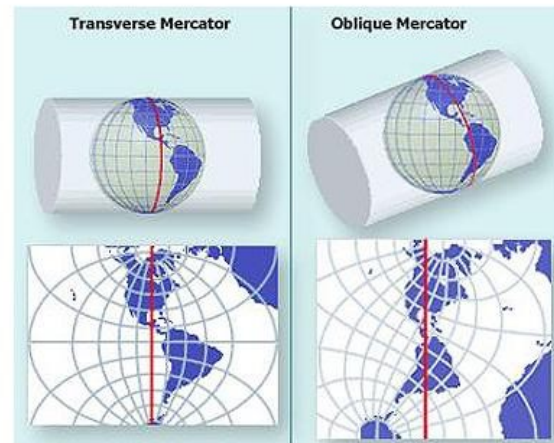
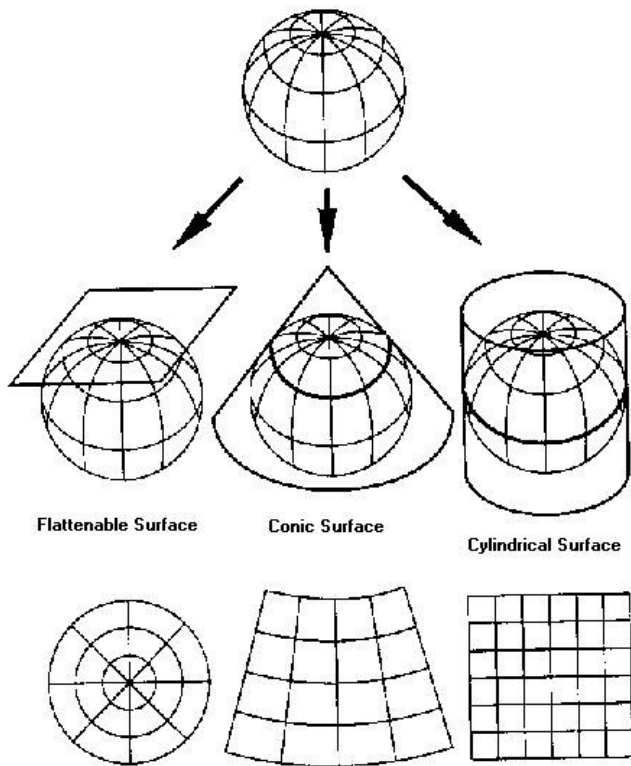
Oblique



Equatorial



Transverse



17.8. Map scale

The scale of a map on any projection is always important and often crucial to the map's usefulness for a given purpose. The distance is indicated by the scale. The scale shows the proportion that the distance between two points on the map bear to the distance between the same two points on the ground. There are three ways of representing this proportion: 1) a statement of scale 2) a lined or plane scale 3) representative fraction. A statement of scale expresses the relationship in words, for e.g., 1cm represents 1km. A linear or plain scale represents the same relationship by means of a line with marked upright divisions. Representative fraction (RF) is a fraction whose numeration one represents a length on the map and whose denominator indicates how many times this length has to be multiplied to get the same distance on the ground.

ALL THE BEST