ATMOSPHERE ACTIVITIES

Chase the Cloud!

The study of clouds and their characteristics may well be the key to understanding climate and climate change.

Clouds are generally classified based on characteristics such as altitude, appearance or origin. On the basis of altitude, clouds are classified as:

- **high clouds—have bases above 5485 meters**
- **middle clouds—have bases between 2135 and 5485 meters**
- **low clouds—have bases below 2135 meters**

Low, thick clouds primarily reflect solar radiation and cool the surface of the Earth. High, thin clouds primarily transmit incoming solar radiation; at the same time, they trap some of the outgoing infrared radiation emitted by the Earth and radiate it back downward, thereby warming the surface of the Earth. Whether a given cloud will heat or cool the surface depends on several factors, including the cloud's height, its size, and the make-up of the particles that form the cloud. The balance between the cooling and warming actions of clouds is very close, although overall, cooling predominates.

Subject
Social Studies, Science

Place
Outdoor

Duration
10 minutes

Group size
Entire class

Materials
Photocopy of Cloud Types Sheet

Objective

To observe and identify different types of clouds, cloud formations, and the cooling/warming effect of clouds.

Activity

Take the students to an open field/ground/playground of school as observation of clouds and cloud types requires an unobstructed view of the sky.

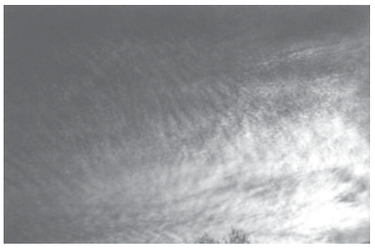
Give each student Cloud Type Sheet as given on page 54-55.

Ask students to observe the clouds carefully for some time, then ask them to identify the type of clouds with the help of the Cloud Type Sheet. Ask them to make a sketch of what they see.

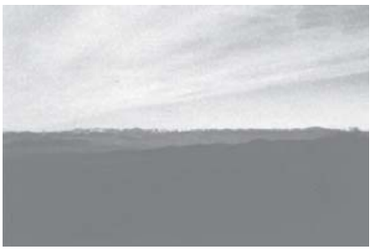
Extension/Variation

Depending of the type of cloud, could you say what weather condition you are experiencing or are soon going to experience?

Cirrus

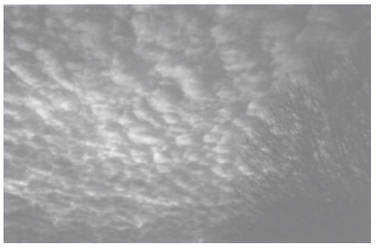


Cirrocumulus



Cirrostratus

Altostratus



Altocumulus

Why do some clouds form only in fair weather, while other bring showers or thunderstorms?

Could you differentiate rain-bearing clouds from other clouds?

Cloud Type Sheet

There are five descriptive terms for the various types of clouds:

CIRRO or high clouds

ALTO or middle clouds

CUMULUS or white puffy clouds

STRATUS or layered clouds

NIMBUS or clouds from which precipitation is falling

The following ten types of clouds, named using the above terms, are to be used when reporting the cloud type for your area:

High Clouds

Cirrus: These clouds look like white delicate feathers. They are generally white wispy forms. They contain ice crystals.

Cirrocumulus: These clouds are thin white layers with a texture giving them the look of patches of cotton or ripples without shadows. They contain primarily ice crystals and perhaps some very cold water droplets.

Cirrostratus: These clouds are a thin, almost transparent whitish layer made up of ice crystals. They may totally or partly cover the sky and can create a halo appearance around the sun.

Middle Clouds

Altostratus: These clouds form a bluish or grayish veil that totally or partially covers the sky. The light of the sun can be seen through them but there is no halo effect.

Altocumulus: These clouds look like waves of the sea with white and gray colouring and shadow. They contain mostly water droplets and perhaps some ice crystals.

Low Clouds

Stratus: These clouds are gray and lie very close to the surface of the earth. They usually look like a sheet layer but sometimes are found in patches. They rarely produce precipitation.

Stratocumulus: These clouds are a gray or whitish colour. The bases of these clouds tend to be more round than flat. They can be formed from old stratus clouds or from cumulus clouds that are spreading out. Their tops also tend to be mostly flat.

Nimbostratus: This is a very dark and gray-coloured cloud layer that blots out the light of the sun. It is massive and has a continuous fall of precipitation.

Cumulus: These clouds have a flat base and a dense, mound-shaped top that resembles a large cauliflower. Where the sun hits these clouds they are a brilliant white. The base tends to be a darker gray. They generally do not produce precipitation.

Cumulonimbus: These are large, heavy, and dense clouds. They have a generally flat, dark surface with very tall and large tops like the shape of a massive mountain or anvil. These clouds are often associated with lightning, thunder and sometimes hail. They may also produce tornados.

Cumulus

Cumulonimbus

Stratus

Stratocumulus

Nimbostratus

Contrails—Are These Clouds?

Have you ever noticed clouds that are formed by a jet engine of an airplane? When jet engines fly at high enough altitudes where the temperature is cold, the vapor contained in the exhaust of the jet turns into ice crystals—like cirrus clouds. These clouds are called **contrails** (short for "condensation trails"), and look like lines in the sky.

Activity

Understanding Seasons

Subject
Science, Social Science (Geography)

Place
Outdoor

Duration
1 year (observation at regular intervals)

Group size
Individual or groups of 3–4 students

Materials
Drawing papers, colour pencils

The primary cause of the seasons is the earth's annual rotation/ revolution around the sun on an axis tilted at about 23.5^{O}. This means that as the Earth goes around its orbit, the Northern hemisphere is at various times oriented either towards or away from the Sun, and likewise for the Southern hemisphere, as illustrated in the figures.

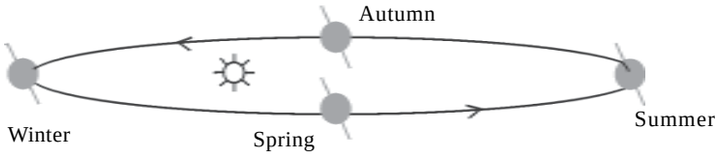
The sun emits rays that hit the Earth's surface at different angles. These rays transmit the highest level of energy when they strike the earth at a right angle (90^{O}). Temperatures in these areas tend to be the highest on earth. As the Earth rotates on its tilted axis around the sun, different parts of the Earth receive higher and lower level of radiant energy. This creates the seasons.

When the earth is on that part of its orbit where the Northern hemisphere is oriented more towards the sun, we experience summer in the Northern hemisphere. The sun rises higher in the sky and is above the horizon for a longer period and the rays of the sun strike the ground more directly.

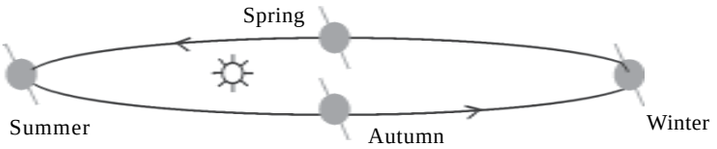
Likewise, when the Northern hemisphere is oriented away from the Sun, we experience winter in the Northern hemisphere. During this season the sun rises low in the sky, is above the horizon for a shorter period and the rays of the sun strike the ground more obliquely.

