2 WEATHER AND CLIMATE

Temperature, pressure, wind, humidity and precipitation, interact with each other. They influence the atmospheric conditions like the direction and velocity of wind, amount of insolation, cloud-cover and the amount of precipitation. These are known as the elements of both weather and climate. The influence of these elements differs from place to place and time to time. It may be restricted to a small area and for a short duration of time.

This influence is often described in the name of weather as sunny, hot, warm, cold, fine, etc depending upon the dominant element of weather at a place and at a point of time. Therefore, weather is the atmospheric condition of a place for a short duration with respect to its one or more elements.

Whereas the average weather conditions, prevalent from one season to another in the course of a year, over a large area is known as climate. The average of these weather conditions is calculated from the data collected for several year (about 35 years) for a larger area. Rajasthan, for example, experiences hot and arid climate, Kerala has tropical rainy climate, Greenland has cold desert climate and the climate of Central Asia is temperate continental. Climate of a region is considered more or less permanent.

Factors Affecting Climate

Different regions of the world have differences in temperature, humidity and precipitation. The factors which cause the variations in the climate of a place or a region.

- **Latitude or Distance from the Equator**

The places near the equator are warmer than the places which are far away from it. This is because the rays of the sun fall vertical on the equator and slanting in the temperate and polar regions. (The vertical rays are concentrated over a small area than the slanting one. Again, the vertical rays pass through a shorter distance in the atmosphere before reaching the earth's surface.) Therefore, lower the latitude higher is the temperature and vice versa. Malaysia which is near the equator is warmer than England which is far way from the equator.

- **Altitude or the Height from the mean sea level**

Shimla situated on a higher altitude is cooler than Jalandhar, although both are almost on the same latitude. The temperature decreases with the height of a place. For a vertical rise of 165 metres there is an average decrease in temperature at the rate of 1°C. Thus the temperature decreases with increase in height.

- **Continentally or the Distance from the Sea**

The water is a bad conductor of heat i.e. it takes longer time to heat and longer time to cool. Due to this moderating effect of the sea, places near the coast have low range of temperature and high humidity. The places in the interior of the continent do not experience moderating effect of the sea. These places have extreme temperatures. The places far from the sea have higher range of diurnal (daily) and annual temperatures. Mumbai has relatively lower temperature and higher rainfall than Nagpur, although both are almost situated on the same latitude.

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- **Nature of the Prevailing Winds**

The on-shore winds bring the moisture from the sea and cause rainfall on the area through which they pass. The off-shore winds coming from the land are dry and help in evaporation. In India, the on-shore summer monsoon winds bring rains while off-shore winter monsoon winds are generally dry.

- **Cloud Cover**

In areas generally of cloudless sky as in deserts, temperature even under shade are very high because of the hot day time sunshine. At night this heat radiates back from the ground very rapidly. It results in a large diurnal range in temperature. On the other hand under cloudy sky and heavy rainfall at Thiruvananthapuram the range of temperature is very small.

- **Ocean Currents**

Ocean waters move from one place to another partly as an attempt to equalize temperature and density of water. Ocean currents are large movements of water usually from a place of warm temperature to one of cooler temperature or vice-versa. The warm ocean currents raise the temperature of the coast and sometimes bring rainfall, while the cold currents lower the temperature and create fog near the coast. Port Bergen in Norway is free from ice even in winter due to warm North Atlantic Drift while Port Quebec in Canada remains frozen during winter months due to chilling effect of the Cold Labrador Current in spite of the fact that Port Quebec is situated in much lower latitude than Port Bergen. The on-shore winds passing over a warm current carry warm air to the interior and raise the temperature of the inland areas. Similarly, the winds blowing over cold current carry cold air to the interior and create fog and mist.

- **Direction of Mountain Chains**

The mountain chains act as natural barrier for the wind. The on-shore moisture laden winds are forced to rise after striking against the mountain; and give heavy rainfall on the windward side. These winds descending on the leeward side cause very low rainfall. The great Himalayas check the moisture laden monsoon winds from crossing over to Tibet. This mountain chain also checks biting polar cold winds from entering into India. This is the reason for which northern plains of India get rains while Tibet remains a perpetual rain shadow area with lesser amount of rainfall.

- **Slope**

The concentration of heat being more on the gentler slope raises the temperature of air above them. Its lesser concentration along steeper slopes lowers the temperature. At the same time, mountain slopes facing the sun are warmer than the slopes which are away from the sun's rays. The southern slopes of Himalaya are warmer than the northern slopes.

- **The Nature of the Soil and Vegetation Cover**

The nature of soil depends upon its texture, structure and composition. These, qualities vary from soil to soil. Stony or sandy soils are good conductor of heat while black clay soils absorb the heat of the sun's rays quickly. The bare surface reradiates the heat easily. The deserts are hot in the day and cold in the night. The forest areas have lower range of temperature throughout the year in contrast to non-forested areas.

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There are four major variables of weather :

Temperature

Temperature is a measure of the level of sensible heat of matter, whether it is gaseous (air), liquid, water or solid (rock or dry soil). The temperature of a surface is determined by the balance among the various energy flows that move across it. Atmospheric temperatures condition many aspects of human life, from the clothing we wear to the fuel costs we pay. Air temperature and temperature cycles also acts to select the plants and animals that make up the biological landscape of a region. Even geological weathering and soil forming processes are dependent upon temperatures over the long term.

Indirectly the sun is the major source of atmospheric temperature. In fact, the atmosphere receives very low amount of heat energy from the sun as it receives most of its energy from the long of heat energy from the sun as it receives most of its energy from the long wave terrestrial radiation. On an average, the heating and cooling of the atmosphere is accomplished through direct solar radiation and through transfer of energy from the earth through the process of conduction conviction and radiation.

Factors Controlling the Latitudinal Distribution of Temperature

Following factors control the distribution of temperatures on the earth's surface:

- **Latitudes:** The amount of insolation on annual basis is directly related to latitudes. Since the amount of insolation received by the ground surface decreases pole ward from the equator i.e., from low latitudes towards highlati9tudes because the sun's rays become more and more oblique (slanting) pole ward and hence air temperature also decreases pole ward. It may be noted the sun's rays are almost vertical over the equator throughout the year but there is no maximum temperature on it rather maximum temperature is recorded along 200 N latitude in July because major portion of insolation is reflected by clouds and sizeable amount of heat is lost in evaporation in the low latitude zone (equatorial zone).

- **Height above mean seal Level:** The temperature decreases with increasing height from the earth's surface at an average rate of 6.5°C per kilometer of the following reasons. The major source of atmospheric heat is the earth's surface from where heat is transferred to the atmosphere through the processes of conduction, radiation and convection. Hence as we ascend higher in the atmosphere the amount of heart to be transported above decreases and hence temperature decreases aloft. The layers of air are denser near the earth's surface and become lighter with increasing altitudes. The lower layer of air contains more water vapor and dust particles than the layer above and hence it absorbs larger amount of heart radiated form the earths; surface than the upper air layers.

- **Distance from the coast:** The marine environment moderates the weather conditions of the coastal areas because there is more mixing of temperatures of the coastal seas and oceans and coastal lands due to daily rhythm of land and sea breezes. Thus, the daily range of temperature near the coastal environment is minimum but it increases as the distance from the sea coast increases. Minimum daily range of temperature is the characteristic feature of marine climate while extremely high daily range of temperature characterizes continental climate.

- **Differential Rate of Heating and Cooling of Land and Water:** The following reasons explain the differential rate of heating and cooling of land and water.

The sun's rays penetrate to a depth of only 3 feet in land because it is opaque but they penetrate to greater depth of several meters in water because it is transparent to solar radiation. The thin layer of soils and rocks of land, thus, gets heated quickly because of greater concentration of insolation in much smaller mass of

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material of ground surface. Similarly, the thin ground layer emits heat quickly and becomes colder. On the other, and the same amount of insolation falling on water surface has to heat larger volume of water because of the penetration of solar rays to greater depth and thus the temperature of the water surface through the amount of insolation received by north the surfaces may be equal.

Since the downward distribution of temperature in the land surface within a day is effective up to the depth of only 10 centimeters. Thus, the land surface becomes warm during day and cold during night very rapidly. On the other hand, water is mobile. The upper surface of water becomes lighter when heated by insolation and thus moves away horizontally to other places and the solar rays have to heat fresh layer of cold water. Secondly, heat is redistributed in water bodies by sea waves, ocean currents and tidal waves. All these extend the period of warming of water surface.

There is more evaporation from the seas and the oceans and hence more heat is spending in this process with the result oceans get less insolation on then the land surface. On the other hand, there is less evaporation form the land surface because of the limited amount of water.

The specific heat (the amount of heat needed to raise the temperature one gram of substance by 10°C) of water is much greater than the land because the relative density of water is much lower than that of land surface. It means more heat is required to raise the temperature of one gram of water by 1°C than one gram of land. It is apparent that same amount of insolation received by same mass of water and land would increase the temperature of land more than the temperature of equal mass of water.

The reflection (albedo) of incoming solar radiation of oceanic water surface is far more than from the land surface and thus water receives les insolation than land.

- **Aspect of Slope:** The ground slope facing the sun receives more insolation because the sun's rays reach the surface more or less straight and hence sun facing ground surfaces record higher temperature than the leeward slopes where sun's rays reach more obliquely. In the northern hemisphere the southward facing slopes of east west stretching mountains receive greater amount of insolation than the northward facing slopes because of their exposure to the sun for longer duration. This is why most of the valleys situated on the southern slopes of Alpine mountains have settlements and cultivation.
- **Prevailing Winds:** The prevailing winds help in redistribution of temperature and in carrying moderating effects of the oceans to the adjacent coastal and land areas. The winds blowing from low latitudes to high latitudes raise the temperature of the regions where they reach while winds blowing form high latitudes to low latitudes lower the temperature. The winds blowing from oceans to coastal lands bring in marine effects and thus lower the daily range of temperature. The winds coming from higher parts of the mountains lower the temperature in the valleys. The temperature rises at the time of arrival of temperature cyclones while it falls sharply after their passage or their occlusion. The winds associated with warm oceanic currents raise the temperature of coastal lands while the winds coming in contact with cold currents lower the temperature of affected coastal lands. Sometimes, local winds change the temperature dramatically. For example, the warm Chinook winds raise the temperature by 30 to 40° of within a few minutes along the eastern slopes of the Rockies in the USA and the snow melts as by magic at the arrival of Chinook. This is why pastures are open throughout the year along the eastern slopes of the Rockies. Loo, a local hot winds, raises the temperature in the Ganga Plain of north India to such an extent that heat waves prolong for several days in continuation and several people die of sun stroke.
- **Ocean Currents:** The warm ocean currents flowing from tropical areas to temperature and cold zones raise the average temperature in the affected areas. For example, Gulf Stream raises the average temperature of the coastal areas of north Western Europe while kuroshio warm current raise the temperature of Japanese coasts. Labrador, Peru, California, Kurile, etc. cold currents lower the temperatures of affected areas. In fact, ocean currents moving from one place to another equalize the temperatures.

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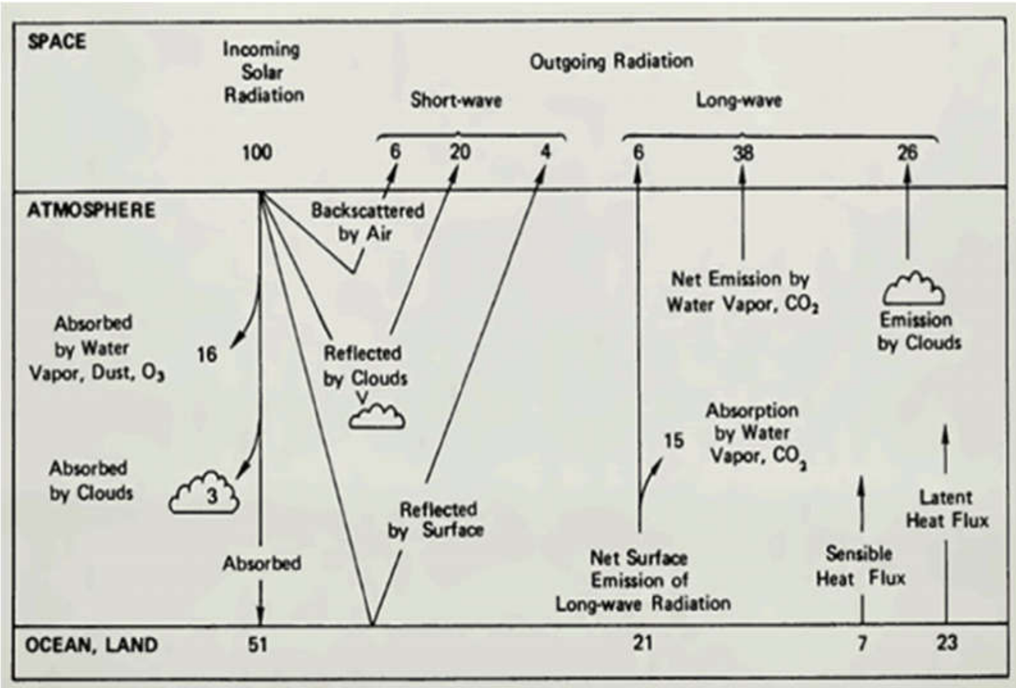
Horizontal Distribution of Temperature

On an average, temperature decrease from the equator towards the poles and thus low latitudes are characterized by highest temperature whereas high latitudes record lowest temperature. This change of temperature rather decrease of temperature pole ward is called temperature gradient. The rate of decrease of temperature between the tropics of Cancer and Capricorn is rather low and therefore temperature decreases more rapidly from the tropics pole ward and therefore temperature gradient is also very high. The horizontal distribution of temperature is represented and studied with the help of isotherms. The lines drawn on maps joining the places of equal temperature reduced to sea level are called isotherms.

Heat Budget

The Earth's climate is a solar powered system. The earth intercepts only ½ of the billionth fraction of the energy radiated from the sun. The earth in turn radiates back the energy received from the sun in the form of long wave terrestrial radiations. As a result, the earth neither warms up nor does it get cooled over a period of time. It maintains its temperature.



This can happen only because the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation. This is known as heat budget of the earth.

Let the solar energy radiated be taken as 100 units. Out of total incoming radiation entering the earth's atmosphere 35 per cent is sent back to space through scattering by dust particles (6%), reflection from clouds (27%) and from the ground surface (2%), 51 per cent is received by the earth's surface and 14 per cent is absorbed by the atmospheric gases and water vapour.

Incoming shortwave solar radiation: equals to 100 units

a) Amount lost to space through scattering and reflection equals to 35% comprises of

- Clouds = 27%
- Reflected by ground = 2%
- Scattered by dust particles = 6%

b) Heat received by earth equals to 51% comprises of

- Through direct radiation = 34%
- Received as diffuse day light = 17%

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c) Absorption by the atmospheric gases and water vapour equals to 14%

After receiving energy from the sun the earth also radiates energy out of its surface into the atmosphere through long-wave radiation. As we have seen above 51 per cent of heat is absorbed by the earth. Thus at the time of outgoing radiations 23 per cent of the energy is lost through direct long-wave terrestrial radiation (in which 6% absorbed by atmosphere and 17% goes directly to space). About 9 per cent out of 51 per cent is spent in convection and 19 per cent is spent through evaporation. Thus the total energy received by atmosphere from sun and the earth becomes 48 per cent.

The atmosphere receives a total of 14 + 34 = 48 units and this amount is radiated back to space by the atmosphere. The total loss of energy to space thus amounts to 100 units: 35 units reflected by the atmosphere, 17 units lost as terrestrial radiation and 48 units from the atmosphere. In this manner, no net gain or loss of energy occurs in the earth's surface.

Outgoing long-wave terrestrial radiation

a) Reflected by earth which was equal to 51 per cent as shown above

- 23% from radiation
- 9% through convection
- 19% through evaporation

b) 48% absorbed in atmosphere moved through radiation back into space.

Although the earth and its atmosphere as a whole have a radiation balance, there are latitudinal variations. The heat/energy is transferred from the lower latitudes to the higher latitudes through winds and ocean currents. In the low latitudes (between 40°N and 40°S) heat gained by short wave radiation is far more than the heat loss by long waves through the earth's radiation. In contrast in the higher latitudes more heat is lost by outgoing long wave than it is received in short waves. In view of the imbalances at high and low latitudes, there is large-scale transfer of heat from tropics to high latitudes by atmospheric and oceanic circulation.

Nowadays Green House Gases are disturbing the earth's heat budget. Carbon dioxide forces the Earth's energy budget out of balance by absorbing thermal infrared energy (heat) radiated by the surface. It absorbs thermal infrared energy with wavelengths in a part of the energy spectrum that other gases, such as water vapor, do not. Carbon dioxide is a very strong absorber of thermal infrared energy with wavelengths longer than 12-13 micrometers, which means that increasing concentrations of carbon dioxide partially "close" the atmospheric window. In other words, wavelengths of outgoing thermal infrared energy that our atmosphere's most abundant greenhouse gas-water vapor-would have let escape to space are instead absorbed by carbon dioxide.

The absorption of outgoing thermal infrared by carbon dioxide means that Earth still absorbs about 70 per cent of the incoming solar energy, but an equivalent amount of heat is no longer leaving. The exact amount of the energy imbalance is very hard to measure, but it appears to be a little over 0.8 watts per square meter.

When increasing greenhouse gas concentrations bumps the energy budget out of balance, it doesn't change the global average surface temperature instantaneously. It may take years or even decades for the full impact of a forcing to be felt. This lag between when an imbalance occurs and when the impact on surface temperature becomes fully apparent is mostly because of the immense heat capacity of the global ocean. The heat capacity of the oceans gives the climate a thermal inertia that can make surface warming or cooling more gradual, but it can't stop a change from occurring.

However, as long as greenhouse gas concentrations continue to rise, the amount of absorbed solar energy will continue to exceed the amount of thermal infrared energy that can escape to space. The energy imbalance will continue to grow, and surface temperatures will continue to rise. This leads to Global Warming.

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Global warming and Climate

Global warming is defined as a increase in the average temperature of the Earth's atmosphere, especially a sustained increase great enough to cause changes in the global climate.

There has been a particularly alarming effect of global warming on the climate of India. India is already a disaster prone area, with the statistics of 27 out of 35 states being disaster prone, with most disasters being water related. The process of global warming has led to an increase in the frequency and intensity of these climatic disasters. According to surveys, in the year 2007-2008, India ranked the third highest in the world regarding the number of significant disasters, with 18 such events in one year, resulting in the death of 1103 people due to these catastrophes.

The anticipated increase in precipitation, the melting of glaciers and expanding seas are projected to influence the Indian climate particularly severely, with an increase in incidence of floods, hurricanes, and storms. Global warming is also posing as a mammoth threat to the foods security situation in India with recurring and severe droughts and ravaging floods engulfing the arable land. Rising temperatures on the Tibetan Plateau are causing the melting of the Himalayan glaciers, reducing the water flow in the rivers Ganges, Brahmaputra, Yamuna, and other major rivers, on which the livelihoods of hundreds of thousands of farmers depend.

According to the The Indira Gandhi Institute of Development Research, if the process of global warming continues to increase, resulting climatic disasters would cause a decrease in India's GDP to decline by about 9%, with a decrease by 40% of the production of the major crops. A temperature increase of 2°C in India is projected to displace seven million people, with a submersion of the major cities of India like Mumbai and Chennai.

India is the most flood distressed state in the world after Bangladesh, accounting for 1/ 5th of the global deaths every year with 30 million people displaced from their homes yearly.

Approximately 40 million hectares of the land is vulnerable to floods, with 8 million hectares affected by it. Unprecedented floods take place every year at one place or the other, with the most vulnerable states of India being Uttar Pradesh, Bihar, Assam, West Bengal, Gujarat, Orissa, Andhra Pradesh, Madhya Pradesh, Maharashtra, Punjab and Jammu & Kashmir. The climatic history of India is studded with a very large number of floods, which have wreaked havoc on the country's economy.

The process of global warming has such an impact on the climate that it increases the severity of precipitation at one time, and minimizes it in the other. Therefore, this process has resulted in severe drought like conditions in India, with tens of millions of deaths resulting from it in the past few centuries. India depends heavily on prolonged and optimum monsoons for its agricultural productivity, failure of which results in the decreased crop productivity, leading to droughts.

Of the total agricultural land in India, about 68% is prone to drought of which 33% is chronically drought prone, receiving rainfall of less than 750mm per year. This is particularly the states of Maharashtra, Gujarat, Rajasthan, Karnataka, Andhra Pradesh and Orissa.

As a result of global warming, the average number of Category 4 and 5 hurricanes per year has increased over the past 30 years. India has an 800km coastline, and is therefore very susceptible to cyclonic activity.

Cyclones have been observed to be more frequent in the Bay of Bengal than the Arabian Sea. Consequently the states of West Bengal, Orissa, Andhra Pradesh, and Tamil Nadu along the Bay of Bengal are the most affected.

The National Institute of Oceanography (NIO), under the Council of Scientific and Industrial Research (CSIR), Government of India, researched on the impacts of climate change on sea level, to assess the degree to which

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mean sea level and the occurrence of extreme events may change, and concluded that an increased occurrence of cyclones in the Bay of Bengal, particularly in the post-monsoon period, along with increased maximum wind speeds associated with cyclones and a greater number of high surges under climate change has been observed. In addition, the strength of tropical cyclones, which represent a threat to the eastern coast of India and to Bangladesh, is also likely to increase.

Global warming has resulted in an increased cyclonic activity, sea level rises displacing people, flooding, and the reduction in the sea food due to the acidification of the waters. Thousands of people have been displaced by ongoing sea level rises that have submerged low-lying islands in the Sundarbans.

A one meter sea level rise is projected to displace approximately 7.1 million people in India and about 5,764 km^2 of land area will be lost, along with 4200 Km of road. Around seven million people are projected to be displaced due to submersion of parts of Mumbai and Chennai if global temperatures were to rise by a mere 2°C.

The effects of global warming have also caused damage to coastal infrastructure, aquaculture and coastal tourism. The aquatic ecosystems such as mangroves, coral reefs and grass lands have also been affected by the climatic change

Thus the process of global warming has affected India intensely, destroying its economy and depriving its people of their basic needs like food and shelter. The current patterns of destructive floods, increasing intensity of cyclones, recurring droughts and the increasing temperatures are all the results of global warming. The Indian government also realizes the predicament it faces, and multiple steps to mitigate these disasters have been taken.

In spite of the steps taken by the Indian government, global warming continues to increase, and the resulting climatic disasters ravage the country in an unabated manner. This can be attributed to the lack of resources, and access to technology. To cope up with the climate change-disasters-security nexus, the country needs to have a better technical understanding, capacity building, networking and expansive consultation processes spanning every section of the society.

The committees and organizations working to counteract against the climatic disasters work independently from each other. The ongoing climatic changes, with an increase in a possibility of more disasters impose imperatives for a unity among all these bodies, resulting in an integrated risk management framework, creating a common platform for the committees to work on. India has a distinctive vulnerability profile as the poor are the most affected.

Tremendous weather events take place more frequently and are becoming more ruthless. Therefore the previous attempts of just rescuing the affected will not be enough now,instead, meticulous steps to prevent these disasters are required. This can only be met if the strategies and policies can cope with climate change, requiring the active participation of the government and the people

Inversion of Temperature

When the normal vertical temperature gradient is inverted, in meteorological parlance, it is called temperature inversion or negative lapse rate. Such situation may occur near the earth's surface or at greater height in the troposphere but the inversion of temperature near the earth's surface is of very short duration because the radiation of heat from the earth's surface during daytime warms u the cold air layer which soon disappears and temperature inversion also disappears. On the other hand, upper air temperature inversion lasts for longer duration because the warming of cold air layer aloft through terrestrial radiation takes relatively longer period of hours.

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Types of Temperature Inversion

Ground Surface Inversion: Ground surface inversion also called as radiation inversion occurs near the earth's surface due to radiation mechanisms. This is also called as non advection inversion because it occurs in states atmospheric condition characterized by no movement of air whether horizontal or vertical. The ground surface inversion occurs under the following conditions:

- Long winter nights so that the loss of heat by terrestrial radiation from the ground surface during night may exceed the amount of insolation received.
- Cloudless and clear sky so that the loss of heat through terrestrial radiation proceeds more rapidly without any obstruction. Clouds absorb terrestrial radiation and hence loss of heat from the earth's surface.
- Presence of dry air near the ground surface, so that it may not absorb much heart radiated from the earth's surface as moist air is capable of absorbing much of the radiant heat from the earth's surface.
- Slow movement of air, so that there is no transfer and mixing of heat in the lower layers of the atmosphere.
- Snow covered ground surface, so that there is maximum reflection of incoming solar radiation. Snow, being bad conductor of heat regards the flow of heat from the ground surface lying below the snow layers to the lower atmosphere.

This inversion promotes stability in the lower portion of the atmosphere and causes dense fogs.

- **Upper Air Inversion:** Upper air inversion is of two type's viz. (I) thermal upper air inversion and (ii) mechanical upper air inversion. The thermal upper air inversion is caused by the presence of ozone layer lying between the heights of 15 to 35 km (even up to 80 km) in the stratosphere. The mechanical inversion of temperature is caused at higher heights in the atmosphere due to subsidence of air and turbulence and convertible mechanisms. Mechanical inversion caused by the subsidence of air currents is generally associated with the anticyclones conditions. This type of inversion of temperature is very common in the middle latitude where high pressures are characterized by sinking air. The pole wards regions of the winds are also characterized by high pressure caused by the subsidence of air resulting into mechanical inversion of temperature. The temperature inversion causes stability in the atmosphere. This is the reason that the pole ward parts of trade winds are characterized by arid conditions.
- **Advection Inversion of Temperature:** Advection Inversion of Temperature is associated with the dynamism of the atmosphere. Strong wind movement and unstable conditions of the atmosphere are prerequisite conditions for advection inversion of temperature.
- **Frontal or Cyclonic Inversion** is caused in the temperate zones due to temperate cyclones which are formed due to the convergence of warm western lies and cold polar winds in the northern hemisphere. The existence of warm air above and cold air below reverse the normal lapse rate and inversion of temperature occurs.
- **Surface Inversion** of temperature is caused horizontal movement of air. It is caused when warm air invades the area of cold air or cold air moves into the area of warm. Cold air being denser settles down in both the case resulting into temperature inversion. The convergence of cold and warm ocean currents also causes surface inversion of temperature.
- **Valley Inversion** generally occurs in the mountainous valleys due to radiation and vertical movement of air. The temperature of the upper parts of the valleys in mountainous areas becomes exceedingly low during winter nights because of rapid rate of loss of heat from the surface through terrestrial radiation. Consequently, the air coming in contact, which the cool surface also becomes cool. On the other hand,

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the temperature of the valley floor does not fall considerably because of comparatively low rate of floss of heat through terrestrial radiation. Thus, there is warm air aloft and cold air in the valley floor and inversion of temperature is caused. This situation is responsible for severe frost in the valley floors causing great damage to fruit or chards and vegetables and agricultural crops whereas the upper parts of the valleys are free from front. This is why the valley floors are avoided for human settlements while the upper parts inhabited in the mountainous valleys of middle latitudes. The mechanism of valley of temperatures.

Significance of Inversion of Temperature

Some of the most significant consequences of temperature inversions are the extreme weather conditions they can sometimes create. One example of these is freezing rain. This phenomenon develops with a temperature inversion in a cold area because snow melts as it moves through the warm inversion layer. The precipitation then continues to fall and passes through the cold layer of air near the ground. When it moves through this final cold air mass it becomes "super-cooled" (cooled below freezing without becoming solid). The super-cooled drops then become ice when they land on items like cars and trees and the result is freezing rain or an ice storm.

Intense thunderstorms and tornadoes are also associated with inversions because of the intense energy that is released after an inversion blocks an area's normal convection patterns.

Although freezing rain, thunderstorms, and tornadoes are significant weather events, one of the most important things impacted by an inversion layer is smog. This is the brownish gray haze that covers many of the world's largest cities and is a result of dust, auto exhaust, and industrial manufacturing.

Smog is impacted by the inversion layer because it is in essence, capped, when the warm air mass moves over an area. This happens because the warmer air layer sits over a city and prevents the normal mixing of cooler, denser air. The air instead becomes still and over time the lack of mixing causes pollutants to become trapped under the inversion, developing significant amounts of smog.

During severe inversions that last over long periods smog can cover entire metropolitan areas and cause respiratory problems for the inhabitants of those areas. In December 1952, for example, such an inversion occurred in London. Because of the cold December weather at the time, Londoners began to burn more coal, which increased air pollution in the city. Since the inversion was present over the city at the same time, these pollutants became trapped and increased London's air pollution. The result was the Great Smog of 1952 that was blamed for thousands of deaths.

Like London, Mexico City has also experienced problems with smog that have been exacerbated by the presence of an inversion layer. This city is infamous for its poor air quality but these conditions are worsened when warm sub-tropical high pressure systems move over the city and trap air in the Valley of Mexico. When these pressure systems trap the valley's air, pollutants are also trapped and intense smog develops. Since 2000, Mexico's government has developed a ten year plan aimed at reducing ozone and particulates released into the air over the city.

London's Great Smog and Mexico's similar problems are extreme examples of smog being impacted by the presence of an inversion layer. This is a problem all over the world though and cities like Los Angeles, California; Mumbai, India; Santiago, Chile; and Tehran, Iran, frequently experience intense smog when an inversion layer develops over them.

Because of this, many of these cities and others are working to reduce their air pollution. To make the most of these changes and to reduce smog in the presence of a temperature inversion, it's important to first understand all aspects of this phenomenon, making it an important component of the study of meteorology, a significant sub-field within geography.

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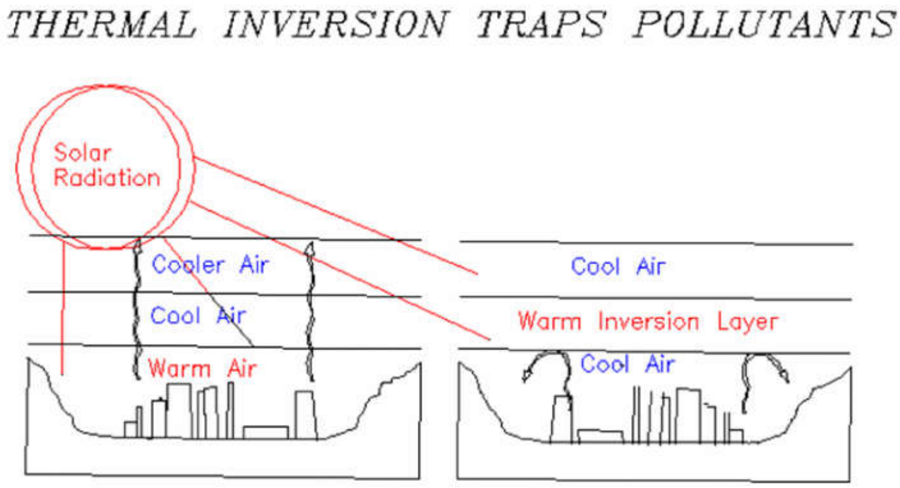

Fog is formed due to the situation of warm air above and cold air below because the warm air is cooled below and resultant condensation causes the formation of tiny droplets around suspended dust particles and smoke during winter nights. The smoke coming out of houses and chimneys intensify fog and become responsible for the occurrence of urban smog. When smog is mixed with air pollutants such as sulphur dioxide, it becomes poisonous and serious health hazard to human beings. Fogs are also formed at the convergence of warm and cold ocean currents. Fog reduce atmospheric visibility and thus they are responsible for accidents of air crafts while taking off and landing and ships in the oceans. Road and rail transports are also badly affected by the occurrence of dense fog. Though generally fog is unfavorable for many agricultural crops such as grams, peas, mustard plants, wheat, etc. but sometimes they are also valuable for some crops such as coffee plants in Yemen hills of Arabia where fog protects coffee plants from direct strong sun's rays.

Inversion of temperature causes frost when the condensation of warm air due to its cooling by cold air below occurs at temperature below freezing point. Frost is definitely economically unfavorable weather phenomenon mainly for crops because fruit orchards and several agricultural crops such as potatoes, tomatoes peas etc. are totally damaged over night.

Inversion of temperature causes atmosphere stability which stops upward (ascent) and downward (descent) movements of air. The atmosphere stability discourages rainfall and favors dry condition. The inversion of temperature caused by the subsidence of air resulting into anticyclones conditions increases aridity. This is why the western parts of the continents situated between 200-300 latitudes and characterized by anticyclones condition represent most widespread tropical deserts of the world.

Urban Heat Island Effect

Around half of the world's human population lives in urban areas. In the near future it is expected that the global rate of urbanization will increase by 70% of the present world urban population by 2030, as urban agglomerations emerge and population migration from rural to urban/suburban areas continues. Urbanization negatively impacts the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. Considered to be a cumulative effect of all these impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area's nearby natural landscape. Though heat islands may form on any rural or urban area, and at any spatial scale, cities are favoured, since their surfaces are prone to release large quantities of heat. Nonetheless, the UHI negatively impacts not only residents of urban-related environs, but also humans and their associated ecosystems located far away from cities. In fact, UHIs have been indirectly related to climate change due to their contribution to the greenhouse effect, and therefore, to global warming.

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The Physics Behind the Urban Heat Island Effect

The rate at which an object can reflect solar radiation is called its **albedo**. The bigger the albedo something has, the better it reflects radiation. Traditional asphalt has a low albedo, which means it reflects radiation poorly and instead absorbs it.

When we build and expand cities, we tend to erect buildings with dark surfaces and lay down asphalt pavement. The buildings and the pavement absorb a significant amount of light and radiation and emit it as heat, warming the city. Because more than half of the surfaces in cities are man-made, cities heat up more than rural areas, where structures are less concentrated. This heat absorption is the reason why the temperature difference between cities and rural areas is highest a few hours after sunset. Cities hold on to more heat for a longer period of time than rural areas do.