The seasons in the Southern hemisphere are determined by the same reasoning, except that they are out of phase with the Northern hemisphere seasons because when the Northern hemisphere is oriented towards the Sun, the Southern hemisphere is oriented away, and vice versa.

The Seasons in the Northern Hemisphere



The Seasons in the Southern Hemisphere



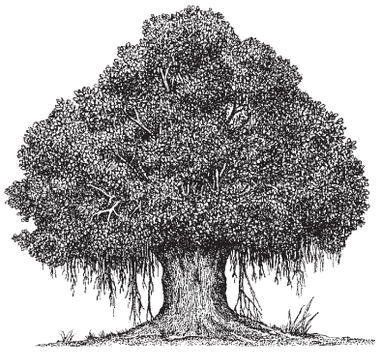
Objective

To understand seasonal changes in trees.

Activity

Ask the students to observe and draw sketches of trees growing either in the school garden or in their home backyards or any other familiar place. They should each select a few different types of trees to add variety to the project. The sketches and pictures prepared should be put on the display board, along with dates. If possible, printed pictures of those trees should accompany the sketches.

The trees should be visited and sketched at intervals of a month. The sketches (with dates) made on subsequent visits should be displayed alongside the first ones for comparison. The seasonal differences portrayed graphically should be explained in a small note under each sketch.



It will be noticed that some of the trees may have leaves throughout the year, i.e. they are "evergreen", while others change leaf colour and drop their leaves. These are "deciduous".

The flowering period and subsequent fruiting time should be noted. The possible influence of seasons on periods of leaflessness and flowering should be discussed.

Extension/Variation

Students should observe life on and around their trees and explain any seasonal differences.

Did they notice changes in plant life and the vegetation?

Students should observe and note down the birds visiting these trees and nearby places. In case they do not know their names, they should note down the shape, size, colour and other features which they have noticed.

Did they notice changes in animal behaviour e.g. birth of babies, hibernation, and migration?

What were the changes in physical environment—warmer or colder, rainier or drier?

Forecasting Weather

Subject
Science, Social Science (Geography)

Place
Outdoor, classroom

Duration
A month, (daily 5-10 minutes observation)

Group size
Individual or groups of 3-4 students

Materials
Drawing papers, colour pencils

People have always scanned the skies for clues to the weather. Farmers and fishermen have, through the ages, learned to read the clouds and winds, and predict what the weather would bring. Today there are people who specialize in the study of weather. The study of weather is called Meteorology and the people who study it are called Meteorologists. They measure, record and interpret the weather. They forecast what the coming weather may be, and predict future weather patterns. Many instruments are used to study and measure the atmospheric elements and their variations. Some of these are: *rain-guage* to measure rainfall, *Six's thermometer* to measure temperature, *wind vane* to identify the direction of the wind, *anemometer* to measure the speed of airflow in the atmosphere, *wet-bulb-dry-bulb thermometer* to measure humidity.

Objective

To help develop students' skills for observing weather changes and recording data graphically.

Activity

a) Ask students to prepare a table as shown below:

Weather Prediction Table

Date	Our Prediction	Forecast According to Newspaper/ Radio /TV	Actual Weather
7.06.03	Cloudy	Cloudy	
8.06.03	Sunny	Cloudy	
9.06.03	Cloudy	Rainy	
10.06.03	Sunny	Windy	

b) Also prepare a calendar of the current month on (as shown on page 59) with days and date marked on it.

India Meteorological Department

The India Meteorological Department (IMD) was established in 1875. It is the National Meteorological Service of the country and the principal government agency in all matters relating to meteorology, seismology and allied subjects.

Calendar for the Month: June 2003

Sun	Mon	Tues	Wed	Thurs	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

c) Let the students discuss the weather. How many types of weather conditions can they describe? Ask the students to prepare symbols for different weather conditions as shown in the figure alongside. The students can develop symbols according to the weather conditions prevailing in their area.

d) Every evening, ask the students to make weather predictions for the next day, before they leave the school. Let them record it in the 'Weather Prediction Table'.

e) Let them look at the newspaper every morning before they come to school and note the prediction for that day in the relevant column.

f) The next day they must fill in the last column.

How often were their predictions right? How often was the newspaper right?

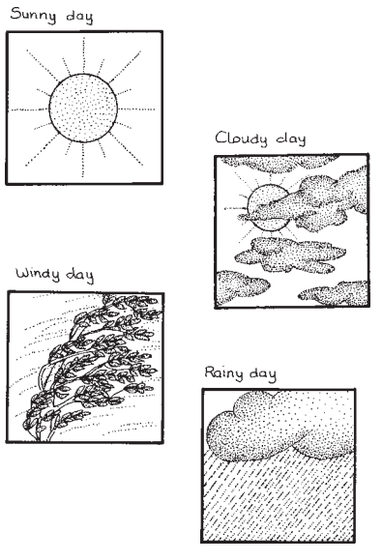
g) At the end of each day, they should be asked to fill each of these squares in the Calendar with a symbolic drawing appropriate to the weather prevailing on that day. For example, if the season is monsoon and it is very cloudy on Monday the 1st, the students will write 'very cloudy'and also depict it graphically.

h) Ask them to talk to parents and grand-parents and collect proverbs regarding weather. How true are these, according to their experience?

Farmers' Weather Bulletins

Farmers' Weather Bulletins are issued daily by India Meteorological Department forecasting offices for broadcast in different regional languages through the stations of All India Radio in their evening programmes for farmers. A second bulletin is issued for broadcast in the morning during the rainy season. The bulletins are also published in newspapers. Farmers' Weather Bulletins provide a district-wise forecast of weather for the next 48 hours, with an outlook for the following 2 days, taking into account the effects of weather on crops grown in their respective regions.

Weather Symbols



Weather Predictions

You may think only the meteorology department can predict or forecast weather. Guess who else can predict weather?

People have always been interested in knowing about weather, particularly farmers, sailors and others, because their livelihoods depend on it. Before different scientific instruments were invented, people used the things around them as a guide to predict weather—the sky, the behaviour of animals, birds and plants.

The scientific basis of many of these have not been proved but it is undeniable that some very small changes in weather affect plants and animals more than they affect us. Animals react to the weather far more spontaneously than human beings and a great deal can be learned by observing this behaviour in farm animals like cows, sheep, pigs, and horses.

Some Traditional Beliefs from Different Parts of the World

Sheep bleat persistently when rain is on the way. They also frolic about and feed greedily.

Goats will graze with their heads towards the wind on a fine day, but if bad weather is coming, they will crop with their tails to the wind.

Horses smell strongly and rabbits stare about with ears twitching when rain is in the air.

Cats will wash themselves with more care than usual, bringing their paws right over the nose and ears. If frost is in the air, they will sit with the back to the fire.

Bees are extremely sensitive to the weather. They do not swarm before a storm. They become agitated and irritable when thunder is about.

Spiders tighten the strands of their webs when they sense that the wind is coming.

Frogs croak noisily, when rain is on the way.

Robin sings at evening, when rain is on the way. If a robin sings unusually loudly, then bad weather is about.

Ducks quack noisily when it is to rain.

Geese are extra rowdy and crowd about in restless flocks, when bad weather is approaching.

If a **Skylark** sings, then it won't rain.