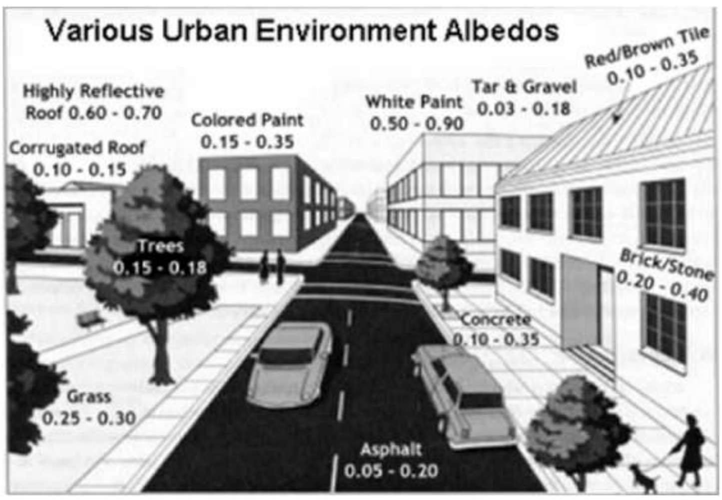
But that's not the only thing that causes the urban heat island effect. Scientists believe that vegetation plays a large part in keeping an area cool through a process called **evaporative cooling. Evaporation** is when liquid turns into gas. Plants take in water through their roots and depend on it to live. But after the plant is done with it, dry air absorbs that water by turning it into gaseous **water vapor**. The air provides the heat that drives this process, so during the process, the air loses heat and becomes cooler. We experience the same type of thing when we sweat -- when air hits our sweaty skin, it absorbs the moisture and cools the air around us. Because building a city means replacing vegetation with structures, the city loses the evaporative cooling advantages of vegetation.

Other factors also contribute to the effect. For instance, cars and air conditioners, which are ubiquitous in urban areas, convert energy to heat and release this heat into the air.

Impacts

It has been largely demonstrated that cities with variable landscapes and climates can exhibit temperatures several degrees higher than their rural surroundings (i.e. UHI effect), a phenomenon which if increases in the future, may result in a doubling of the urban to rural thermal ratio in the following decades. Hence, assessment of the UHI and strategies to implement its mitigation are becoming increasingly important for government agencies and researchers of many affected countries.

As it would be expected, the characteristic inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated outdoor spaces or inner spaces of residential and commercial buildings with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide, as well as other pollutants such as sulphur dioxide, carbon monoxide and particulate matter. Furthermore, the increased energy demand means more costs to citizens and goverments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote high air temperatures that contribute to formation of ozone precursors, which combined photochemically produce ground level ozone.



A direct relationship has been found between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. Heat stroke, heat exhaustion, heat syncope, and heat

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cramps, are some of the main stress events, while a wide number of diseases may become worse, particularly in the older people and children. In a similar way, respiratory and lung diseases have shown to be related to high ozone levels induced by heat events.

The anomalous heat of the city creates relatively low air pressures that cause cooler, rural air to converge on the urban center, thus forcing warm air to ascend (i.e., convection), which at higher altitudes condensates and precipitates. Studies carried out in several cities of the United States such as Atlanta, New York, Chicago and Washington, have shown that urban-induced precipitation and thunderstorm events are mainly initiated by the UHI. Other meteorological impacts of the UHI are associated with reductions in snowfall frecuencies and intensities, as well as reductions in the diurnal and seasonal range of freezing temperatures. Lastly, high temperatures may produce physiological and phenological disturbances on ornamental plants and urban forests.

Although in winter time the UHI can result in energy savings (i.e. winter penalty), there is a great consent among researchers that this benefit is outweighed by the detrimental effects that occur in summer time.

Mitigation Strategies

In countries like the United States heat is the primary weather-related cause of death, and therefore, promotion of strategies for mitigating the UHI are a big concern for government agencies. There are two main UHI reduction strategies: first, to increase surface reflectivity (i.e., high albedo), in order to reduce radiation absorption of urban surfaces, and second, to increase vegetation cover, mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises.

Reflective surfaces simply results from light colored or white paint on the surface of a given construction material or from covering the construction material surface with a white membrane. Both techniques have been mainly applied on roofs and pavements. Cool roofs are specially important in commercial and residential buildings, where significant energy demand for cooling can be saved by reducing heat gain to the building. Cool pavements have mainly based on the use of whitened asphalt roads, a very warm material. For this purpose their surfaces have been mixed with white chip seals or coated with a light concrete cover called white topping.

Increasing vegetation cover is mainly focused on planting trees at nearby houses, and residential and commercial buildings. A particular emphasis has been placed on vegetation planting on the roofs of buildings (i.e., green roofs), in order to achieve the same aim as lighter-colored roofs. Strategically placing trees in front of windows and on the sunniest sides of a house maximizes energy savings. Trees placed on the east and west sides of a structure are most effective because they block the morning sun as well as the afternoon sun. Larger trees also tend to be more effective, as they provide a greater canopy cover and shade area. In addition, energy demand and costs also can be reduced by placing an air-conditioner in a shaded window, for example shaded by a strategically planted tree.

Pressure

Air is a mixture of several gases. Gas molecules are in constant state of collision and move freely. Pressure of air at a given place is defined as a force exerted against surface by continuous collision of gas molecules. Air pressure is thus defined as total weight of a mass of column of air above per unit area at sea level. The amount of pressure exerted by air at a particular point is determined by temperature and density which is measured as a force per unit area.

The distribution of atmospheric pressure over the globe is known as horizontal distribution of pressure. It is shown on maps with the help of isobars. An isobar is a line connecting points that have equal values of pressure. Isobars are analogous to the contour lines on a relief map. The spacing of isobars expresses the rate and direction of change in air pressure. This change in air pressure is referred as pressure gradient.

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The pressure gradient may be thought of as being analogs to the slope of a hill. Like a steep hill, a steep pressure gradient causes greater acceleration of a parcel of air than does a weak pressure gradient. Thus, closely spaced isobars represent a strong pressure gradient and high velocity winds, while widely spaced isobars indicate a weak pressure gradient and light winds.

The horizontal distribution of atmospheric pressure is not uniform in the world. It varies from time to time at a given place; it varies from place to place over short distances. The factors responsible for variation in the horizontal distribution of pressure are as follows:

(i) Air Temperature: The earth is not heated uniformly because of unequal distribution of insolation, differential heating and cooling of land and water surfaces. Generally there is an inverse relationship between air temperature and air pressure. The higher the air temperature, the lower is the air pressure.

The fundamental rule about gases is that when they are heated, they become less dense and expand in volume and rise. Hence, air pressure is low in equatorial regions and it is higher in polar regions. Along the equator lies a belt of low pressure known as the "equatorial low or doldrums". Low air pressure in equatorial regions is due to the fact that hot air ascends there with gradual decrease in temperature causing thinness of air on the surface. In polar region, cold air is very dense hence it descends and pressure increases. From this we might expect, a gradual increase in average temperature towards equator. However, actual readings taken on the earth's surface at different places indicate that pressure does not increase latitudinally in a regular fashion from equator to the poles. Instead, there are regions of high pressure in subtropics and regions of low pressure in the sub-polar areas.

(ii) The Earth's Rotation: The earth's rotation generates centrifugal force. This results in the deflection of air from its original place, causing decrease of pressure. It is believed that the low pressure belts of the sub polar regions and the high pressure belts of the sub-tropical regions are created as a result of the earth's rotation. The earth's rotation also causes convergence and divergence of moving air. Areas of convergence experience low pressure while those of divergence have high pressure.

(iii) Pressure of Water Vapour: Air with higher quantity of water vapour has lower pressure and that with lower quantity of water vapour has higher pressure. In winter the continents are relatively cool and tend to develop high pressure centres; in summer they stay warmer than the oceans and tend to be dominated by low pressure, conversely, the oceans are associated with low pressure in winter and high pressure in summer

Pressure Belts of the World

a) Equatorial Low Pressure Belt

At the Equator heated air rises leaving a low-pressure area at the surface. This low pressure area is known as equatorial low pressure. This area extends between 50N and 50S latitudes. The zone shifts along with the northward or southward movement of sun during summer solstice and winter solstice respectively. The pressure belt is thermally induced because the ground surface gets heated during the day. Thus warm air expands, rises up and creates low pressure.

b) Sub-tropical High Pressure Belt

The warm air risen up at the equator due to heating reaches the troposphere and bend towards the pole. Due to coriolis force the air descends at 30-35° latitude thus creates the belt of sub-tropical high pressure. The pressure belt is dynamically induced as it owes its origin to the rotation of the earth and sinking and settling of winds. This zone is characterized by anticyclonic conditions which cause atmospheric stability and aridity. Thus the hot deserts of the world are present in this region extending between 25-35 degree in both the hemisphere.

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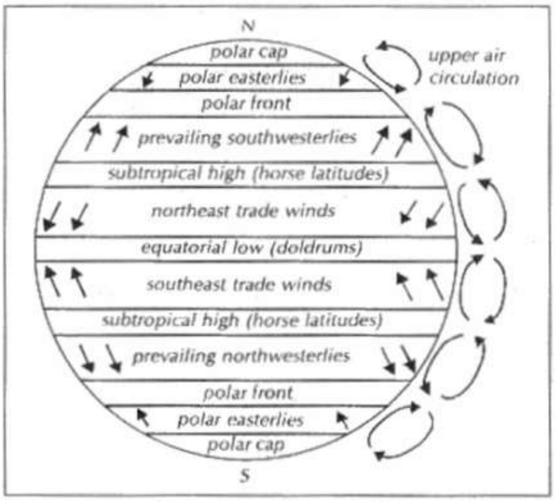
c) Sub-Polar Low Pressure Belt

This belt is located between 60-65 degree latitudes in both the hemisphere. This pressure belt is also dynamically induced. As shown in the figure the surface air spreads outward from this zone due to rotation of the earth thus produces low pressure. The belt is more developed and regular in the southern hemisphere than the northern due to over dominance of water in the former.

d) Polar High Pressure Belt

High pressure persists at the pole due to low temperature. Thus the Polar High Pressure Belt is thermally induced as well as dynamically induced as the rotation of earth also plays a minor role.



Coriolis Force

The rotation of the Earth creates force, termed Coriolis force, which acts upon wind. Instead of wind blowing directly from high to low pressure, the rotation of the Earth causes wind to be deflected off course. In the Northern Hemisphere, wind is deflected to the right of its path, while in the Southern Hemisphere it is deflected to the left. Coriolis force is absent at the equator, and its strength increases as one approaches either pole. Furthermore, an increase in wind speed also results in a stronger Coriolis force, and thus in greater deflection of the wind.

Shifting of Pressure Belts

The surface pattern of air pressure seldom remains stationary in its latitudinal zone. There are daily, seasonal and annual changes in air pressure because of northward and southward movement of the overhead sun (summer and winter solstices), contrasting nature of the heating and cooling of land and water, etc. The lowest pressure is developed between 2 to 4 P.M. during the day due to maximum temperature while highest pressure is recorded between 4-6 A.M. due to minimum temperature during night. Costal land records low pressure while adjoining oceanic area has high pressure during the day. This situation is reversed during night. Except polar high pressure belt all the pressure belts move northward with the northward movement of the sun during summer solstice. On the other hand, except the polar high pressure belt, all the belts move southward due to southward movement of the sun during winter solstice when the sun is vertical at the tropic of Capricorn. The pressure belts occupy their normal ideal position at the time of vernal equinox (21 March) and autumn equinox (23 September) when the sun is vertical at the equator.

Winds

Wind is defined as air motion with respect to the earth's surface. Wind is basically caused by surface difference in atmospheric pressure following a simple physical principle that any fluid subjected to gravity will move until the pressure at every level is uniform.

There are two types of movement in the atmosphere: horizontal movement and vertical movement. Vertically moving air columns are known as currents. Upwards and downward air currents are referred to as surface updrafts and downdrafts. Vertical motions occurring in the atmosphere are of great significance for the formation of clouds, precipitation and various types of storms.

Winds are the means by which uneven distribution of pressure over the globe is balanced out. Winds have been considered by meteorologists as an essential part of the thermodynamic mechanism of atmosphere which

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serves as a means of transporting heat moisture and other properties from one part of the earth to another. It ultimately maintains the global energy balance.

Factors Affecting Wind Motion

Out of the numerous factors that affect wind motion, the following are considered to be most important.

- **Surface Pressure Gradient:** It is the direction and magnitude of the pressure gradient which ultimately determines wind direction and its velocity. The interrelationship between gradient force and wind can be seen in the form of wind direction and wind speed. Since the direction of wind motion is always from higher pressure towards lower pressure, the line showing the direction of wind is always perpendicular to the isobars. When the pressure gradient is steep, the wind velocity is higher, while the weak pressure gradient causes the wind to blow at a low speed. The velocity of wind can be estimated from the spacing of isobars. Closely spaced isobars mean a steep pressure gradient and high velocity winds; widely spaced isobars, on the other hand, indicate a weak pressure gradient and light winds. The principal factor which creates these difference is the unequal heating of the earth's land and sea surface. Hence, there is a close relationship between pressure and temperature. Thus, greater the temperature difference, steeper the pressure gradient and the resultant wind.

- **Coriolis Force:** Coriolis force is not a force in the true sense of the term. In fact, it is an effect which results from the rotational movement of the earth and the movement of air relative to the earth. The Coriolis force is zero at the equator and maximum at the poles.

  According to Ferrels' law, moving fluid are turned rightward in the northern hemisphere and leftward in the Southern hemisphere under the impact of force called Coriolis force.

  The Coriolis force is directly proportional to horizontal velocity of the moving body and mass of the moving body; and since the Coriolis force acts at right angles to the horizontal direction of the moving object, it affects its direction and not the speed. Besides, this force is equal in all direction. The pressure gradient force is directed towards the area of low pressure and is opposed by the Coriolis force, which is directed towards the area of high pressure. When the two opposing forces are equal in magnitude, the wind will continue to flow parallel to the isobars. This wind which blow parallel to the isobars is called Geostrophic wind.

  In fact, the wind, instead of blowing parallel to the isobars, tends to adjust its speed and direction so as to reach a balanced between the pressure gradient force and the Coriolis force. The state of equilibrium reached by the two opposing force is called geographic balance. Thus, geographic winds are those that are generated by this balance of the two oppositing force. A steep gradient force will create winds with high velocities and these in turn will generate an equally strong Coriolis force.

- **Frictional Force:** The configuration or undulation on the surface of the earth act as a barrier in the wind movement. It reduces the speed of the wind through frictional force which acts very close to the surface of the earth. Since Coriolis force is proportionate to wind speed, the friction consequently reduces it. On the contrary, the pressure gradient force remains unaffected by wind speed, hence it exceeds the Coriolis force along or near the earth's surface. This results in the movement of air at an angle across the isobars toward the low pressure area.

  The friction effects are carried upward from the earth's surfaces by the vertical movements of edits. They transport slow moving air from lower altitude to higher altitude, and fast moving air from higher to lower altitudes.

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At about 1000 meters from the ground, the effect of frictional forces becomes too small, therefore, the winds are very nearly equal to the geostrophic winds.

- **Centrepetal Force:** This force applies when the isobaric pattern is markedly curved as within cyclonic systems or around high pressure centres. The fact that air is following a curved path means that in additional to the PGF and Coriolis force, a third force is acting as centrlay force and it produces a wind called gradient wind.

Planetary Winds

Planetary winds are major component of the general global circulation of air. These are known as planetary winds because of their prevalence in the global scale throughout the year. Planetary winds occur due to temperature and pressure variance throughout the world.

(a) Trade Wind

Winds blowing from the subtropical high pressure belt or horse latitudes towards the equatorial low pressure belt of the ITCZ are the trade winds. In the Northern Hemisphere, the trade winds blow from the northeast and are known as the **Northeast Trade Winds;** in the Southern Hemisphere, the winds blow from the southeast and are called the **Southeast Trade Winds.**

The weather conditions throughout the tropical zone remain more or less uniform. This belt is subjected to seasonal variation due to northward and southward movement of sun.

The equatorward part of the trade wind are humid because they are characterized by atmospheric instability thus causing heavy precipitation.

(b) Westerly Wind

The Westerlies are the prevailing winds in the middle latitudes between 35° and 65° blowing from the high pressure area in the sub tropical high pressure belt, i.e., horse latitudes towards the sub polar low pressure belt. The winds are predominantly from the south-west to north-east in the Northern Hemisphere and from the north-west to south-east in the Southern Hemisphere.

The Westerlies are strongest in the winter season at times when the pressure is lower over the poles, while they are weakest in the summer season when pressures are higher over the poles. The Westerlies are particularly strong, especially in the southern hemisphere, as there is less land in the middle latitudes to obstruct the flow. The Westerlies play an important role in carrying the warm, equatorial waters and winds to the western coasts of continents, especially in the southern hemisphere because of its vast oceanic expanse.

(c) Polar Wind

The winds blowing in the Arctic and the Antarctic latitudes are known as the Polar Winds. They have been termed as the **'Polar Easterlies'**, as they blow from the Polar High Pressure belt towards the Sub-Polar Low-Pressure Belts. In the Northern Hemisphere, they blow in general from the north-east, and are called the North-East Polar Winds; and in the Southern Hemisphere, they blow from the south-east and are called the South-East Polar Winds. As these winds blow from the ice-capped landmass, they are extremely cold. They are more regular in the Southern Hemisphere than in the Northern Hemisphere.

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Periodic Winds

The direction of these winds changes with the change of seasons. Monsoon winds are the most important periodic winds.

The word 'Monsoon' has been derived from the Arabic word 'Mausim' meaning season. The winds that reverse their direction with the change of seasons are called monsoon winds. During summer the monsoon winds blow from sea towards land and during winter from land towards sea. Traditionally these winds were explained as land and sea breezes on a large scale. But this explanation does not hold good now. Now a days the monsoon is generally accepted as seasonal modification of the general planetary wind system. The Asiatic monsoon is the result of interaction of both planetary wind system and regional factors, both at the surface and in the upper troposphere. India, Pakistan, Bangladesh, Myanmar (Burma), Sri Lanka, the Arabian Sea, the Bay of Bengal, South-east Asia, North Australia, China and Japan are important regions where monsoon winds are prevalent.

Summer Monsoon

During the summer, monsoon winds blow from the cooler ocean surfaces onto the warmer continents. In the summer, the continents become much warmer than the oceans because of a number of factors. These factors include:

(i) Specific heat differences between land and water.

(ii) Greater evaporation over water surfaces.

(iii) Sub-surface mixing in ocean basins, which redistributes heat energy through a deeper layer.

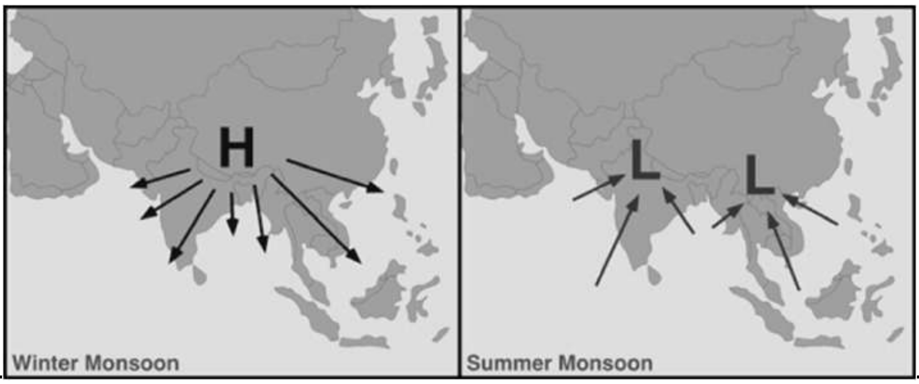
Precipitation is normally associated with the summer monsoons. Onshore winds blowing inland from the warm ocean are very high in humidity, and slight cooling of these air masses causes condensation and rain. In some cases, this precipitation can be greatly intensified by orographic uplift. Some highland areas in Asia receive more than 10 meters of rain during the summer months.

Winter Monsoon

In the winter, the wind patterns reverses, as the ocean surfaces are now warmer. With little solar energy available, the continents begin cooling rapidly as longwave radiation is emitted to space. The ocean surface retains its heat energy longer because of water's high specific heat and subsurface mixing. The winter monsoons bring clear dry weather and winds that flow from land to sea.

World Monsoonal Climate

The Asiatic monsoon is the result of a complex climatic interaction between the distribution of land and water, topography, and tropical and mid-latitudinal circulation. In the summer, a low-pressure center forms over northern India and northern Southeast Asia because of higher levels of received solar insolation. Warm moist air is drawn into the thermal lows from air masses over the Indian Ocean. Summer heating also causes the development of a strong latitudinal pressure gradient and the



Winter Monsoon
Summer Monsoon

development of an easterly jet stream at an altitude of about 15 kilometers at the latitude of 25° north. The jet stream enhances rainfall in Southeast Asia, in the Arabian Sea, and in South Africa. When autumn returns to Asia the thermal extremes between land and ocean decrease and the westerlies of the mid-latitudes move in. The easterly jet stream is replaced with strong westerly winds in the upper atmosphere. Subsidence from an upper atmosphere cold layer above the Himalayas produces outflow that creates a surface high-pressure system that dominates the weather in India and Southeast Asia.

Besides, Asian continent, monsoon wind systems also exist in Australia, Africa, South America, and North America.

Local Winds

Local winds usually affect small areas and are confined to the lower levels of the troposphere. Some of the local winds are given below :

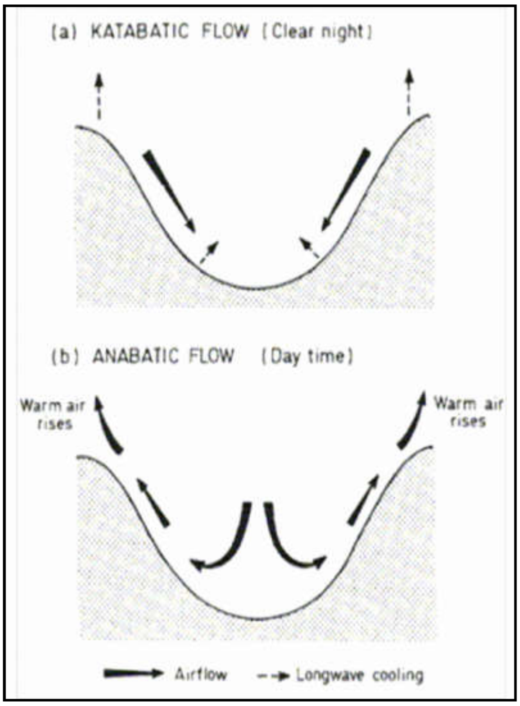
(a) Land and Sea Breezes:

A **land breeze** is created when the land is cooler than the water such as at night and the surface winds have to be **very** light. When this happens the air over the water slowly begins to rise, as the air begins to rise, the air over the surface of the ocean has to be replaced, this is done by drawing the air from the land over the water, thus creating a sea breeze.

A **sea breeze** is created when the surface of the land is heated sufficiently to start air rising. As air rises, it is replaced by air from the sea and creates a sea breeze. Sea breezes tend to be much stronger and can produce gusty winds as the sun can heat the land to very warm temperatures, thereby creating a significant temperature contrast to the water.

(b) Mountain and Valley winds:

Mountain-valley breezes are formed by the daily difference of the thermo effects between peaks and valleys. In daytime, the mountainside is directly heated by the sun, the temperature is higher, air expands, air pressure reduces, and therefore air will rise up the mountainside from the valley and generate a valley breeze. The valley breeze reaches its maximum force at around 2 p.m. After this time, the breeze decreases in power and come to a complete stop by sunset. By nightfall, the mountainside region is able to dissipate heat more quickly, due to its higher altitude and therefore temperature drops rapidly. Cold air will then travel down the mountainside from the top and flow into the valley, forming a mountain breeze.



In daytime, valley breezes carry water vapor to the peak, which will often condense into clouds; these are the commonly seen peak and flag clouds. When the mountain breeze travels down and gathers in the valleys, water vapor will condense. Therefore in valley or basin regions, there are usually clouds and fog before sunrise. During late spring or early autumn, the cold air trapped in the valley and basin will often generate frost. That's why farmers usually plant cold-sensitive plants such as tangerines and coffee on mountainsides.

(c) Hot and cold winds

Loo, Foehn and Chinook are important hot winds of local category.

Loo are hot and dry winds, which blow very strongly over the northern plains of India and Pakistan in the months of May and June. Their direction is from west to east and they are usually experienced in the afternoons. Their temperature varies between 45°C to 50°C.

Foehn is strong, dusty, dry and warm local wind which develops on the leeward side of the Alps mountain ranges. Regional pressure gradient forces the air to ascend and cross the barrier. Ascending air sometimes causes precipitation on the windward side of the mountains. After crossing the mountain crest, the Foehn winds starts descending on the leeward side or northern slopes of the mountain as warm and dry wind. The temperature of the winds vary from 15°C to 20°C which help in melting snow. Thus making pasture land ready for animal grazing and help the grapes to ripe early.

Chinook is the name of hot and dry local wind which moves down the eastern slopes of the Rockies in U.S.A. and Canada. The literal meaning of chinook is 'snow eater' as they help in melting the snow earlier. They keep the grasslands clear of snow. Hence they are very helpful to ranchers.

The local cold winds originate in the snow-capped mountains during winter and move down from the slopes towards the valleys. They are known by different names in different areas.

Mistrals are most common local cold winds. They originate on the Alps and move over France towards the Mediterranean Sea through the Rhone valley.

They are very cold, dry and high velocity winds. They bring down temperature below freezing point in areas of their influence. People in these areas protect their orchards and gardens by growing thick hedges and build their houses facing the Mediterranean sea.

Hot Winds		
Sirocco	-	Sahara Desert
Leveche	-	Spain
Khamsin	-	Egypt
Harmattan	-	Sahara Desert
Santa Ana	-	USA
Zonda	-	Argentina
Brick fielder	-	Australia
Cold Winds		
Mistral	-	Spain and France
Bora	-	Adriatic coast
Pampero	-	Argentina
Buran	-	Siberia
Descending Winds		
Chinook	-	USA

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Fohn	-	Switzerland
Berg	-	Germany
Norwester	-	New Zealand
Samun	-	Persia (Iran)
Nevados	-	Ecuador

Jet-Steams

The term was introduced in 1947 by Carl Gustaf Rossby. Average speed is very high with a lower limit of about 120 km in winter and 50 km per hours in summer. The JET STREAMS located in the upper troposphere (9 - 14 km) are bands of high speed winds (95-190 km/hr). The two most important types of jet streams are the **Polar Jet Streams** and the **Subtropical Jet Streams**. They are found in both the Northern and Southern Hemispheres.

Polar Jet Stream: These jet streams are created when cold air from the Polar Regions meets warmer air from the equator. This temperature gradient as a result forms a pressure gradient that increases wind speed. During the winter, these jet streams bring winter storms and blizzards to the United States and in summer, they become weaker and move towards high latitudes. They are found in both Northern and Southern Hemispheres.

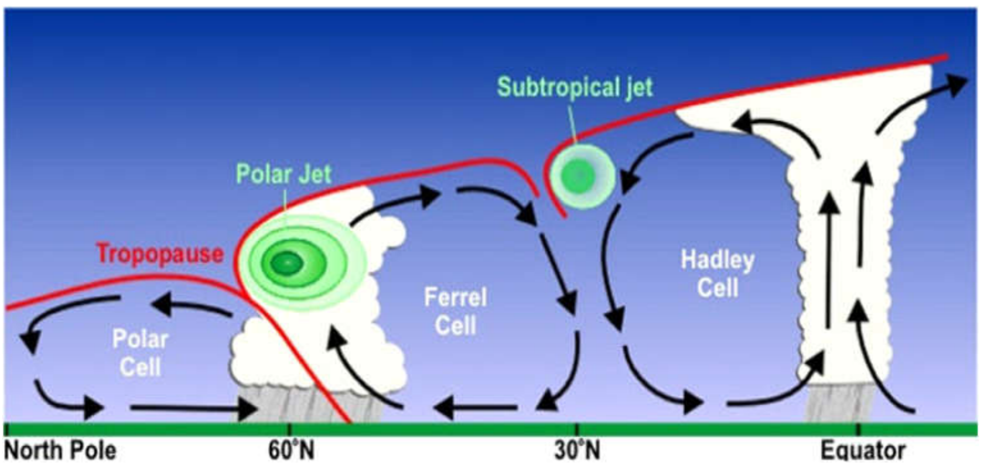
Sub-Tropical Jet Stream: These jet streams are formed as warm air from the equator moves towards the poles that form a steep temperature incline along a subtropical front that like the polar jet streams produce strong winds. In Southeast Asia, India, and Africa, these jet streams help bring about the region's monsoon or rainy climate. As these jet streams warm, the air above the Tibetan highlands, a temperature and pressure gradient is formed as the air from the ocean is cooler than that above the continental high lands. This as a result forms on-shore winds that produces the monsoon.

Formation of Jet Stream

Warm air masses in the south meet cool air masses from the north and create temperature and air pressure gradients. The pressure difference between a high and low pressure zone can be very large, thereby creating high winds. Pressure and temperature differences in the jet stream can be large as a global warm front from the south and a cold front from the north meet.

Index Cycle of the Jet Stream

There are many stages for the development of jet streams. In the first stage the jet stream lies quite close to the polar regions and flows from west to east. In the northern hemisphere, the cold air mass is found to the north of the upper level westerlies. To the south of the jet lies the mild air of the mid latitudes. The westerlies in this stage have shifted towards higher latitudes where there is a lot of cyclonic



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activity. Pressure systems in this stage have got east west orientation. North south pressure gradient is relatively steeper. The air mass exchange between the temperature and tropical regions is at its minimum. The first stage thus represents the high zonal index.

In the second stage, the amplitude of jet stream waves increases. The whole of the jet moves towards the equator as a result of which there is an inroad of cold polar air southward. The warm air masses from lower latitudes move towards higher latitudes.

In the third state, the bends in the jet stream become sharper and the amplitude of waves registers a further increase. At this stage the tropical air masses move farther north, and the cold polar air moves farther south. Now the jet stream is positioned nearer the equator and the exchange of tropical and polar air masses takes place on a much larger scale. The temperature gradient is directed from east to west.

In the last stage of index, cycle, the giant size meanders of the jet are cut off from the main stream. The result is that an immense pool of cold and dense polar air is isolated in the upper troposphere of the lower latitudes where it is encircled by entirely different air masses. In the upper atmosphere of higher latitudes the tropical air masses are entrapped by the colder air. This is called the low zonal index of the jet stream. The zonal character of the upper level westerlier is no longer in existence. They are fragmented into a number of cells.

Jet Stream and Surface Weather

The jet stream is said to play a very significant role in controlling the behaviour of terrestrial atmosphere. Although weather scientists are not yet clear about the ever changing form and features of jet stream, it is true that there is a close relationship between the jet stream and surface weather. But the exact nature of this relationship still remains poorly understood.

Now it is an established fact that the so called polar front jet streams are closely related to the middle latitude weather disturbances. The meanders of the more northerly upper troposphere jet stream determine the location of the surface polar front. Besides, the paths followed by the cyclones are also largely controlled by these upper level high velocity westerlies. Even the distribution of precipitation by extra tropical cyclones is indirectly influenced by the jet streams aloft. Meteorologists agree that areas lying below the jet may have heavy precipitation. The jet streams also play an important role in the movement of different air masses which may produce a prolonge period of drought or flood. Whatever be the cause of the everchanging patterns of the jet, there is hardly any doubt that the jet streams have important repercussions upon the world weather.

There are evidences that the eddies produced in these upper air streams come down to affect the cyclonic weather. Rainfall, snowfall, thunder storms of varying intensities, tornadoes, cold waves or snow storms are all directly affected by the jet streams aloft.

Besides, migration of high and low pressure cells on the surface of the earth is also directly related to the shifting position of the jet streams as they move around the earth. For instance, the dynamically produced high pressure cells within the subtropical belts owe their existence to the upper westerlies and the jet stream. Thus, it is evident that different surfaces weather patterns are closely linked with changes in the path of the jet stream.

El Nino and La Nina situation

Normal condition

In general, the water on the surface of the ocean is warmer than at the bottom because it is heated by the sun. In the tropical Pacific, winds generally blow in easterly direction. These winds tend to push the surface water toward the west also. As the water moves west it heats up even more because it's exposed longer to the sun.

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Meanwhile in the eastern Pacific along the coast of South America an upwelling occurs. Upwelling is the term used to describe when deeper colder water from the bottom of the ocean moves up toward the surface away from the shore. This nutrient-rich water is responsible for supporting the large fish population commonly found in this area. Indeed, the Peruvian fishing grounds are one of the five richest in the world.

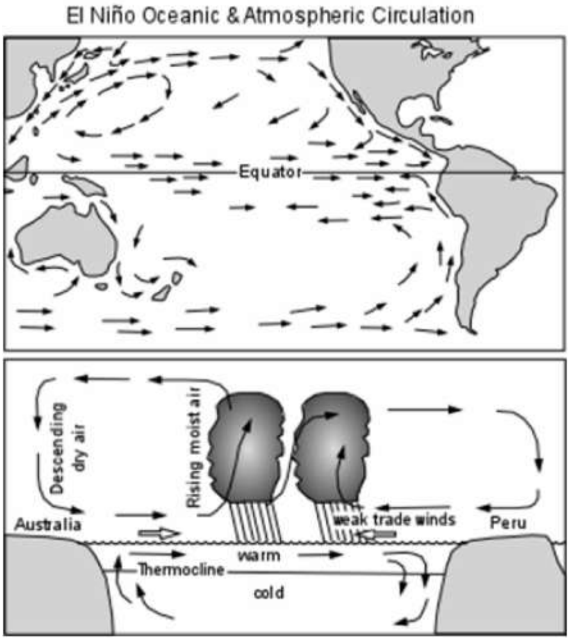
Because the trade winds push surface water westward toward Indonesia, the sea level is roughly half a meter higher in the western Pacific than in the east. Thus you have warmer, deeper waters in the western Pacific and cooler, shallower waters in the east near the coast of South America. The different water temperature of these areas affects the types of weather these two regions experience.

In the east the water cools the air above it, and the air becomes too dense to rise to produce clouds and rain. However, in the western Pacific the air is heated by the water below it, increasing the buoyancy of the lower atmosphere thus increasing the likelihood of rain. This is why heavy rain storms are typical near Indonesia while Peru is relatively dry.

El Nino condition

El Nino happens when weakening trade winds (which sometimes even reverse direction) allow the warmer water from the western Pacific to flow toward the east. This flattens out the sea level, builds up warm surface water off the coast of South America, and increases the temperature of the water in the eastern Pacific.