Flowers and plants are also sensitive to weather conditions.

Daisies close up tightly during rain, inclining their heads downwards to ward off the water and they do not open out again until the sun shines.

Onion skin will be very thin if mild winter is coming. If the skin is thick and tough, then following winter will be cold and rough.

Measuring Rainfall

Activity

Indian agriculture has traditionally depended on a successful monsoon. Rainfall is seasonal and crop production is extremely sensitive to monsoon rains. Eighty per cent of the country gets eighty per cent or more of the annual rainfall during the three-four months of the monsoon. India's topography, soils, rainfall, and the availability of water for irrigation have been major determinants of the crop. Statistics indicate that over seventy per cent of the total cultivated area is rainfed. About fourty four per cent of our total food grain is provided by such rainfed agriculture.

The India Meteorological Department (IMD) forecasts rainfall and other weather conditions. Extensive analysis of past rainfall data has been carried out by IMD to help agricultural planning in drought-prone and dry land farming areas of the country. Monsoons play a critical role in determining whether the harvest will be bountiful, average, or poor in any given year.

Objective

To develop an interest in maintaining weather records among students and to introduce to them a method of measuring rainfall.

Activity

1. Ask the students to make a rain-guage, following the instructions given below.
   a. Take a transparent plastic bottle and mark a circular line at a point close to the top (where the width is the same as its base).
   b. Cut along the line and separate the two parts. The lower part will serve as the body and the upper part as a funnel for the rain-gauge.
   c. Attach a transparent plastic scale to the side of the body of the rain-gauge as shown in the figure.
   d. To add stability to the rain-guage, drop a handful of glass marbles inside the bottom of the body to act as weights. Pour a little water into the rain-guage such that all the marbles are immersed and the level of water touches the bottom mark of the scale. This would help ensure that the width of the bottom of the measured area is the same as the width at the top, even in bottles whose bottoms are raised. This is essential for the rain-guage to show correct reading.

Subject
Science, Social Studies

Place
Outdoor

Duration
10 minutes everyday over a period of 3 months during monsoon season

Group size
Entire class

Materials
Newspapers, chart paper, graph paper, writing materials, a transparent plastic bottle, a transparent plastic scale, a small bucket, a large preferably concave plastic plate (large enough to cover the bucket), a nail and hammer.

Seasons and Crops

There are three main crop seasons, namely, kharif, rabi and summer. Major kharif crops are rice, jowar, bajra, maize, cotton, sugarcane, sesame and groundnut which are sown before the onset of monsoon. Major rabi crops are wheat, jowar, barley, gram, linseed, rapeseed and mustard which are grown when monsoon recedes. Rice, maize and groundnut are grown in summer season. Paddy is also grown in rabi season where plenty of water is available for irrigation.

The Monsoon Season in India

The term 'monsoon' is derived from the Arabic word *mausim* meaning season and is applied to the seasonal reversals of wind along the shores of the Indian Ocean that blow from the southwest one half of the year and from the northeast the remaining half. Two distinct phases are characteristics of the annual cycle of the monsoon.

1) The short wet season that is moist and warm with winds blowing inland from the oceans towards the land. This season extends from June to September and brings with it rain for almost the entire year.
2) The long dry season that brings dry air from the colder continents. The dry season extends for eight months from October to May and experiences a reversal in wind movements.

By and large, the monsoon in India is very reliable. The long-term average rainfall of around 85 cm for the whole country has been received on almost all occasions. On more than 70 per cent of occasions, the rainfall is 75 to 90 cm. Only twice or thrice in a century has the rainfall been as low as 60 cm, but never below 50 cm. In many parts of the world, normal average rainfall is less than 50 cm. Thus we can consider our monsoon rather reliable.

Even the onset or the start of the rainy season has been remarkably regular. On more than 70 per cent of the occasions, the variations have been less than one week. There are very few occasions when the variations have been as much as 10 or 15 days.

However, in drought-prone areas like Gujarat, Rajasthan, etc., the variations in the amount of rainfall can be as much as 40 per cent from the regional mean. Another problem is that, at times, there is a deficiency of rainfall for two or three consecutive years. Still, we have almost never had a large deficiency happen for more than three consecutive years.

The problem is that the heavy spells of rain are not uniformly distributed over the 4 months. There are hardly 100 rainy days at any place. In the drought-prone areas the number of rainy days are even less—40, 20, etc. Even during these rainy days, more than half of the total rainfall occurs in hardly 10 or 20 hours in very heavy spells of rains. For example, Ahmedabad had a rainfall of 38.7 cm on July 23, 2000.

In cities and towns, a large part of the open land has been built-up. The rain that falls on the roofs of built-up areas flows to the roads from where it cannot seep into the ground. Buildings have reduced the natural ability of the land for absorbing the rainwater and storing it as groundwater. Most of the rainwater escapes as floodwater and we face the consequences in the form of water shortage. Thus, even a place like Cherapunji in Assam that receives a large amount of rainfall becomes a drought-prone area after the rainy season.

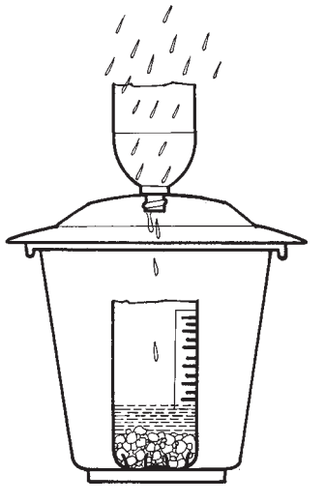
e. Place the body of the rain-guage in the centre of a small bucket.

f. Take a large concave plastic plate (big enough to cover the bucket completely) and make a hole at its centre. The diameter of the hole should be equal to the diameter of the stem of the funnel.

g. Cover the bucket using the plastic plate, such that the curved portion (convex surface) of the plate is upwards as shown in figure.

h. Fit the funnel in the hole in the plastic plate. Ensure that the entire set-up is aligned in such a way that the water flowing from the funnel falls into the body of the rain-guage.

i. During days of heavy rainfall, the rainwater collected might exceed the capacity of the body of the rain-guage. The excess water would overflow and get collected in the bucket. In such cases, note the level of water in the rain-guage, and empty it. Then pour the overflow water collected in the bucket, into the rain-guage and measure it. Repeat this, until all the overflow water in the bucket becomes empty. The sum of all would give the overall depth—the total amount of rainfall.



2. Ask the students to leave their rain-gauge on a flat area in the open, on a table one metre above the ground and away from walls, trees, etc.

3. Ask the students to read the rain-gauge daily everyday within one hour of noon. Ask them to record the measurement in the following table.

Day/Date	**How Much Rainwater is Collected in Raingauge ?**
14.06.03	
15.06.03	

4. Tell them that when they read the rain-gauge, their eyes should level with water in the rain-gauge (to avoid parallax error). They read the lower meniscus.

5. After the measurement, ask them to empty the water in the rain-gauge, by inverting it and allowing the water to drain out.

6. Ask the students to remount the rain-guage for the next day.

7. On days when water in the rain-guage is accidentally spilled, tell the students not to take the measurement (or if the measurement is lost

for some reason), enter either letter "M" (for missing), or if data could be collected from the nearest meteorological station, or from newspapers, the appropriate value. [It is a common mistake to substitute zeroes for missing values, which leads to wrong analyses later.]

8. Tell them to display the information collected in the form of a chart or graph.
9. After a month, ask them to calculate the average rainfall,
10. After some months, ask the students to plot graphs to get a clearer picture of how the rainfall changes over a period of time.

Extension/Variation

1. Give the students the data of average rainfall of some major cities.
2. Take them on a visit to the nearest meteorological station. How they measure and analyze the collected data.

Measuring Temperature

Activity

Trends indicate that global temperature is rising. This rise in temperature and subsequent change in climate could has impacts for all life forms. Different species of plants and animals may respond in different ways to the increase in global temperature. Many species that cannot adjust to warmer temperatures could become extinct. Species sensitive to any atmospheric change will be at risk. Keeping track of temperature is very important in order to understand changes in climate pattern. The instrument used to measure temperature is called thermometer. The temperature of a place changes constantly. The maximum and minimum temperature of a place could be found with the help of the thermometer within 24 hours.

Objective

To help students learn to measure temperature accurately using thermometer and how a maximum-minimum thermometer works.

Activity

a) Mount the maximum/minimum thermometer in the instrument shelter as instructed.

b) Ask the students to read the thermometer daily.

c) Ask them to read the current daily temperature at the top of the column of mercury on either the maximum or minimum sides of the U-tube.

d) Take the maximum and minimum readings at the base of the indicators.

e) Ask them to note down this reading in the table given below.

Date	Current Air Temperature (in ^{O}C)	Maximum Daily Air Temperature (in ^{O}C)	Minimum Daily Air Temperature (in ^{O}C)
15.07.2003			
16.07.2003			

Subject
Social Studies, Science

Place
Outdoor

Duration
10 minutes

Group size
Entire class

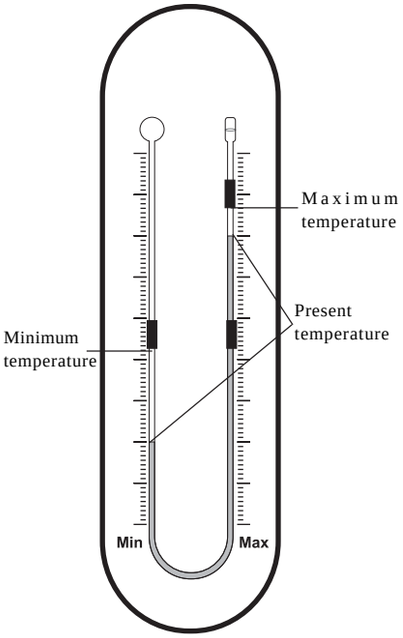
Materials
A maximum and minimum thermometer, an instrument shelter

Mounting the Instrument Shelter

The instrument shelter should be mounted on a post that is secured in the ground as firmly as possible so as to eliminate vibrations. The shelter's door should face north in the Northern hemisphere and south in the Southern hemisphere, to reduce exposure of the thermometer to direct sunlight when the door is open for the daily measurement. The shelter protects the thermometer from radiation from the sun, sky, ground and surrounding objects, but allows air to flow through so the air temperature inside the shelter is the same as the air temperature outside the shelter.

The thermometer in the instrument shelter should be so mounted that there is air flow all around the thermometer case. It should be attached to the blocks on the rear wall. No part of it should touch the walls, floor or ceiling of the shelter.

Six's Thermometer



f) Let them put up a large sheet of graph paper on a notice board and plot these points every day.

How the Maximum-Minimum Thermometer Works

The temperature of a place changes continually. Six's Thermometer is a special kind of device used for measuring the maximum and minimum temperature of a place in a day, without the constant presence of an observer. It is a 'U' shaped tube (as shown in the figure) with small bulbs at both its ends—left and right. On the right and on the left the bulbs and the thin tubes connected to them contain alcohol. The bulb on the maximum side is only partly filled with alcohol, while the bulb in the minimum side is completely filled. The centre of the 'U-tube' (or the lower end of the tube) contains mercury. Inside the 'U-tube', between the alcohol and mercury, two metallic (steel) indices are placed in such a way that the mercury can push them only upwards. On the maximum side, the temperature scale increases from bottom to top, and on the minimum side the temperature scale decreases from bottom to top.

When the temperature increases, the mercury and the alcohol expand. As the glass bulb on the maximum side is partly empty, expansion takes place towards this side and the index here is pushed up (to show maximum temperature), whereas the index on the minimum side remains still (the metallic indices can only be pushed upwards).

Conversely, as the temperature falls, the mercury and the alcohol shrink. This time, the index on the maximum side remains still at the position, as the metallic indices can only be pushed upwards. However, the index on the minimum side is pushed up to show the minimum temperature. Thus, it is possible to measure the highest and lowest temperatures for the period of measurement, without the constant presence of an observer.

To carry out further measurements, the Six's Thermometer is reset by dragging the metal pointers to rest on the mercury, using a magnet.

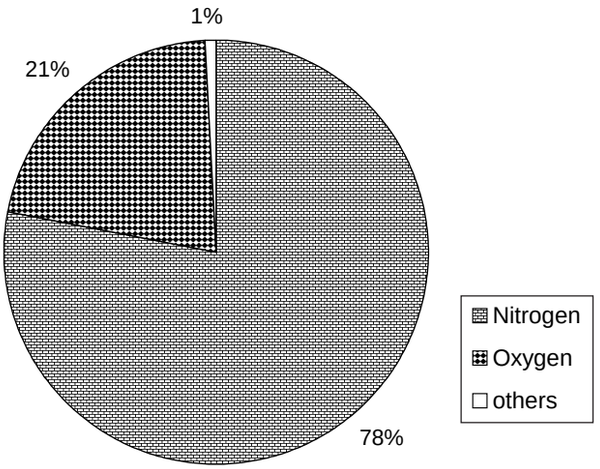
More About Atmosphere

Air and Atmosphere

The earth is surrounded by a blanket of gases which is called the atmosphere. It reaches to a height of about 560 kilometers from the surface of the earth. The atmosphere is made up of a number of different gases. The percentage of some of these gases remains constant, while that of others changes. The most abundant gas is nitrogen, and it makes up about seventy eight per cent of the air we breathe. The next-most abundant gas is oxygen, which forms nearly twenty one per cent of the atmospheres. All living things need oxygen to carry out their life processes. Carbon dioxide too is present but in a much smaller percentage, i.e. 0.03 per cent. Plants use it to make foods through photosynthesis. There are also some traces of water vapour, ozone and other particles and gases.

Gases Whose Percentage is Constant		Gases Whose Percentage Varies	
Nitrogen	78.1%	Argon	0.9%
Oxygen	20.9%	Neon	0.002%
		Helium	0.0005%
		Krypton	0.0001%
		Hydrogen	0.00005%

Composition of Air (%)



Layers of Atmosphere

Four distinct layers of the atmosphere have been identified. These are differentiated by their thermal characteristics, chemical composition, movement, and density. The four layers are: Troposphere, Stratosphere, Mesosphere and Thermosphere.