An El Nino condition results from weakened trade winds in the western Pacific Ocean near Indonesia, allowing piled-up warm water to flow toward South America.



The deeper, warmer water in the east limits the amount of nutrient-rich deep water normally surfaced by the upwelling process. Since fish can no longer access this rich food source, many of them die off. This is why these conditions are called "El Nino", or "the Christ Child", which is what Peruvian fisherman call the particularly bad fishing period around December. More importantly, the different water temperatures tend to change the weather of the region.

What happens to the ocean also affects the atmosphere. Tropical thunderstorms are fueled by hot, humid air over the oceans. Hotter the air, the stronger and bigger the thunderstorms. As the Pacific's warmest water spreads eastward, the biggest thunderstorms move with it.

The clouds and rainstorms associated with warm ocean waters also shift toward the east. Thus, rains which normally would fall over the tropical rain forests of Indonesia start falling over the deserts of Peru, causing forest fires and drought in the western Pacific and flooding in South America. Moreover the Earth's atmosphere reponds to the heating of El-Nino by producing patterns of high and low pressure which can have a profound impact on weather far away from the equatorial Pacific. For instance, higher temperature in western Canada and the upper plains of the United States whereas colder temperature in the southern United States. The east coast of southern Africa often experiences drought during El Nino.

La Nina

If, on the other hand, the surface trade winds strengthen along with it the east-west oceanic temperature gradients the resulting weather pattern leads to an anti-El Niño, that is often referred to as La Niña. Such events

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are characterized by a high positive Southern Oscillation Index (i.e., an increased westward pressure gradient over the equatorial Pacific), stronger surface trade winds over the central Pacific, and cooler SSTs in the eastern equatorial Pacific. Such a weather pattern, on the other hand, is associated with increased cyclone activity in the western Pacific, off shore of eastern Australia, the Phillipines, and the western Atlantic region.

Precipitation

Moisture, or water vapour, is an extremely important constituent of the atmosphere. Water vapour present in the air is known as humidity. The nature and amount of precipitation, the amount of loss of heat through radiation from the earth's surface, latent heat of atmosphere etc. depend on the amount of water vapour present in the atmosphere.

Water vapour is derived through the process of evaporation from oceans, seas, rivers, lakes, etc. Humidity capacity that is content of water vapour in the air is directly positively related with temperature, i.e., higher the temperature higher the humidity capacity. Oceanic and coastal areas record higher humidity capacity. It decreases from equator to pole.

Humidity of a place can be expressed in Absolute humidity which is the ratio of the mass of water vapour actually in the air to a unit mass of air, including the water vapour. It is expressed in gram per cubic metre of air. For example, if the absolute humidity of air is 10 grams it means that one cubic metre of that air holds 10 grams of moisture in the form of water vapour. Absolute humidity is variable and changes from place to place and with change in time. The ability of an air to hold water vapour depends entirely on its temperature. The capacity of holding water vapour of an air increases with the increase in its temperature.

Relative humidity is the most important and reliable measure of atmospheric moisture. It is the ratio of the amount of water vapor actually in a volume occupied by air to the amount the space could contain at saturation. The relative humidity increases when the temperature of the air goes down or when more moist air is added to it. The relative humidity decreases when the temperature of the air increases or when less moist air is added to it

Evaporation and Condensation concept related to Precipitation

Evaporation is the process in which water changes from its liquid state to gaseous form. This process takes place at all places, at all times and at all temperatures except at dew point or when the air is saturated. The rate of evaporation is affected by several factors such as;

(i) The rate of evaporation is higher over the oceans than on the continents.

(ii) When the temperature of an air is high, it is capable of holding more moisture in its body than at a low temperature. It is because of this that the rate of evaporation is more in summers than in winters. That is why wet clothes dry faster in summers than in winters.

(iii) If the relative humidity of a sample of air is high, it is capable of holding less moisture. On the other hand if the relative humidity is less, it can take more moisture. Hence, the rate of evaporation will be high. Aridity or dryness of the air also increases the rate of evaporation. During rainy days, wet clothes take more time to dry owing to the high percentage of moisture content in the air, than on dry days.

(iv) Wind also affects the rate of evaporation. If there is no wind, the air which overlies a water surface will get saturated through evaporation. This evaporation will cease once saturation point is reached. However, if there is wind, it will blow that saturated or nearly saturated air away from the evaporating surface and replace it with air of lower humidity. This allows evaporation to continue as long as the wind keep blowing saturated air away and bring drier air.

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(v) The cloud cover prevents solar radiation and thus influences the air temperatures at a place. This way, it indirectly controls the process of evaporation.

Condensation is the process by which atmospheric water vapour changes into water or ice crystals. It is just reverse of the process of evaporation. When the temperature of saturated air falls below dew point, the air cannot hold the amount of humidity which it was holding earlier at a higher temperature. This extra amount of humidity changes into water droplets or crystals of ice depending upon the temperature at which condensation takes place.

Process of condensation

The temperature of the air falls in two ways. Firstly, cooling occurs around very small particles of freely floating air when it comes in contact with some colder object. Secondly, loss in air temperature takes place on a massive scale due to rising of air to higher altitudes. The condensation takes place around the smoke, salt and dust particles which attract water vapour to condense around them. They are called hygroscopic nuclei. When the relative humidity of an air is high, a slight cooling is required to bring the temperature down below dew point. But when the relative humidity is low and the temperature of the air is high, a lot of cooling of the air will be necessary to bring the temperature down below dew point. Thus, condensation is directly related to the relative humidity and the rate of cooling.

Condensation takes place in two situations, firstly, when dew point is below freezing point or below 0° C and secondly, when it is above freezing point. In this way, the forms of condensation may be classified into two groups:

(i) Frost, snow and some clouds are formed when dew point is below freezing point.

(ii) Dew, mist, fog, smog and some clouds are formed when dew point is above freezing point.

The forms of condensation may also be classified on the basis of place where it is occurring, for example, on the ground or natural objects such as grass blades and leaves of the plants or trees, in the air close to the earth's surface or at some height in the troposphere.

(i) Dew

When the atmospheric moisture is condensed and deposited in the form of water droplets on cooler surface of solid objects such as grass blades, leaves of plants and trees and stones, it is termed as dew. Condensation in dew form occurs when there is clear sky, little or no wind, high relative humidity and cold long nights. These conditions lead to greater terrestrial radiation and the solid objects become cold enough to bring the temperature of air down below dew point. In this process the extra moisture of the air gets deposited on these objects.

Dew is formed when dew point is above freezing point. Dew formation can be seen if the water is poured into a glass from the bottle kept in a refrigerator. The outer cold surface of the glass brings the temperature of the air in contact with the surface down below dew point and extra moisture gets deposited on the outer wall of the glass.

(ii) Frost

When the dew point is below freezing point, under above mentioned conditions, the condensation of extra moisture takes place in the form of very minute particles of ice crystals. It is called frost. In this process, the air moisture condenses directly in the form of tiny crystal of ice. This form of condensation is disastrous for standing crops such as potato, peas, pulses, grams, etc. It also creates problems for road transport system.

(iii) Mist and Fog

When condensation takes place in the air near the earth's surface in the form of tiny droplets of water hanging and floating in the air, it is called mist. In mist the visibility is more than one kilometer and less than two kilometers. But when the visibility is reduced to less than one kilometer, it is called fog. Ideal conditions for the formation of mist and fog are clear sky, calm and cold winter nights.

(iv) Smog

Smog is a fog that has been polluted and discoloured by smoke, dust, carbon monoxide, sulphur dioxide and other fumes. Smog frequently occurs in large cities and industrial centres. It causes respiratory illness.

(v) Cloud

Clouds are visible aggregates of water droplets, ice particles, or a mixture of both along with varying amounts of dust particles. A typical cloud contains billions of droplets having diameters on the order 0.01 to 0.02 mm; yet liquid or solid water accounts for less than 10 parts per million of the cloud volume. Clouds are generally classified on the basis of their general form or appearance and altitude.

Clouds are very significant because

- They cause all forms of precipitation.
- They play a major role in the heat budget of the earth.
- They reflect, absorb some part of incoming solar radiation as well as some part of long-wave terrestrial radiation re-radiated by the earth.

Types of clouds

1. **Cirrus clouds:** These clouds form above 20,000 feet (6,000 meters) and since the temperatures are extremely low at such high elevations, these clouds are primarily composed of ice crystals. High-level clouds are typically thin and white in appearance, but can appear in a magnificent array of colors when the sun is low on the horizon.
2. **Cirro-cumulus:** These clouds appear as small, rounded white puffs. The small ripples in the cirrocumulus sometimes resemble the scales of a fish. A sky with cirrocumulus clouds is sometimes referred to as a "mackerel sky."
3. **Cirro-stratus:** These clouds are thin, sheet-like high clouds that often cover the entire sky. They are so thin that the sun and the moon can be seen through them.
4. **Altocumulus clouds:** These are middle level clouds that are made up of water droplets and appear as gray, puffy masses, sometimes rolled out in parallel waves or bands.
5. **Altostratus clouds:** These are gray or blue-gray middle level clouds composed of ice crystals and water droplets. These clouds usually cover the entire sky. In the thinner areas of the cloud, the sun may be dimly visible as a round disk. Altostratus clouds often forms ahead of storms that produces continuous precipitation.
6. **Stratus clouds:** These are uniform grayish clouds that often cover the entire sky. They resemble fog that does not reach the ground. Usually no precipitation falls from stratus clouds, but sometimes they may drizzle. When a thick fog "lifts," the resulting clouds are low stratus.
7. **Nimbostratus clouds:** These form a dark gray, "wet" looking cloudy layer associated with continuously falling rain or snow. They often produce precipitation that is usually light to moderate.

Notes

8. **Cumulonimbus clouds:** These are thunderstorm clouds that form if cumulus congestus clouds continue to grow vertically. Their dark bases may be no more than 300 m (1000 ft) above the Earth's surface. Their tops may extend upward to over 12,000 m (39,000 ft). Tremendous amount of energy is released by the condensation of water vapour within a cumulonimbus. Lightning, thunder, and even violent tornadoes are associated with the cumulonimbus.

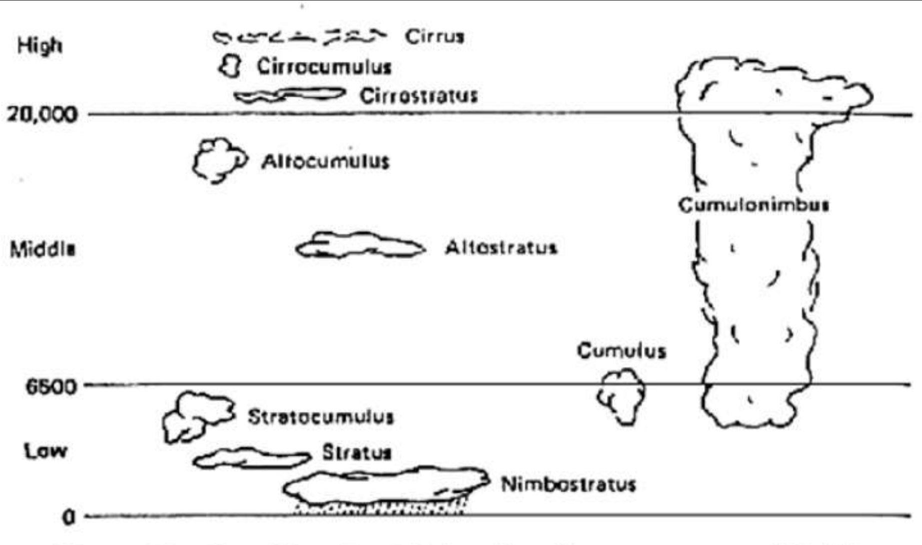

Figure 68. Prevailing cloud designations by appearance and height.

9. **Cumulus clouds:** These are puffy clouds that sometimes look like pieces of floating cotton. The base of each cloud is often flat and may be only 1000 m (330 ft) above the ground. The top of the cloud has rounded towers. When the top of the cumulus resembles the head of a cauliflower, it is called cumulus congestus or towering cumulus. These clouds grow upward, and they can develop into a giant cumulonimbus, which is a thunderstorm cloud.

Precipitation

Precipitation is water released from clouds in the form of rain, freezing rain, sleet, snow, or hail on the Earth's surface. When air is lifted in the atmosphere, it expands and cools and leads to the formation of clouds. The clouds floating overhead contain water vapour and cloud droplets, which are small drops of condensed water. For precipitation to happen, first tiny water droplets must condense on even tinier dust, salt, or smoke particles, which act as a nucleus. Some vapor freezes into tiny ice crystals which attract cooled water drops. The drops freeze to the ice crystals, forming larger crystals known as snowflakes. When the snowflakes become heavy, they fall as it exceeds the cloud updraft speed. When the snowflakes meet warmer air on the way down, they melt into raindrops.

Conditions of Occurrence of Precipitation

- Precipitation is the result of a complex series of micro-physical processes within a cloud.
- Precipitation may form as a result of collision and coalescence within a cloud.
- Precipitation may form where ice crystals and water droplets coexist within a cloud; this precipitation mechanism is known as the Bergeron-Findeisen process.
- Precipitation-size droplets do not form instantly. It takes time for the droplets to grow in size. Only if the conditions favourable to droplet growth last for a sufficient length of time then only precipitation will reach the ground.

Forms of Precipitation

The precipitation falls on the earth in various forms of droplets of water, ice flakes and solid ice balls or hail and at times droplets of water and hail together.

Notes

The form that precipitation takes is largely dependent upon the method of formation and temperature during the formation. The forms of precipitation are as follows:

(i) Drizzle and Rainfall :

Drizzle is a fairly uniform precipitation composed exclusively of fine drops of water with diameter less than 0.5 mm. Only when droplets of this size are widely spaced are called rain.

(ii) Snowfall:

When condensation takes place below freezing point (-0°C), the water vapour changes into tiny ice crystals. These tiny ice crystals grow in size and form ice flakes which become big and heavy and start falling on the ground. This form of precipitation is called snowfall. Snowfall is very common in Western Himalaya and mid and high latitude regions in winter.

(iii) Sleet:

Sleet is frozen rain, formed when rain before falling on the earth, passes through a cold layer of air and freezes. The result is the creation of solid particles of clear ice. It's usually a combination of small ice balls and rime.

(iv) Hail :

Hail is precipitation of small balls or pieces of ice (hail stones) with diameters ranging from 5 to 50mm, falling either separately or agglomerated into irregular lumps. Hailstones are comprised of a series of alternating layers of transparent and translucent ice.

Rain is the most common form of precipitation. When minute droplets of water are condensed from water vapor in the atmosphere on to nuclei, they may float in the atmosphere as clouds. If the droplets coalesce, they will form larger drops which will be enough to overcome by gravity and will fall as rain to the surface of the earth.

There are three major types of rainfall

a) **Conventional Rainfall:** It occurs when moist air, having been warmed by Conduction from a heated surface, expands, rises and is adiabatically cooled to the dew point. Cumulus clouds develop and may fall accompanied by thunder.

Convectional rainfall occurs commonly during the afternoon near the equator due to high temperature and high humidity.

b) **Orographic Rainfall:** This type of rainfall occurs when air is forced to ascend the side of a mountain range. When land barriers such as mountain ranges, hilly regions or even escarpments of plateaus lie in the path of prevailing winds, large portion of the atmospheric air is forced to rise above these barriers. This resultant precipitation is termed as orographic. Because the air has deposited on the windward side of the mountain, there will be normally less rainfall on the leeward side which is known as RAIN SHADOW AREA.

c) **Frontal Rainfall:** Cyclonic or Frontal precipitation results when the warm, moist air mass (warm front) meets a cool and dry air mass (cold front). The molecules in the cold air are more tightly packed together (i.e., more dense), and thus, the cold air is heavier than the warm air. The warmer air mass is forced up over the cool air. As it rises, the warm air cools, the water vapour in the air condenses, and forms clouds and results in precipitation.

Notes

This type of system is called Frontal Precipitation because the moisture tends to occur along the front of the air mass.

Factors Affecting Rainfall Distribution

(i) Moisture supply to the atmosphere is the main factor in determining the amount of rainfall in any region. Equatorial and rest of the tropical region have highest evaporation and hence highest supply of moisture. Coastal areas have more moisture than interior parts of continents. Frigid regions have very low evaporation hence very scanty precipitation.

(ii) Wind direction in the belts of trades and westerlies winds is very important. Winds blowing from sea to land cause rainfall. Land bearing winds are dry. Winds blowing from higher to lower latitudes will get heated and give no rain while those blowing from lower to higher latitudes will get cooled and cause rainfall. Sub-tropical deserts have very little rainfall because they have off-shore winds.

(iii) Ocean currents : Warm current are associated with warm moist winds which cause rainfal1, cold current have cold dry wind and hence no rainfall.

(iv) Presence of mountain across the direction of wind causes more rainfall on the windward side and creates rain shadow on the leeward side.

(v) Pressure belts are closely related with wind direction and rainfall. Areas of low pressure attract rain bearing winds while areas of high pressure do not.

Global Distribution of Rainfall

The global distribution of precipitation is influenced by the general circulation of the atmosphere, proximity to large bodies of water, and topography.

Factors controlling the distribution of rainfall over the earth's surface are the belts of converging-ascending air flow, air temperature, moisture-bearing winds, ocean currents, distant inland from the coast, and mountain ranges.

The Earth's atmosphere is known to have regions characterized by large scale rising air, and other regions with descending air; these vary by latitude and by season. Rising air is found primarily near the equator and in the mid-latitudes (40° to 60° North and South latitude), so these tend to be wet areas. Descending air dominates in the subtropics (20° to 30° North and South latitude) and the poles. The global distribution of precipitation shows that the wettest areas on Earth are in the "rising air" zones, while the driest areas (subtropical deserts and the even drier polar areas) are in the "descending air" belts.

The Earth revolves around the Sun thus the orientation of its axis relative to the Sun changes. This causes the apparent position of the Sun relative to the Earth to change, and creates distinct seasons. Between March and September, the axis of Earth is tilted toward the Sun, and hence the Sun shines more directly over the Northern Hemisphere, resulting in more sunlight, more heat, and the warmer temperatures of Northern summer. In the other 6 months, the Earth's axis is tilted away from the Sun, and the Sun shines more directly over the Southern Hemisphere, bringing summer to countries south of the Equator (and winter to the north).

The "rising" and "sinking" zones move northward and southward with the Sun's path. Thus, the wet area near the Equator moves northward into the Northern Hemisphere in its summer and southward into the Southern Hemisphere during its summer. Similarly, the dry zones and wet zones at higher latitudes shift northward and southward throughout the year.

The result of these shifting zones is latitude bands with distinctive precipitation characteristics:

0-5° latitude: wet throughout the year (rising zone)

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5-20° latitude: wet summer (rising zone), dry winter (sinking zone)

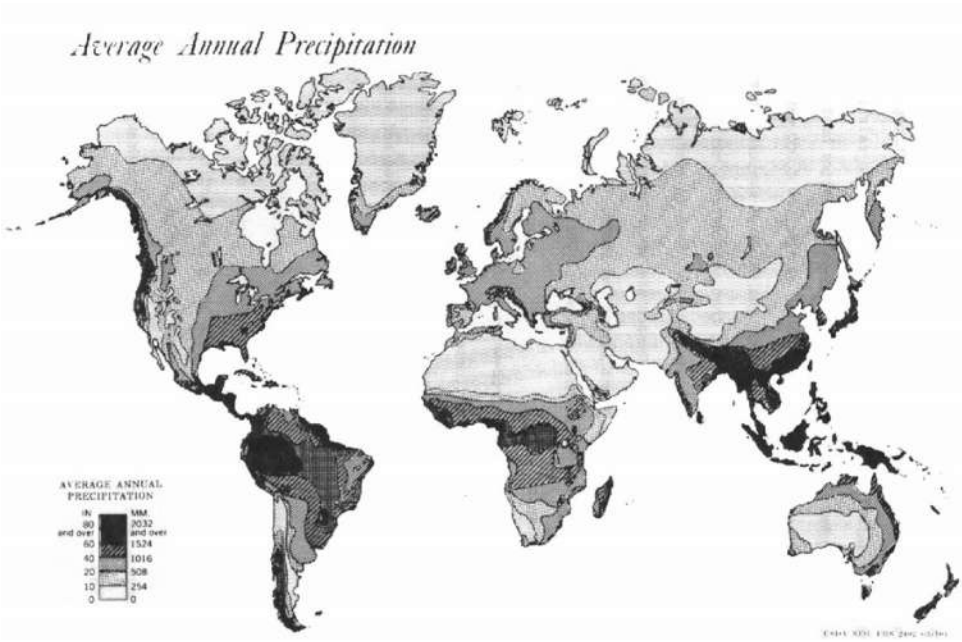
20-30° latitude: dry all year (sinking zone)

30-50° latitude: wet winter (rising zone), dry summer (sinking zone)

50-60° latitude: wet all year (rising zone)

60-70° latitude: wet summer (rising zone), dry winter (sinking zone)

70-90° latitude: dry all year (sinking zone)



If the Earth had no mountains, and oceans were homogeneous with respect to their heat content, the climate would occur in latitude bands like those listed above. However, due to presence of mountains, strong influence on precipitation exerts.

When moving air encounters a hill or mountain, it is forced to rise. As the rising air cools and condenses, precipitation is heaviest on the upwind side of a mountain, where the air is rising. This process is known as orographic lifting. On the downwind side, air descends, warms, and becomes drier thus forms rain shadow area. One example of a mountainous area receiving frequent rain is Mt. Waialeale on Kauai, Hawaii. It is a sharp peak directly in the path of steady trade winds which blow from the northeast most of the time. On the upwind (northeast) side of Waialeale, the air rises and condenses; resulting in almost constant clouds-nearly every day thus experiences rain. Waialeale is among the wettest places on Earth. In contrast, on the downwind (southwest) side of Mt. Waialeale, the air descends, warms, and dries, in an area known as a "rain shadow." The result is a semiarid area with less than 51 centimeters (20 inches) of rain a year.

The other factor that affects the rainfall distribution is presence of water bodies, i.e., oceans, lakes, rivers, etc.

Zonal Distribution of Rainfall

- **Equatorial Zone of Maximum Rainfall:** This zone extends **upto 10°** latitudes on either side of the equator characterized by warm and moist air masses. Rainfall occurs mainly due to convectional rainfall and mean annual ranges from 1750mm to 2000mm.
- **Trade Wind Rainfall Zone:** This zone extends between **10-20 degrees** latitudes in both the hemispheres and is characterized by north-east and south-east trade winds. These winds yield rainfall in the eastern part of the continent as they flow over oceans and brings moisture. Thus, the western part of the continents becomes extremely dry and deserts.
- **Subtropical Zone of Minimum Rainfall:** This zone extends between **20-30 degrees** latitudes in both the hemisphere where descending air from above induces high pressure and winds thus results in anti cyclonic conditions.
- **Mediterranean Rainfall Zone:** This rainfall zone extends between **30-40 degrees** latitudes in both the hemispheres where rainfall occurs through Westerlies and cyclones during winter season while summer seasons are dry.

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- **Mid-latitudinal Zone:** This zone extends between **40-50 degrees** latitudes in both the hemispheres where rainfall occurs due to Westerlies and Temperate Cyclones.
- **Polar Zone:** It extends from **60 degree to pole** in both the hemispheres. Precipitation mainly occurs in the form of snow.

Indian Monsoon

Monsoons refer to a system of winds in the tropical regions under which the direction of winds is reversed completely between the summer and the winter seasons. Under this system, the winds blow from land to sea in winter and from sea to land in summer. Therefore, most of the rainfall in the region influenced by the monsoon is received in the summer season while winter season is generally dry.

According to the traditional belief, the monsoon is caused by the differential heating of land and sea. Due to higher temperature over the land in summer, a low pressure area develops over the continents and the winds blow from neighbouring oceans towards the land. These winds are of maritime origin and hence cause ample rainfall in summer. On the other hand, the continents become colder than the neighboring oceans in winter. As a result a high pressure area is developed over the continents. Therefore, winds blow from land to sea in winter. These winds, being of continental origin, are dry and do not cause rain. This traditional theory of monsoon has been criticized by the German meteorologist Flohn. He argues that the differential heating of land and sea is not enough to cause a seasonal reversal of winds at a global scale. He has explained the origin of the monsoon on the basis of seasonal shift of the pressure and wind belts under the influence of the shift of the vertical rays of the sun.

According to this theory, as the vertical rays of the sun shift northwards over the Tropic of Cancer in summer season, the Inter-Tropical Convergence Zone (ITCZ) also shifts to north. This results in the formation of a low pressure area over the northwestern parts of India. This low pressure is further intensified by the high temperature in this region. This low pressure area sucks the air from the Indian Ocean towards the Indian landmass in the form of Southwest monsoons. In winter season, the ITCZ shifts southwards and a mild high pressure is produced over northern parts of India. This high pressure is further intensified by the equator ward shift of the sub tropical high pressure belt. Due to high pressure over northern lndia, the winds start blowing from northeast as retreating monsoons. According to recent observations, the origin of Indian monsoon is influenced by a number of other factors, besides the differential heating of land and sea and the seasonal shifts of pressure and wind belts.

a) **Role of Jet Streams:** M.T.Yin had given this concept stating that the burst of monsoon depends upon the upper air circulation. Two prominent jet streams effect the monsoon winds.

- **The Sub Tropical Westerly Jet Stream:** This jet stream dominates in winter time in upper troposphere circulation of the northern latitudes. It has a global extent between latitudes 25-32° N and can be located over South Asia at an elevation of about 12 km., the jet stream is split owing to the presence of Himalayan mountain system in its path.

  The winds tend to descend over north-western part of India resulting in atmospheric stability.

- **Equatorial Easterly Jet Stream:** This jet is a prominent feature of the upper air circulation during the Indian monsoon season appearing as a band of strong easterlies extending from South East Asia across the Indian Ocean and Africa to the Atlantic.

  The western and eastern jet streams flow in the north and south of the Himalayas respectively. The eastern jet becomes powerful and stationed and this results in more active south west monsoon.

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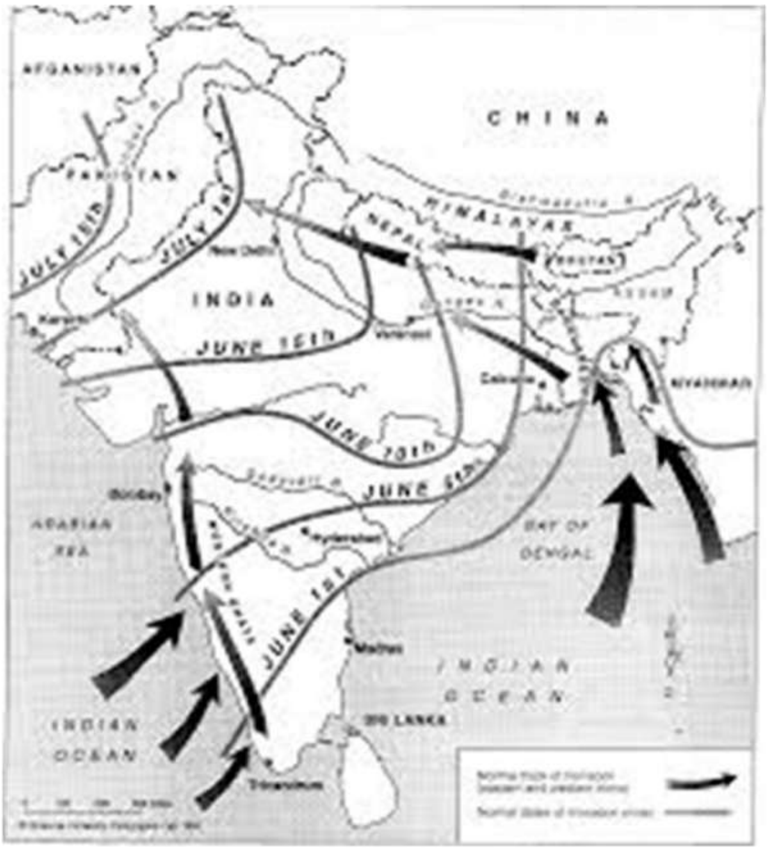
b) **Role of Tibetan Plateau:** The Tibetan plateau is located more than 4500 km above sea level with a length of 2000 km and with a width of 600 km in the west and 1000 km in the east.

This plateau is considered to be one of the key factors in the development of monsoon. The Tibetan plateau exerts its influence as a mechanical barrier as well as high heat plateau. An anticyclone appears in upper troposphere due to latent heating over the Tibetan plateau. It generates an area of rising air, during its ascent the air spreads outwards and gradually sinks over the equatorial part of the Indian Ocean. It picks up moisture from the Indian Ocean and causes rainfall in India and adjoining countries.



The peninsular shape of India divides these Southwest monsoons into two branches - Arabian Sea branch and Bay of Bengal branch.

(a) Arabian Sea branch of Southwest monsoons strikes the western coast of India and causes heavy rains on the western slopes of the Western Ghats. After crossing the Western Ghats, these winds cause less rainfall on the eastern slopes as they gain temperature while descending. This area is, therefore, known as rain shadow zone. This explains why interior parts of Maharashtra, Karnataka and Telangana get meagre rains from these winds. Southwest monsoons striking along the coast of Saurastra and Kuchchh and pass over Rajasthan and beyond to meet the Bay of Bengal branch. These winds cause widespread rain in these states and western Himalayan region.

(b) The Bay of Bengal branch is divided into two sub branches after striking eastern Himalayas. One branch moves towards the east northeast direction and causes heavy rains in Brahmaputra valley and northeast hills of India. The other branch moves towards northwest along the Ganga valley and the Himalayan ranges causing heavy and widespread rains over vast areas. In this region, the amount of rainfall decreases from east to west owing to the progressive decrease in humidity of these winds.

The Characteristics of Southwest Monsoons

(i) These winds generally strike the Indian coast in the first week of June but their arrival and departure may be before time or even it may be delayed.

(ii) There may be dry spells in between rainy periods. Such long dry spells may even lead to failure of crops.

(iii) At times, these winds skip over certain regions without any cause. The amount and timing of rainfall and intervening duration of wet and dry spells varies from year to year. This is known as the vagaries of the monsoons.

(iv) The spatial distribution of rainfall is uneven - some regions may receive heavy rains while the others will have to be contented with meagre or scanty rains.

(v) Generally, these winds start retreating by the end of September. But, sometimes, their departure may be delayed till October or they may retreat even much earlier

El Nino-Southern Oscillation (ENSO) Effect

A warm ocean current that originates along with Peru coast replacing usual cold current (Hambolt or Peru Current) is known as El Nino current. This warm surface water reaching towards the coast of Peru with El Niño is pushed westwards by the trade winds thereby raising the temperature of the southern Pacific Ocean. A reverse condition is known as La Niña.

Average temperature increases by 0.5 degree Celsius of eastern tropical Pacific oceans and this condition remains for 7-9 months and it occurred occasionally irregularly with periodicity of 2-7 years. Similarly cold phase of its also persists and occurred like hot phase and it is known as La Nina phenomenon.

The ENSO is known to have a pronounced effect on the strength of SW Monsoon over India with the Monsoon being weak (causing droughts in India) during the El Niño years whereas La Niña years had particularly good Monsoon strength over India.

Notes

Climate and Disaster

Climate change is predicted to have a range of serious consequences, some of which will have impact over the longer term, like spread of disease and sea level rise, while some have immediately obvious impacts, such as intense rain and flooding. While recognising the importance of the other predicted consequences of climate change, this report focuses on this second category: the 'extreme weather events' responsible for natural disasters. They include:

- Extreme temperature highs - heat waves
- Storms, including windstorms, hurricanes, etc.
- High levels of precipitation, and associated flooding
- Lack of precipitation, and associated drought

India with its vast population and unique geo-physical characteristics is one of the world's most 'disaster-prone' countries. Natural hazards such as cyclones, earthquakes, drought, floods or landslides occur in different parts of India in varying intensity. This means that we are all 'vulnerable' in different degrees to disasters caused by these hazards. On the East Coast, cyclones occur frequently. In the interior of the Plateau or in the Himalayas earthquakes, and in the Ganga-Brahmaputra plain, floods are more common.

Rajasthan or Western Orissa often experience severe drought, as do other areas in South India. In addition to this, social conditions that govern the way communities live, further affect the extent to which people are affected by the hazard. In order that we protect ourselves from the harmful effects of a disaster, we have to prepare ourselves in advance, to face them better. The process involving activities that help us to face disasters effectively is commonly known as 'disaster preparedness'.

India is Disaster-Prone...

- Over 55% of the Land Area
- Vulnerable to Earthquakes
- 12% to Floods
- 8% to Cyclones
- 70 % of the Land under Cultivation is prone to drought

Cyclones

A long coastline of about 7,516 km of flat coastal terrain, shallow continental shelf, high population density, geographical location and physiological features of its coastal areas makes India, in the North Indian Ocean (NIO) Basin, extremely vulnerable to cyclones and its associated hazards like storm tide and astronomical tide (the combined effects of storm surge), high velocity wind and heavy rains. Though the frequency of Tropical Cyclones (TCs) in the NIO covering the Bay of Bengal and the Arabian Sea is the least in the world (7% of the global total), their impact on the east coast of India as well as the Bangladesh coast is relatively more devastating. This is evident from the fact that in the last 270 years, 21 of the 23 major cyclones (with a loss of about 10,000 lives or more) worldwide occurred over the area surrounding the Indian subcontinent (India and Bangladesh). This is primarily due to the serious storm tide effect in the area. Thirteen coastal states and Union Territories (UTs) in the country, encompassing 84 coastal districts, are affected by tropical cyclones.

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Four states (Tamil Nadu, Andhra Pradesh, Orissa and West Bengal) and one UT (Puducherry) on the east coast and one state (Gujarat) on the west coast are more vulnerable to hazards associated with cyclones.

About 8% of the area in the country is prone to cyclone-related disasters. Recurring cyclones account for large number of deaths, loss of livelihood opportunities, loss of public and private property and severe damage to infrastructure, thus seriously reversing developmental gains at regular intervals.

A cyclone is a region of low atmospheric pressure, which occurs in the hot oceans of temperate and tropical latitudes. It is a swirling atmospheric disturbance, accompanied by powerful winds (exceeding the 300 km/h sometimes) blowing in a clockwise direction in the Northern hemispheres and anti clock wise direction in the Southern hemisphere, by pouring rain, and enormous waves in the ocean. Cyclones occur due to a combination of warm sea temperature, high relative humidity and atmospheric instability.