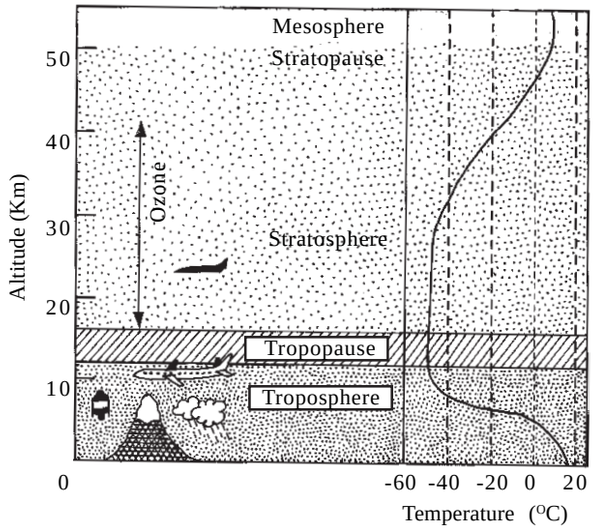
Troposphere

The troposphere starts at the Earth's surface and extends 8 to 14.5 kilometers high. It is the bottom layer of the atmosphere. This part of the atmosphere is the densest and consists of various gases, dust particles and water vapour. Most of the weather processes like clouds, rain and snow occur in this layer. As one climbs higher in this layer, the temperature drops from about 17^{O}C to -52^{O}C. This is why high mountains still have snow on them even in the summer months.

The troposphere is the area where the clouds that we see in the sky are found. The tropopause separates the troposphere from the next layer. Together the tropopause and the troposphere are known as the lower atmosphere.

Stratosphere

The stratosphere starts just above the troposphere and extends 50 kilometers high. Compared to the troposphere, this part of the atmosphere is dry and less dense. The temperature in this region increases gradually to -3^{O}C. Ninety-nine per cent of 'air' is located in the troposphere and stratosphere. The stratopause separates the stratosphere from the next layer.



Mesosphere

The mesosphere starts just above the stratosphere and extends 85 kilometers high. In this region, the temperatures again fall as low as -93^{O}C, as altitude increases. The mesopause separates the mesosphere from the thermosphere. The regions of the stratosphere and the mesosphere, along with the stratopause and mesopause, are referred to as the middle atmosphere.

Thermosphere

The thermosphere starts just above the mesosphere and extends 600 kilometers high. This layer is known as the upper atmosphere. Temperatures in this region can go as high as 1,727^{O}C. The temperatures go up as the altitude increases and they are very high in this layer, because the gaseous molecules here are constantly bombarded by high-energy solar radiation. Here, a small change/ variation in solar energy causes a large change in temperature. Chemical reactions occur much faster here than on the surface of the Earth, because of the high temperatures.

Beyond the Atmosphere

The exosphere starts at the top to the thermosphere and continues until it merges with interplanetary gases, or space. In this region of the atmosphere, hydrogen and helium are the prime components, found in extremely low densities in this region. Because they are very light atoms, they have a high velocity and thus escapes from the atmosphere.

Don't Confuse Weather and Climate!

Weather is the daily changes in the sunshine, wind and rain. Climate is the average conditions of sunshine, wind and rain over a long time.

Weather and Climate

The atmospheric conditions found in a place at any particular time is weather. The various atmospheric conditions that constitute weather include temperature, varying pressure, hot and cold air currents, formation of clouds, precipitation, solar radiation, etc.

Climate is the average weather of a large area over a long period. It refers to the general pattern of atmospheric or weather conditions, seasonal variations and weather extremes in a region, averaged over a long period—at least 30 years. The two most important factors determining the climate of an area are temperature and precipitation.

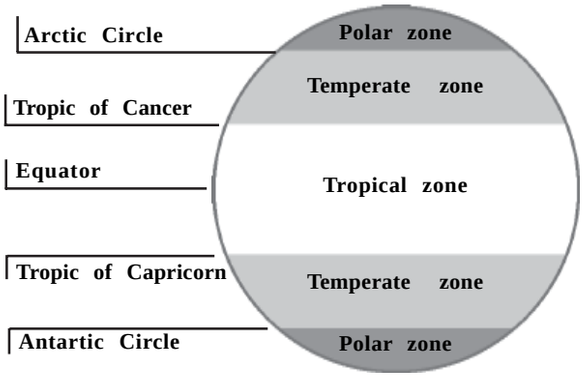
Global Climatic Zones

Have you ever thought why one area of the world is a desert, another a grassland, and another a rainforest? Why are there different forests and deserts, and different types of life forms in each area? This is because of climate.

There are three types of climatic zones, namely tropical, temperate and polar zones. The same season is quite differently manifested in each of these zones. The seasonal differences are due to the duration and the directness of incoming solar energy (insolation).

Temperature, precipitation and the amount of moisture influence the kind of vegetation that occur in an area. Several aspects of precipitation are important: the total amount of precipitation per

Global Climate Zones



year, the form in which it arrives (rain, snow), and the seasonal distribution of the precipitation. Is it evenly spaced throughout the year? Are there wet and dry seasons?

Areas with low moisture and low temperatures produce **tundra**; areas with high moisture and freezing temperatures produce **deciduous or coniferous forests**; dry areas produce **deserts**; moderate amounts of rainfall or seasonal rainfall support **grasslands**; and areas with high rainfall and high temperatures support **tropical rainforests**.

Adaptations to Climate

Animals and plants found in different climatic regions have special adaptations. An adaptation to climate is the special characteristic that enables a plant or animal to be successful in that particular climate.

In Deserts

Deserts have generally hot and extremely dry climate. Plants and animals show many adaptations to cope with this. To reduce water loss, desert trees are mostly thorny with highly reduced leaf surfaces, and roots that go deep in search of water. Cacti and other succulents are the dominant plant species here. Photosynthesis, which normally occurs in green leaves, is carried out in the chlorophyll containing green stems. Desert animals also show adaptations to survive in the desert climate. A large number of desert mammals are burrowing in nature. This helps in overcoming extreme temperature variations. Many are nocturnal, being active during the cool night rather than the hot daylight hours. During daytime, they spend a considerable amount of time in underground burrows to avoid extreme temperatures.

In Tropical Rainforests

The climate of the tropical rainforest is hot and wet. With over 200 centimeters of rain per year, plants in these forests have adaptations which enable them to shed water efficiently, rather than to hold it. The leaves of many rainforest plants have drip tips for this purpose.

In Tundra

The tundra is the coldest and the driest region. Animals here have special adaptations that allow them to survive in the winter weather. Some of these include: short legs; long hair; and a coat of thick fur. They have short tails and large, furry feet. Many animals have white fur which camouflages them against the snow.

For example, polar bears have distinct white fur to deal with this extremely harsh habitat and to blend into their snowy surroundings. The animals of the Tundra have developed many adaptations such as thick insulating cover, pelage and plumage that turn white in the winter and brown in the summer. Penguins have adapted to their icy environment in another way. Penguins are covered in feathers just like all other birds. Penguin feathers are short and dense. When a penguin grooms its feathers, it spreads oil over them with its beak. This makes the feathers waterproof and helps to keep the penguin warm when it is swimming in the ice cold seas.

Because of permanently frozen soil layer (permafrost), the tundra region lacks trees. During the brief summer, the top layers of the soil thaws and many plants and lichens grow. Plants in the tundra have many adaptations such as being small and able to grow close to the ground, to protect from the cold and harsh temperatures.