In a cyclone, clouds gather around a centre that is called the "eye of the cyclone". A zone of calm, accompanied by good weather characterises the eye. It is in edge of the eye called the "wall of the eye" (in a radius of 20 to 30 kilometres) that the worst conditions prevail, with devastating winds. So, as the eye of the cyclone crosses an area, the wind drops. As it passes, the wind speed rises again, and hence the calm should not be confused as the 'end' of the cyclone. The diameter of the cyclone is often several hundreds of kilometres. That of the eye varies between 20 and 50 km and the cloudy mass of the cyclone raises to occupy all of the troposphere.

The Principal Dangers from a Cyclone are

(i) Gales and strong winds; (that may uproot trees, destroy telephone lines and electricity poles which may disable power and communication).

(ii) Torrential rain that can cause flooding.

(iii) High tidal waves (also known as 'storm surges'). Most casualties are caused by coastal inundation by tidal waves and storm surges. The rise in water level caused by a storm surge can cause severe flooding in coastal areas, particularly when this surge coincides with the normal high-tide.

It has been estimated that over 58 per cent of the cyclonic storms that develop in the Bay of Bengal approach or cross the east coast in October and November. Only 25 per cent of the storms that develop over the Arabian Sea hit the west coast. In the pre-monsoon season, corresponding figures are 25 per cent over the Arabian Sea and 30 per cent over the Bay of Bengal.

Impact

Cyclones are characterized by their destructive potential to damage structures such as houses, lifeline infrastructure such as power and communication towers, hospitals, food storage facilities, roads, bridges, culverts, crops, etc., due to high velocity winds.

Exceptionally heavy rainfall causes flooding. Storm surge inundates low-lying areas in the coastal areas resulting in loss of life and destruction of property, besides eroding beaches and embankments, destroying vegetation and reducing soil fertility.

Besides the loss of lives and livestock, cyclones have high destructive potential due to the strong winds that damage structures, and heavy rainfall which causes floods and storm surge that inundates low-lying coastal areas.

Although it is not possible to completely avoid natural disasters, their effects can be minimised by taking some known long- and short term structural and non-structural mitigation measures such as developing proper early warning systems, creating awareness at all levels in the concerned communities, coastal afforestation, construction

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of shelters, embankments, dykes, coastal roads, bridges, canals, etc., through better preparedness, mitigation measures and improved response mechanisms.

Environmental Degradation Magnify Cyclones

Forests along the coast act as natural wind and water barriers, shielding the coastal communities from the destructive power of cyclones and storm surges. They form natural windbreakers to reduce the impact of cyclonic storms on the coastal areas. But deforestation and encroachment of the coastal shelterbelt area, as this forestland is known, by paddy cultivators, prawn farmers, etc. has been depleting these forests. Natural calamities are hard to avert. But in Orissa the ordeal was also man-made. There has been a systematic destruction of mangrove and other tropical trees having branches that send down roots. This growth protects the coastal areas. Greedy people have deforested the coastal areas, leaving no impediment between the sea and habitations.

Cyclone Forecasting and Warning

An effective cyclone disaster prevention and mitigation plan requires: (i) efficient cyclone forecast - and warning services; (ii) rapid dissemination of warnings to the government agencies, particularly of marine interests like ports, fisheries and shipping and to the general public and (iii) construction of cyclone shelters in vulnerable areas, a ready machinery for evacuation of people to safer areas and community preparedness at all levels to meet the exigencies

The Indian Meteorological Department (IMD) is responsible for cyclone tracking and warning. Cyclone tracking is done through the INSAT satellite and 10 cyclone detection radars. Warning is issued to cover ports, fisheries and aviation departments. The warning system provides for a cyclone alert of 48 hours and a cyclone warning of 24 hours. There is a special Disaster Warning System (DWS) for dissemination of cyclone warning through INSAT satellite to designated addresses at isolated places in local languages.

One of the most successful ways of reducing loss of human lives during cyclones is the provision of cyclone shelters. In densely populated coastal areas, where large scale evacuations are not always feasible, public buildings can be used as cyclone shelters. These buildings can be so designed, so as to provide a blank façade with a minimum number of apertures in the direction of the prevailing winds. The shorter side of the building should face the storm, so as to impart least wind resistance. Earth berms and green belts can be used in front of these buildings to reduce the impact of the storm.

Floods

Floods occur regularly in India affecting about 10% of area. The term flood is generally used when the water-flows in rivers, streams and other water bodies cannot be contained within natural or artificial banks. According to the estimates of the National Flood Commission (1980), commonly known as the Rashtriya Barh Ayog, Assam and Bihar are the States worst affected by floods followed by U.P. and West Bengal. However, during monsoon months, all states are prone to floods, including even Rajasthan. The severity of flooding at any location is a function of factors such as intensity and extent of rainfall and antecedent conditions of catchment area, physical characteristics of the river, topography, etc. In many cases, the natural process of flooding is aggravated by man-made hindrances to free out-flow/absorption of floodwater both in agricultural areas and particularly in urban areas with unplanned or unauthorized construction activities; sudden large releases from upstream reservoirs, which often is more than the carrying capacity of the basin results in massive destruction of river embankments and downstream flooding. Increasing pace of urbanization, population growth and development have all led to pressures on the flood plains magnifying the damage caused by floods. The

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incidence of floods in recent times in urban areas such as Mumbai, Surat, Vadodara and other places is symptomatic of this trend and is the direct result of unauthorized construction activities in flood plains and river beds, poor urban planning and implementation, lack of investment in water drainage and sewerage for several decades as well as inadequate planning and response mechanisms. Freak weather conditions, possibly due to the result of global warming, have been reflected recently in incessant rains in August 2006, resulting in floods in the deserts of Rajasthan, leading to loss of about 300 lives, immense damage to housing and infrastructure and widespread devastation in an area where people are not used to floods and have few mechanisms to cope with the crisis. The country has to shift towards efficient management of flood plains, disaster preparedness, response planning, flood forecasting and warning.

Causes of Floods

Inadequate capacity of the rivers to contain within their banks the high flows brought down from the upper catchment areas following heavy rainfall, leads to flooding. The tendency to occupy the flood plains has been a serious concern over the years. Because of the varying rainfall distribution, many a time, areas which are not traditionally prone to floods also experience severe inundation. Areas with poor drainage facilities get flooded by accumulation of water from heavy rainfall. Excess irrigation water applied to command areas and increase in ground water levels due to seepage from canals and irrigated fields also are factors that accentuate the problem of water-logging. The problem is exacerbated by factors such as silting of the riverbeds, reduction in the carrying capacity of river channels, erosion of beds and banks leading to changes in river courses, obstructions to flow due to landslides, synchronisation of floods in the main and tributary rivers and retardation due to tidal effects.

Flood Control and Management

- There should be a master plan for flood control and management for each flood prone basin.
- Adequate flood-cushion should be provided in water storage projects, wherever feasible, to facilitate better flood management. In highly flood prone areas, flood control should be given overriding consideration in reservoir regulation policy even at the cost of sacrificing some irrigation or power benefits.
- While physical flood protection works like embankments and dykes will continue to be necessary, increased emphasis should be laid on non-structural measures such as flood forecasting and warning, flood plain zoning and flood proofing for the minimisation of losses and to reduce the recurring expenditure on flood relief.
- There should be strict regulation of settlements and economic activity in the flood plain zones along with flood proofing, to minimise the loss of life and property on account of floods.
- The flood forecasting activities should be modernised, value added and extended to other uncovered areas. Inflow forecasting to reservoirs should be instituted for their effective regulation.

Drought

Droughts refer to a serious shortfall in availability of water, mainly, but not exclusively, due to deficiency of rains, affecting agriculture, drinking water supply and industry. Droughts occur in several parts of the world and can bring untold misery to populations particularly those depending on agriculture and living on generally degraded land. The causative factors are both natural and manmade. The impact of droughts on societies varies depending on coping capabilities and the general health of the national economies concerned.

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Droughts in India have their own peculiarities requiring appreciation of some basic facts. These are:

- India has an average annual rainfall of around 1150 mm; no other country has such a high annual average, however, there is considerable variation.
- More than 80% of rainfall is received in less than 100 days during the South-west monsoon and the geographic spread is uneven. 21% area receives less than 700 mm rains annually making such areas the hot spots of drought.
- Inadequacy of rains coupled with adverse land-man ratio compels the farmers to practice rain-fed agriculture in large parts of the country.
- Irrigation, using groundwater aggravates the situation in the long run as ground-water withdrawal exceeds replenishment; in the peninsular region availability of surface water itself becomes scarce in years of rainfall insufficiency.
- Per capita water availability in the country is steadily declining.
- As against total annual availability 1953 km^3, approximately 690 km^3 of surface water and 396 km^3 of from ground water resources can be put to use. So far, a quantum of about 600 km^3 has been put to use.
- The traditional water harvesting systems have been largely abandoned.

The above factors demonstrate the complexity of Indian droughts and the constraints which rule out 'perfect solutions'. Further, the causes for droughts are increasingly attributable to the mismatch between supply and demand, particularly the demand for non-agricultural purposes. In other words, it is not as if a simple pre-existing problem is awaiting better remedies, the problem itself is becoming more complex.

In some areas, however, the effects of drought are magnified by other reasons:

Environmental Degradation, especially the loss of green cover affects rainfall received in the region, increasing the possibility of water stress. In areas where vegetation has decreased over the years, rainwater is easily washed away into rivers and the sea, and not retained by the soil, leading to low productivity. Over exploitation of water depletes the source faster than rainfall could recharge it, especially in areas that receive scanty rainfall.

Drought results in acute shortage of water, fodder, food and employment. It affects us in different ways.

Drought affects Farmers: It causes loss of crops, lack of fodder and water to feed their cattle.

Drought affects Poor Families: Constant drought reduces agricultural production. This leads to insufficient availability or supply of crops in the market. We learn in economics, that when demand is more than supply, the prices increase. Food-grains become costly, and poor people suffer because of inadequate purchasing power.

Drought affects Women: Even today, especially in rural India, women don't have the same status as men in society. This means that they are not given their fair share in access to nutritious food, good living conditions, education, health, etc. In a drought situation, when there is a dearth of food, women who are usually the last to eat at home, eat the least, and hence suffer from malnutrition. Drought also increases their work burden, since they have to work longer to earn the same wages, and often travel longer to fetch water, fodder and fuel-wood.

Drought affects people living in desert land: They depend more on animal husbandry than on agriculture. Severe scarcity of fodder and water and degradation of vegetation leads to their dependence on assistance from outside, in some areas.

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Drought affects employment: A fall in agricultural production leads to a fall in employment opportunities for rural people who depend on agricultural labour for a living. It also causes people to migrate to other places in search of employment. These are called 'distress migrations'.

Drought affects Children also: Lack of nutritious food in drought affected areas results in malnutrition, which makes them more prone to various infections and diseases. It affects their health and education, since migrations take them away from school and health camps that also provide vaccinations. School-dropouts most often become wage earners, leading to higher child-labour.

Drought is a slow onset disaster, and hence gives us ample time for mitigation, preparedness and response, unlike sudden disasters. We know that drought is a result of multiple causes, the main indicator and cause being abnormally low rainfall. The Indian Meteorological Department tells us the duration and quantity of rainfall expected every season, but this being a natural phenomena, is beyond our control. We can however make planned efforts to conserve natural resources, and prevent misuse of land and water.

Hence, while we cannot prevent drought, we can certainly reduce its intensity and impact through individual and collective actions. It is important to remember that any steps taken to mitigate or prepare for drought have to be sustained for a long period of time, and must involve a cross-section of people such as community, Panchayat representatives, volunteers, government functionaries, teachers and students. Let us now see how we can help.

Long- term Drought Mitigation Strategies

- Construction of Community Based Rain Water Harvesting Structures
- Promoting Watershed Programmes
- Increasing Forest cover through plantations
- Adopting drought resistant varieties of paddy and other crops
- Using alternative crops in drought conditions
- Capacity building of communities in Drought Management and introducing livelihood options besides agriculture and animal husbandry which are water intensive
- Encouraging crop and seed insurance schemes

Landslides and Avalanches

Landslides are mass movements of rocks, debris or earth, down mountain slopes or riverbanks. Such movements may occur gradually, but sudden sliding can also occur without warning. They often take place in conjunction with earthquakes, floods and volcanic eruptions. At times, prolonged rainfall causing heavy landslides block the flow of rivers for quite some time, which on bursting can cause havoc to human settlements downstream.

The hilly terrains of India, particularly in the Himalayas and the Western Ghats, are most vulnerable to landslides. The Himalayan mountain belt comprises of tectonically unstable younger geological formations and often the slides are huge, and in most cases, the overburden along with the underlying lithology is displaced during sliding.

In contrast, the Western Ghats and Nilgiri Hills are geologically stable but have uplifted plateau margins influenced by neo tectonic activity and the slides are usually confined to be over burden without affecting the bedrock beneath. The slides are generally in the nature of debris flows occurring mainly during monsoons, but the effects are felt more acutely due to higher density of population in the region. Measures to control

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landslides include micro zonation so as to regulate settlements in hazard prone areas, non interference with the natural water channels, construction of retaining walls against steep slopes and strengthening of weak areas with grouting. In India, landslide studies are conducted by a number of institutions, research and academic. However, there is a need for better coordination among these institutions and also the user agencies.

The sliding down of snow cover on mountain slope causes avalanches. Avalanches may occur due to a combination of factors such as the slope of the mountain, depth of snow cover, wind velocity and atmospheric temperature, vibrations caused by gunfire and strength of resisting forces like vegetation cover of trees and shrubs. When the balance between the gravitational force of snow cover and the resisting force of the slope and the anchoring effect of shrubs are lost, avalanches are caused. Avalanches create various crisis situations for the local administration; road traffic may be blocked and communication links to vital areas may be disrupted and winter sports may be disturbed, stranding tourists in places with scant facilities. Small rivers may be blocked creating danger of down stream flooding. Avalanches may sometimes hit or bury human settlements down the slopes, as in the Kashmir avalanche of 2005, which killed 278 persons, mostly living in temporary winter hutments.

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Climate & Resources

Relation of Climate and Soil Formation

The natural environment differs in various parts of the earth. But what determines that whether a particular region would be a grassland or a desert or a lush green forest? The answer is differences in the climate of these regions. Climate is a critical factor in soil formation, food production and energy demand of any geographical region.

Climatic variations can have profound effects on the environment and thus on humankind. To assess the effects of these variations we must first have some understanding of the factors that constitute climate.

The earth is a mosaic of many types of climates and a variety of controls interact to shape the climate of any region. The controls that exert a regular and predictable influence on climate are latitude, altitude and proximity to large water bodies.

In addition, the climate is strongly influenced by circulation pattern of the atmosphere and ocean currents. Circulation determines the types of air masses that regularly develop over a region or move across it from other regions. This affects the rainfall, while ocean currents affect the climate of large land masses.

The term soil generally is used to describe the material on the thin skin of the Earth's crust and that has been under the influence of certain physical and biological processes.

Climate includes type and amount of precipitation, temperature, humidity, evapotranspiration, duration of sunshine and a number of other variables.

Precipitation and temperature are the main parameters of climate and are important in influencing the nature of the soil that forms. Precipitation is important because of its effect on the soil-moisture regime. Much of the precipitation that falls in Arizona is lost to runoff and evaporation from vegetation and soil surfaces. Still more of the moisture that enters the soil is taken up by vegetation through roots and transpired from plant leaf surfaces, further reducing soil moisture levels. In low precipitation areas, not enough water is added to the soil for through leaching. Water that enters the soil penetrates to such a limited depth that soluble constituents are not removed from the soil profile. Thus, most of Arizona that does not receive much precipitation contains soils that have soluble salts and carbonates, and generally are neutral to alkaline in reaction (pH). The higher elevations in Arizona receive more precipitation than the lower, and more water percolates through the soil to remove soluble substances. Soils in these areas generally are leached of soluble salts, lack carbonates and are more acid.

Lack of moisture in the lower, arid regions of the state also limits vegetative production and inhibits soil organic matter buildup. Soils in the higher, more humid regions, on the other hand, are higher in organic matter because of greater vegetative growth.

Temperature is important in soil formation because it influences the effectiveness of precipitation. Arizona has two principal rainy seasons, December to March and July to August. Higher temperatures associated with summer rains cause much more moisture loss by evaporation and transpiration than is lost during the winter season; therefore, soil moisture levels and leaching rates are much less than during the winter season. Soils at the higher elevations in Arizona that receive more precipitation also are cooler. Thus, the amount of water available to moisten soils is greater and leaching intensities are enhanced further.

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Climate affects both vegetative production and the activity of organisms. Hot, dry desert regions have sparse vegetation and hence limited organic material available for the soil. The lack of precipitation inhibits chemical weathering leading to coarse textured soil in arid regions. Bacterial activity is limited by the cold temperatures in the tundra causing organic matter to build up. In the warm and wet tropics, bacterial activity proceeds at a rapid rate, thoroughly decomposing leaf litter. Under the lush tropical forest vegetation, available nutrients are rapidly taken back up by the trees. The high annual precipitation also flushes some organic material from the soil. These factors combine to create soils lacking much organic matter in their upper horizons.