Atmospheric Conditions

Atmospheric conditions like temperature, humidity (moisture), pressure of air and winds, wind velocity and direction, clouds, snow and rainfall, solar radiation at a particular location over a short period—all these constitute weather. Each of these factors is important in determining the weather condition and climate pattern of the place. Climate in turn determines what kinds of life are found in different regions. We shall see some of these factors and how they impact one another.

Humidity

The amount of water vapour present in the air is called humidity. Some water in the form of invisible vapour is intermixed with the air throughout the atmosphere. It is the condensation of this vapour which gives rise to most weather phenomena: clouds, rain, snow, dew, frost and fog. There is a limit to how much water vapour the air can hold and this limit varies with temperature. When the air contains the maximum amount of vapour possible for a particular temperature, the air is said to be saturated.

The evaporation of water takes place readily when the humidity is low, whereas if the humidity is higher, the evaporation process is slower. People sweat when the humidity is high, because the sweat does not readily evaporate. Such weather is muggy and uncomfortable. This type of weather is experienced in coastal areas and during cloudy days. During winter, the increase in humidity makes the air feel more chilly.

Clouds

Water is present in the atmosphere in the form of gas (water vapour), liquid (rain drops or cloud droplets), and solid (ice crystals or frozen rain). If the temperature is above freezing, the water vapour condenses into cloud droplets. If the temperature is below freezing, tiny ice crystals are formed. Clouds are simply the visible form of these crystals or droplets.

Clouds play an important and complex role in the climate system. They are the source of precipitation; they affect the amount of the sun's energy that reaches earth; and they insulate the earth's surface and lower atmosphere.

Clouds help to maintain the heat balance of the earth. They reflect some of the sunlight away from earth, thus making the planet cooler than it would be otherwise. On the other hand, they also absorb some of the heat energy given off by the earth's surface and release some of this back towards the ground, thus making the surface warmer than it would be otherwise. Satellite measurements have shown that, on an average, the cooling effect of clouds dominates over their warming effect.

Precipitation

Precipitation refers to all forms of liquid or solid water that falls from the atmosphere and reaches the Earth's surface. Liquid precipitation includes rainfall and drizzle; solid precipitation includes snow, ice pellets, hail and freezing rain. Precipitation is a vital component of climate and sustains life. Where it is scarce, deserts occur. Where it is abundant, there is luxurious plant growth. Precipitation is critical to agriculture, fresh water supplies and in some regions, power supplies. Two key factors that affect precipitation level are the amount of water vapour in air, and the temperature.

Warm air can hold more vapour than cold air. As water vapour rises in the atmosphere, it cools and eventually condenses into a liquid form once more, on tiny particles of dust floating through the air. When enough water droplets combine, they form a cloud. As the air continues to cool, the cloud becomes saturated with water droplets and water begins to fall as rain. The process by which the water returns back to the earth as liquid (rain) or solid (ice, hail or snow), is called precipitation.

Pressure

Air exerts pressure on everything within and around it. Pressure is a force, or weight, exerted per unit

area of a surface, and is measured in Pascals (Pa). Atmospheric pressure is quoted in millibars (mb) and is measured by a barometer. 1 mb is equal to 100 Pa, and standard atmospheric pressure is about 1000 mb. In fact, actual values of atmospheric pressure vary from place to place and from hour to hour. At sea level, values range between 970 mb and 1040 mb. Pressure decreases with increasing altitude. When it is observed at different stations, the readings need to be adjusted to sea level.

Movement of Air

Movement of air is caused by temperature or pressure differences, and is experienced as wind. When there are differences of pressure between two places, air moves from the high-pressure region to the low-pressure region. This movement of air does not follow the quickest straight-line path, but follows a spiraling route, outwards from high pressure and inwards towards low pressure. This is due to the rotation of the Earth beneath the moving air.

Air temperature is generally higher at ground level due to heating by the sun, and decreases with increasing altitude. This vertical temperature difference creates a significant uplift of air, since warmer air nearer the surface is lighter than colder air above it. This air cools with vertical uplift, and the moisture it contains condenses into cloud droplets, which eventually produce precipitation. Sometimes air from warmer regions of the world collides with air from colder regions. This air-mass convergence occurs in the mid-latitudes, where the warm air is forced to rise above the colder air, generating fronts and depressions.

Seasonal Change

All seasonal changes are driven by changes in the amount of the Sun's energy reaching the earth's surface. As the earth orbits the sun, the atmosphere, surface water, soil moisture, temperature and vegetation all are impacted by seasonal changes. Seasonal patterns are influenced by a combination of latitude, elevation and geography. The Earth makes its annual rotation around the sun on an axis (imaginary line connecting North Pole and South Pole) tilted at about 23.5^{O}. Because of this tilt, various regions are tipped towards or away from the sun, which causes changes in seasons, and opposite seasons in Northern and Southern hemispheres.

Impact of seasonal changes on the earth systems

Earth's living systems have adapted to earth's seasonal changes in many ways. Animals migrate during the course of the year to avoid extreme conditions. Plants have their highest photosynthesis levels in the summer when the sun is highest. Seeds germinate when soil temperature and moisture are favourable. Soil conditions vary seasonally. Seasonal biological changes such as leaves falling enrich the soil. The rate at which rain soaks into the ground differs in different seasons. Hurricanes and storms are season-dependent, as are rains. Rainy and dry seasons affect the quantity and quality of water in rivers and lakes. Seasonal monsoons are essential for the replenishment of water reserves.

Climate Change

Earth's climate is a result of complex interactions of the sun, atmosphere, oceans, land and biosphere. From the ice ages of the past, to the industrial age of the present, the climate of the earth has been changing. There are both natural and human-made causes due to which climate is changing. Most natural changes follow a regular pattern, and hence their sequence may be predicted. Ice ages of the past are examples of climatic changes due to natural factors. The changes due to human activities not only have a greater, more serious and sudden impact on the climate, but also occur faster (even over a period of decades).

While changes in climate are natural, what is disturbing today is the fact that human activities are leading to an unprecedented acceleration in such changes. By the year 2050, scientists predict that the world will be warmer by an average of between $1.5^{O}C$ and $4.5^{O}C$. The increase in some gases in the

atmosphere, resulting from human activities such as burning of fossil fuels and deforestation, are some of the reasons for this. As these emissions continue to rise, it is feared that they will lead to a substantial change in the climate. This warming of the earth is referred to as **Global Warming**. The most important phenomenon contributing to this warming is the **Greenhouse Effect**.

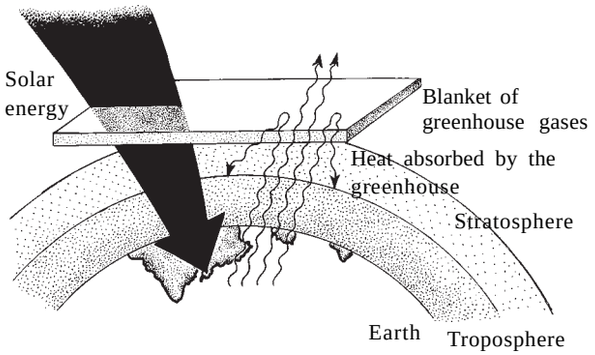
The Greenhouse Effect and Global Warming

In the normal course of things, the earth's surface absorbs some of the sun's rays and is warmed, while some of the heat is radiated back into the atmosphere. Naturally occurring gases in the atmosphere trap a part of this outgoing heat and prevent it from escaping back to space. This leads to warming of the earth's surface and a substantial rise in the temperature in the troposphere. This phenomenon keeps our atmosphere within a range of temperatures which allows life to exist. If these gases were not found naturally in the atmosphere, the planet would be much colder than it is at present, and life as we know it may not be possible.

The gases that absorb heat are carbon dioxide, methane, ozone and chlorofluorocarbons (CFCs). Some of them occur naturally, while others are human-made. These gases are called greenhouse gases (GHGs) because they act like the glass of a greenhouse. The heat absorbed by the surface of the earth is retained and it cannot escape into space. This trapping of heat in the troposphere is called the Greenhouse Effect.

Global climate is dependent on the concentrations of GHGs in the earth's atmosphere. If these concentrations increase or decrease significantly, our climate will change.

Today, release of greenhouse gases from human activities is dramatically increasing. Vehicular and industrial pollution are adding carbon dioxide, carbon monoxide, sulphur dioxide etc. Also, some new man-made chemicals like CFCs which act as GHGs are being introduced into the atmosphere.



Greenhouse effect could result in a change in the global climate

The resulting gradual increase in the temperature of the earth is referred to as Global Warming**.**

Greenhouse Gases

The most important greenhouse gases are carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4) and nitrous oxide (N_20). There are other gases also, like ozone and carbon monoxide which contribute to global warming.

Carbon dioxide: Carbon dioxide contributes about 55 per cent of the global warming caused by greenhouse gases. Burning of fossil fuels like coal, oil, natural gas, and biomass, generate carbon dioxide. These sources are increasing the amount of carbon dioxide in the atmosphere.

Destruction of forests by burning also gives rise to carbon dioxide. Vegetation helps reduce carbon dioxide by taking it in for photosynthesis and giving out oxygen. Trees, therefore, acts as sinks for carbon dioxide. But when trees are cut, they cannot perform this function.

Oceans serve as a gigantic reservoir of carbon dioxide, having a huge capacity to absorb heat and remove carbon dioxide from the atmosphere. Because carbon dioxide dissolves in water, the oceans can take up the excess carbon dioxide released in the atmosphere. The phytoplanktons too are a sink for carbon dioxide as a result of photosynthesis.

Methane: Methane accounts for about 18 per cent of the increase in greenhouse gases. Methane enters the atmosphere primarily from biological sources. These include the activity of methane-producing bacteria in the guts of termites and various kinds of ruminant animals such as cattle, as well as the guts of humans; and production of methane by bacteria which live in paddy fields, wetlands, rubbish heaps etc. The largest agricultural source of methane production is associated with rice cultivation.

Methane and Rice Fields

Methane is generated biologically by methanogenic bacteria. The warm, waterlogged soil of rice/ paddy fields provides ideal conditions for methanogenesis. Methanogenesis is the production of methane and carbon dioxide by biological processes that are carried out by methanogens. Methanogens are single-celled microorganisms that produce methane by the fermentation of simple organic carbon compounds or oxidation of H_2 under anaerobic (without oxygen) conditions with the production of carbon dioxide.

Possible sources for methane emission from paddy fields are organic matter applied to the fields, such as rice straw, soil organic matter, and carbon supplied from rice plants.

Chlorofluorocarbons: CFCs are entirely human-made greenhouse gases. In the past they were used as coolants in compressors of refrigerators and air conditioners. Many perfume and room freshener containers used CFCs. CFCs were also used to clean electronic circuit boards in computers, phones, etc. After the Montreal Protocol (1987), which required countries to phase out the usage of CFCs and stop the production and consumption of Ozone Depleteing Substances (ODS) within a stipulated time, to protect the ozone layer, strict measures have been taken in the country to phase out ODS. These measures include ban of trade in ODS, licensing import and export of ODS, and ban on creation of new ODS production facilities and switch-over to non-ODS technology by some enterprises.

Nitrous oxide: Nitrous oxide accounts for 6 per cent of the human input of greenhouse gases. It is released during nylon production; from burning of biomass and fossil fuels like coal; from the breakdown of nitrogen fertilizers in soil; livestock wastes and nitrate-contaminated groundwater. Both natural and man-made fertilizers contribute towards the release of nitrous oxide through denitrification—the reduction of nitrate in soils. Nitrification, a process of converting ammonia into nitrate, can also produce nitrous oxide.

Human Sources of Greenhouse Gases

Greenhouse gases	Sources
Carbon dioxide	Fossil fuels burning, Deforestation
Methane	Farm animals, paddy fields, biomass burning, losses from natural gas, wells and pipe-lines, sewage/landfills
CFCs	Refrigeration, foams, aerosols, solvents
Nitrous oxide	Fossil fuel burning, fertilizers, biomass burning, deforestation

Other Gases

Ozone (O_3) has 2000 times the heat retention property of carbon dioxide. It is found mainly from 30 to 80 km height. It interacts with ultraviolet radiation from the sun and prevents most of it from reaching the earth. At ground level, it is found in small quantities in air and is formed when other

The Ozone Problem

Ozone is a naturally occurring gas found in very small traces in the earth's atmosphere. The ozone molecule is made up of three oxygen atoms. Ozone molecules make up a very sparse layer in the upper atmosphere (stratosphere). This is called the Ozone Layer. Some ozone is also found in the lower atmosphere (troposphere).

The presence of ozone can be a good or a bad thing depending on where it is present. In the stratosphere, ozone acts as a protective layer shielding the earth from harmful ultraviolet radiations. In the troposphere, ozone acts as a harmful pollutant and sometimes causes photochemical smog. More than a trace of this gas in the troposphere can damage human lungs and tissues, and also harm plants.

Ozone is also a greenhouse gas and contributes to the greenhouse effect and therefore plays a role in climate. It is affected by the seasons, changing wind patterns and other natural factors.

How is ozone measured?

Total column ozone is recorded in *Dobson Units* (DU), a measure of the thickness of ozone layer by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. The total amount of ozone in a 'column' of air from the earth's surface up to an altitude of 50 km is the ***total column ozone.*** In other words, 100 DU = 1 mm of pure ozone gas at normal temperature and pressure at sea level.

Ozone depletion

For billions of years, a delicate balance has been maintained by nature. However today, many human activities are harming the ozone layer and are leading to a decrease in the ozone levels in the stratosphere. The reduction in the amount of ozone in the upper atmosphere is known as **Ozone Depletion**. The chemicals causing this are called **Ozone Depleting Substances (ODS)**. The main ozone depleting substances are CFCs and halons. Besides these, some other ODS are methyl chloroform, carbon tetrachloride and methyl bromide.

Depletion of the ozone layer allows potentially dangerous ultraviolet rays into the lower atmosphere. Our health would suffer due to the excess of UV radiation on earth. It can weaken our immune systems and make us more prone to disease. Exposure to UV radiation causes skin cancers and damages our eyes.

Increased UV radiation affects plants by reducing leaf size and increasing germination time. This could decrease crop yield. There may be reduction in the growth of microscopic phytoplankton when UV radiation penetrates deep below the surface of oceans. These tiny, floating producers form the base of ocean food chains and food webs, and help remove carbon dioxide from the atmosphere. The food chain of the terrestrial ecosystems will also be affected as the land plants will be adversely affected by high levels of UV.