Climate, interacting with vegetation, also affects soil chemistry. Pine forests tend to dominate cool, humid climates. Decomposing pine needles in the presence of water creates a weak acid that strips soluble bases from the soil leaving it in an acidic state. Additionally, pine trees have low nutrient demands so few soil nutrients are taken back up by the trees to be later recycled by decaying needle litter. Broadleaf deciduous trees like oak and maple have higher nutrient demand and thus continually recycle soil nutrients keeping soils high in soluble bases.

Influence of Climate Change on Soil Properties and Processes

Carbon and nitrogen are major components of soil organic matter. Organic matter is important for many soil properties, including structure formation and maintenance, water holding capacity, cation exchange capacity, and for the supply of nutrients to the soil ecosystem. Soils with an adequate amount of organic matter tend to be more productive than soils that are depleted in organic matter, therefore, one of the biggest questions concerning climate change and its effects on soil processes and properties involve how potential changes in the C and N cycles will influence soils.

Early expectations were that increased atmospheric CO_2 would lead to increased plant productivity coupled with increased C sequestration by soil, meaning increased plant growth and the soil-plant system would help offset increasing atmospheric CO_2 levels. This increase in plant growth is known as the CO_2 fertilization effect. However, recent studies indicate that CO_2 fertilization effect may not be as large as originally thought. Increasing levels of ozone as the climate changes may actually counteract the CO_2 fertilization effect leading to reduced plant growth under elevated CO_2. Nitrogen limitations may negatively affect plant growth , and modeling of C dynamics as influenced by N indicates less C sequestration by soil than originally expected given CO_2 fertilization. A long-term elevated CO_2 experiment in a grasslands ecosystem indicated that N and P became limited within two years, again limiting plant biomass response to elevated CO_2. The increases in plant productivity they did see were due primarily to soil moisture status as opposed to a CO_2 fertilization effect.

Increased temperature is likely to have a negative effect on C allocation to the soil, leading to reductions in soil organic C and creating a positive-feedback in the global C cycle (increased temperatures lead to increased CO_2 release from soils to the atmosphere, which leads to increase in temperature) as global temperatures rise.

When CO_2 enrichment increases the soil C:N ratio, decomposing organisms in the soil need more N, which can reduce N mineralization. Mineralization is an essential step in supplying N to plants. Therefore, if N mineralization is reduced, it would be expected that plant-available N levels in the soil would also be reduced and plant productivity would be negatively affected.

Changes in average temperatures and in precipitation patterns will also influence soil organic matter. This in turn will affect important soil properties such as aggregate formation and stability, water holding capacity, cation exchange capacity, and soil nutrient content. Exactly how soil organic matter will be influenced by climate change involves highly complex and interconnected systems that make it difficult to isolate a single variable, such as temperature or precipitation patterns, and reach meaningful conclusions about how a change in that single variable affects the system being studied.

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Relation of Climate and Agriculture

A large section of our population is dependent on agriculture for their livelihood. Let us first talk about crops. In most parts of the country two crops are produced in a year though in certain places even three crops are produced. Rabi and Kharif are the two most important crops of India. Rabi crops are sown in October-November and harvested in March-April except certain crops like sugarcane, which are sown and harvested in other months.

Rabi crops include wheat, barley, peas, grains, pulses like arhar, cotton and oilseeds except groundnut. Kharif crops include maize, millets, pulses like urad and moong, hemp and paddy which are sown in July and harvested in the end of September or beginning of October.

The variety of crops and their yield depends upon various factors like soil, rainfall, temperature, availability of irrigation facilities, etc. In the plains of northern India, alluvial soil is found. In Punjab and western half of Uttar Pradesh, production of wheat is more favoured and good yield is procured because of fertile soil, favorable temperature and adequate rainfall. In the eastern half of Uttar Pradesh, Bihar and West Bengal where soil is fertile, temperature is nearly the same as, Punjab and Western Uttar Pradesh but rainfall is more than these areas, paddy is produced easily. In West Bengal and Tamil Nadu heavy rains help raise three crops of paddy during a year. Among the non-food grain crops, the most important is oilseed, sugarcane, raw cotton, jute, tea, coffee, rubber and tobacco. Cotton production is abundant in the Southern Peninsular Plateau except in the coastal plains. Cotton requires black soil, less quantity of rains and a comparatively dry climate. Besides these agricultural products, different kinds of fruits and various spices are produced in our country.

Agriculture is vulnerable to climate change, and weather extremes brought about by global warming can severely impact food production. Regions around the globe have already felt the short-term effects of climate change, but it may take decades for the worst effects to be felt. Understanding the relationship between agriculture and climate is essential to adapting to these changes to ensure that the food needs of the world's 7 billion people are met. Each of the following factors affects both agriculture and climate variability.

Rising average temperatures can extend the growing season in areas with previously cool springs and autumns, but can also be detrimental to crops in areas with already high temperatures. Soil evaporation rates and the chance of severe drought also increase with rising temperatures.

Changes in rainfall affect crop yields by altering soil erosion rates and the amount of moisture in soil. As a result of global warming, precipitation will likely increase most in high latitudes and decrease in subtropical land regions. Rainfall may decrease by up to 20 percent in these areas, causing an increase in other extreme weather events.

The rise of atmospheric carbon dioxide levels may at first seem like a blessing for crops. The gas does have fertilizing properties that can be beneficial for some crops like rice, soyabeans and wheat, but the positive effects of carbon dioxide on plants are more than countered by the overall negative effect that the greenhous gas has on global temperatures.

Pollution has a significant effect on agriculture and climate. Crop growth is limited by high levels of ozone in the lower atmosphere, and climate change increases ozone concentrations. The negative effects of increased ozone also offset any benefits that carbon dioxide may have on crops.

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Major Sources of Direct Agricultural GHG Emissions

Soil Emissions

Nitrous oxide emissions account for about 60 percent of total agricultural sector emissions. Nitrous oxide is produced naturally in soil through the microbial processes of nitrification and de-nitrification, but the large increase in rise of nitrogen fertilizer for the production of high nitrogen-consuming crops like corn has increased emissions.

Enteric Fermentation

During digestion, microbes in the animal's digestive system ferment feed. This process, called enteric fermentation, produces methane, a powerful greenhouse gas, as a by-product which can be emitted by the exhaling and belching of the animal. Cows and other ruminants have higher methane emissions than pigs and poultry because of their unique digestive systems.

Manure Management

Methane is also produced by the anaerobic (without oxygen) decomposition of manure. When manure is handled as a solid or deposited naturally on grassland, it decomposes aerobically (with oxygen) and creates few methane emissions. However, manure stored as a liquid or slurry in lagoons, ponds, tanks or pits decomposes anaerobically and creates methane emissions.

CO_2 From Fossil Fuel Consumption

These emissions are primarily from combustion of gasoline and diesel to fuel farm equipment, including tractors, combines, irrigation pumps, grain dryers, etc., but also include emissions related to the production of fertilizers, pesticides and herbicides, which are primarily derived from fossil fuels.

Rice Cultivation

Much of the world's rice is grown in flooded plains. The flooding (used to provide water to the crop and to help protect the rice crop from pests and weed pressure) means that the manure, soils and other organic matter on the fields are in an anaerobic environment, and decomposition of these materials and the soil emissions result in methane being produced and released into the atmosphere.

Climate change's effect on agricultural production is of utmost concern. A number of factors determine crop yields, primarily temperature and precipitation. Although in some regions temperature and precipitation changes will have limited production benefits, agricultural experts agree that in general a changing climate will result in overall lower agriculture yields. When crops are exposed to high temperatures, crop development slows.

Many regions will see increase in heat extremes, extended heat waves and intense precipitation events leading to yield reduction, soil erosion and increased flooding. At high latitudes, annual river runoff and water availability will increase, while many semi-arid regions, including the Western U.S., Mediterranean Basin, southern Africa and northeast Brazil, will see a decrease in water availability.

Already, changes in weather patterns have had demonstrable effects on agriculture globally, as droughts and heavy precipitation have inflicted crop damage and decreased yields.

Weed, disease and pest pressures will also increase as a result of climate change. Many weeds and insect pests that thrive in warm weather will gain hold in regions previously too cool to support their growth, and increased carbon dioxide levels will likely benefit weeds more than food crops.

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Monoculture crop systems that make up the bulk of U.S. agriculture will be particularly at risk from increase in weeds and pest pressures, as well as changing microclimates. Unlike polyculture systems, where a diversity of crop types planted together, or in close proximity, ensures some protection against devastation from pests or weather, monocultures are highly vulnerable systems that can be wiped out entirely from a single pest, blight or weather event.

Animal agriculture will be negatively affected as well. Higher levels of animal disease and parasites are predicted with increased temperatures, and this will likely result in greater costs for disease control and higher levels of livestock mortality. Further, the decline in grain yields and resulting decreased grain availability could lead to increased feed costs and overall livestock production costs, especially for industrial confinement systems.

All of these changes will have profound effects on farmers ability to raise crops and feed animals, and therefore to feed, cloth and fuel a growing population. The effects will differ greatly by crop and region, and will likely affect farmers in lower latitudes, particularly sub-Saharan Africa, most severely. These regions are also where technology and information transfer is the lowest, where a majority of livelihoods depend on agriculture, and where the most food insecure peoples live-pointing not only to a coming climate crisis, but also to growing concerns about food security and economic development.

Agriculture and the Climate Solution

Farming as it is increasingly practiced today-industrial, monocultural and fossil fuel intensive is both a cause and victim of climate change. However, there are other ways to farm that can significantly lower greenhouse gas emissions, store additional carbon from the atmosphere in the soil, and reduce vulnerability to the effects of climate change. First, agriculture can reduce its own level of emissions. One of the biggest opportunities for reduction is in the area of synthetic fertilizer use. Made from natural gas, nitrogen-based fertilizers are energy and greenhouse gas intensive to produce, and increased use of these fertilizers has been linked to increased greenhouse gas emissions from soils.

A great percentage of fertilizer needs can be met by increased use of animal manures, compost (especially from food and organic materials in the waste stream), green manure crops that are ploughed into the soil to provide nutrients and organic matter, and resource-conserving crop rotations that include legumes, which fix nitrogen in the soil. While these practices may not fully replace synthetic fertilizer use, especially with nitrogen-dependent crops such as corn, they can significantly reduce the need for these fertilizers while at the same time providing soil and water quality benefits.

A more permanent solution to the synthetic fertilizer dilemma may be found in more perennial cropping systems. These crops provide multiple advantages from a climate perspective, including eliminating or significantly reducing the need for tillage; deeper root systems that both protect and build soil; better drought tolerance; and lower fertilizer and pesticide requirements. Markets already exist for perennial crops such as grasses and alfalfa for animal fodder, and much of the focus for sustainable bioenergy and biofuel feedstocks is on perennial crops. But there are currently fewer options for perennial substitutes for many of our food crops, especially grains and oilseeds.

Another area of possible agriculture emissions reductions is in the livestock sector. Enteric fermentation, primarily a concern for ruminant animals such as cattle, sheep, goat, buffalo, etc., is one of the biggest emission source. The way these animals digest grasses and feed produces methane, which has been calculated to account for 5 to 10 percent of overall human-caused GHG emissions.

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As one might expect, these emissions are harder to reduce or mitigate than those of many other sectors.

In addition to enteric emissions, there are other areas where the trend towards concentrated animal feeding and production systems have resulted in large climate impacts on both "ends" of the animal-feed and manure. Grain production for animal feed can be quite carbon intensive, and has been demonstrated that livestock diet has a strong influence on enteric emissions from the cattle.

This problem is then often compounded in the emissions from the manure, as what goes into the cow has a major influence in what comes out, including GHG emissions from the manure. And as this manure is generally stored in an anaerobic setting, the result is much more potent methane emissions than carbon dioxide that would result from the manure being dispersed on the field or composted. While much focus has been on capturing this methane for energy production, most of the gas could be avoided entirely through grass-based farming, especially rotational grazing systems, which eliminate or significantly reduce both the feed and manure-related emissions, while also contributing to increased carbon storage in the soil.

Principles for a Responsible and Climate-Friendly Approach to Agriculture

- Climate policy must adopt an integrated and coherent approach that acknowledges and supports the importance of sustainable agriculture to long term sustainable development. The agricultural sector both depends upon and impacts the natural environment. Because of this, agriculture has a unique and substantial role to play as a steward of our natural resources and ecosystems.
- All agricultural systems are not equal in their impacts upon the environment and in their contribution to climate change. Addressing climate change in the agricultural sector requires recognition of historical differences among different types of agriculture, and different country contributions to the problem of climate change. This means that actions to reverse climate change in agriculture must acknowledge differences in the respective economic and technical capacities of farmers (both within countries and internationally) in accordance with the principle of common and differentiated responsibility.
- Agriculturally based climate mitigation and adaptation efforts must complement, not impede, the production of a safe and healthy food system. A system of sufficient and safe food production for all people on the planet is paramount. Climate-friendly agriculture practices must also ensure abundant food production.
- Climate mitigation must include a fair international system that rewards farmers for their contributions to mitigation, including carbon sequestering activities and renewable energy services.
- Climate change solutions must build the capacity for farmers to create healthy and resilient communities and ecosystems, including safeguarding water systems.

Relation of Climate and Rock Cycle

Rocks are naturally formed and are simply composed of crystals or particles of one or more minerals. There are many kinds of rock, and they can be classified in a number of ways. However, geologists classify rocks based on how the rocks were formed. The three classes are igneous rocks (formed directly from liquid rock), metamorphic rocks (formed by direct alteration of existing rocks), and sedimentary rocks (formed by eroded materials from other rocks).

The rock cycle consists of a series of constant processes through which Earth materials change from one form to another over time. As within the water cycle and the carbon cycle, some processes in the rock cycle occur

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over millions of years and others occur much more rapidly. There is no real beginning or end to the rock cycle, but it is convenient to begin exploring it with magma.

Magma, or molten rock, forms only at certain locations within the Earth, mostly along plate boundaries. When magma is allowed to cool, it crystallizes, much the same way that ice crystals develop when water is cooled. This process can be seen at Iceland, where magma erupts out of a volcano and cools on the surface of the Earth, forming a rock called basalt on the flanks of the volcano. But most magma never makes it to the surface and it cools within Earth's crust. Deep in the crust below Iceland's surface, the magma that doesn't erupt cools to form gabbro. Rocks that form from cooled magma are called igneous rocks; intrusive igneous rocks if they cool below the surface (like gabbro), extrusive igneous rocks if they cool above (like basalt).

Rocks like basalt are immediately exposed to the atmosphere and weather. Rocks that form below the Earth's surface, like gabbro, must be uplifted and all of the overlying material must be removed through erosion in order for them to be exposed. In either case, as soon as rocks are exposed at the Earth's surface, the weathering process begins. Physical and chemical reactions caused by interaction with air, water, and biological organisms cause the rocks to break down. Once rocks are broken down, wind, moving water, and glaciers carry pieces of the rocks away through a process called erosion. Moving water is the most common agent of erosion - the muddy Mississippi, the Amazon, the Hudson, the Rio Grande, all of these rivers carry tons of sediment weathered and eroded from the mountains of their headwaters to the ocean every year. The sediment carried by these rivers is deposited and continually buried in floodplains and deltas.

Under natural conditions, the pressure created by the weight of the younger deposits compacts the older, buried sediments. As groundwater moves through these sediments, minerals like calcite and silica precipitate out of the water and coat the sediment grains. These precipitants fill in the pore spaces between grains and act as cement, gluing individual grains together. The compaction and cementation of sediments creates sedimentary rocks like sandstone and shale.

Climate has three basic influences on the rock cycle: weathering & erosion, rate of limestone production, and rate of fossil production.

Weathering and Erosion: Weathering is the breakup of rocks due to physical and chemical processes, while erosion is the transport of weathered rock particles by wind and water. The primary way that climate affects weathering and erosion is through its connection to the water cycle.

When water freezes in cracks and crevices in rock and expands, the rocks are physically broken apart. The amount of rainfall will affect weathering as will the types of plants in the area (which are greatly affected by the amount of rainfall), whose roots break rocks apart and may chemically dissolve some rocks.

Rate of Limestone Production: Limestone rocks are made most prolifically in the warm shallow waters of tropics. Thus, limestone production depends on the extent of tropical regions. The amount of shallow sea area, where limestone forms quickly, depends on sea level. When the edges of the continents are flooded by high sea level because glaciers have melted during warm global climate, more carbonate rocks are produced.

Rate of Fossil Production: Environments and ecosystems depend on climate so different types of sedimentary rocks and fossils are preserved when climates change. Additionally, fossilization processes depend on climate. The chance of animal or plant remains becoming fossilized at all is very minimal, and it is much more likely that the remains will decompose.

Body fossils are remains of actual organisms. Most living things never become fossils. It takes special conditions for a fossil to form. Hard parts made of mineral such as shells and bones are much more likely to become body fossils than soft tissues, such as skin, organs, and eyes, which usually decay. This means that animals like jellyfish, which have no bones made of hard mineral, are rarely preserved.

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But since the rate of decomposition is different in different climates, remains are more likely to become fossils in same environment than others. In warm, humid environments, less soft tissues are fossilized because the rate of decomposition is high. However, in arctic environments, much like in your freezer, the rate of decomposition is lower and soft tissues are more likely to fossilize.