Besides filtering out harmful ultraviolet rays, ozone creates warm layers of air high in the stratosphere. These layers prevent gases in the troposphere from entering the stratosphere. This thermal umbrella is important in determining the average temperature of the troposphere and therefore the Earth's current climates. Any loss of ozone in the stratosphere or gain in greenhouse gases in the troposphere can change global climate, threatening our health and our economies.

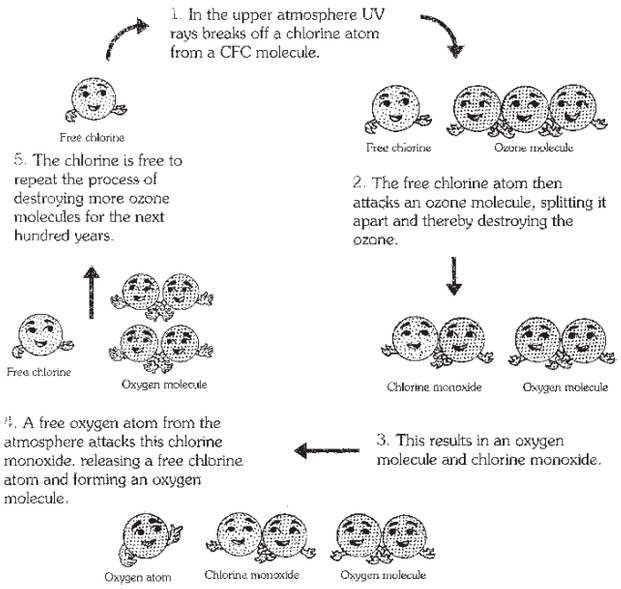
How does ozone get destroyed?

Ozone depleting substances are those which destroy ozone molecules. These are all man-made. Some of them are:

CFCs: Chlorofluorocarbons (CFCs) are gases or liquids made of chlorine, fluorine and carbon. CFCs are entirely man-made. CFCs are powerful ozone destroyers. After being generated on earth by our activities, CFCs rise slowly

into the stratosphere. Here, under the influence of high-energy ultraviolet (UV) radiation, they break down and release chlorine atoms, which speed up the breakdown of ozone molecule (O_3) into oxygen molecule (O_2) and oxygen atom (O). One CFC molecule can break down 100,000 ozone molecules through a catalytic chain reaction. CFCs do not destroy the ozone layer directly, but they act as carriers for the chlorine to the upper atmosphere.

Halons: Halons are similar to CFCs in structure but contain bromine atoms instead of chlorine. Each bromine atom destroys hundreds of times more ozone molecules than does a chlorine atom.



pollutants react in sunlight. It is also harmful to our health, animal and plant life and even to some common materials.

Carbon monoxide (CO) is generally not thought of as a greenhouse gas as it does not trap heat directly. However, it is indirectly responsible for increasing greenhouse warming through raising the levels of methane and ozone. CO participates in the formation of O_3. Motor vehicles are the major source of CO. CO is also very dangerous to human health. CO gets absorbed by the lungs quickly and is carried in the blood, it combines with the Haemoglobin (Hb), forming carboxyhaemoglobin (COHb) and thereby reduces the oxygen-carrying capacity of blood.

Impacts of Climate Change and Global Warming

What will happen if the earth's temperature rises by a small amount? Droughts, rising sea levels and loss of biodiversity are likely to be some of the consequences if the earth continues to become warmer and warmer.

Temperature increase: Earth's mean surface temperature will rise by between 1.5^{O}C and 4.5^{O}C by 2050, if inputs of greenhouse gases continue to rise at the present rate. This may lead to widespread damage to all life forms on earth. The increase in temperature would disrupt crop growth and could cause loss in agricultural production. (*See box on Climate and Vegetation on page 76*)

Rise in sea level: Increase in temperature will lead to melting of glaciers and rise in sea level. Sea level is a sensitive indicator of global warming since it is affected by both thermal expansion and the melting of land-based glaciers. About one-third of the world's population and more than a third of the world's economic infrastructure are concentrated in coastal regions. So a rise in the sea level would displace populations on the coasts and islands. Rise in sea levels would submerge small island states. The Republic of Maldives is a good example of a nation which is exceptionally vulnerable to further sea-level rise. Its problems of living space, availability of fresh water and coastal protection will seriously be increased by accelerated sea-level rise and will jeopardize this small island-nation.

Delta regions are also high risk areas. Many of these regions are already prone to flooding. Thousands of people dependent on these fertile agricultural areas would suffer. A one-meter sea level rise would flood deltas in Bangladesh, China, Egypt and India, where much of the world's rice is grown.

Saltwater intrusion is another major problem as sea level rises. Salt water may invade coastal freshwater aquifers. The intrusion is exacerbated by falling water tables. Rising sea level would allow saltwater to penetrate farther inland and upstream. Higher salinity impairs both surface and groundwater supplies. This effect would impair water supplies, ecosystems, and coastal farmland. Saltwater intrusion would also harm aquatic plants and animals, as well as threaten human water supply [IPCC, 1998]. Salinity intrusion has already been cited in a number of islands in the Bay of Bengal and the Arabian Sea. The Lakshwadeep Archipelago which consists of several coral reefs and islands is facing the danger of submersion if the sea level continues to rise.

Loss of Ecosystems and biodiversity: Rapid climate change would have severe impacts on the natural ecosystem. Large areas of forests would disappear. Species would be forced to migrate, and some species might become extinct. Fishes would die as temperature increases in streams and lakes. Shifts in regional climate would threaten many national parks, wildlife reserves and coral reefs.

Ecosystems will be in peril as more areas experience extreme heat waves and more forest fires. Due to large-scale felling of trees and a high level of dryness, forests may catch fire.

Species adapted to cool climates could become extinct as habitats disappear. Some species would migrate but others would not be able to. Marine ecosystems, especially tropical corals, which grow at a slow rate, would be affected by climate change.

Adverse effect on human health: The rise in global temperature could directly and indirectly affect human health. Deaths due to heat waves and other extremes of climatic conditions are some direct consequences. Indirect effects are more complicated as they involve the interplay of complex ecological relationships and habitats. Factors such as drought, rising sea-levels and new storm patterns would give rise to water-borne diseases. Ultimately body resistance would become weaker, and increase susceptibility to various infections.

Climate and Vegetation

The temperature and precipitation patterns that lead to different climates are caused mostly by the way air circulates over the earth's surface. The difference in the average temperature and precipitation determines the types of life which are found in different biomes like desert, grassland, or forests.

Climate and vegetation both vary with latitude (distance from the equator), and altitude (height above the sea level). Thus, when you travel from the equator towards either pole, you will find colder and wetter climates. Similarly as elevation or height above sea level increases, the climate becomes colder and is often wetter. When you climb a mountain from its base to its summit, the changes in plant life are similar to those you would find in traveling from equator to poles.

Changes in weather patterns would have far-reaching effects on agriculture and forestry. Some places would get drier, and some wetter. Some would get hotter and others cooler. The increase in temperature would disrupt crop growth and could cause loss in agricultural production.