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CHAPTER

6

Landforms and their Evolution

After weathering processes have had their actions on the earth materials making up the surface of the earth, the geomorphic agents like running water, ground water, wind, glaciers, waves perform erosion. It is already known to you that erosion causes changes on the surface of the earth. Deposition follows erosion and because of deposition too, changes occur on the surface of the earth.

As this chapter deals with landforms and their evolution 'first' start with the question, what is a landform? In simple words, small to medium tracts or parcels of the earth's surface are called landforms.

If landform is a small to medium sized part of the surface of the earth, what is a landscape?

Several related landforms together make up landscapes, (large tracts of earth's surface). Each landform has its own physical shape, size, materials and is a result of the action of certain geomorphic processes and agent(s). Actions of most of the geomorphic processes and agents are slow, and hence the results take a long time to take shape. Every landform has a beginning. Landforms once formed may change in their shape, size and nature slowly or fast due to continued action of geomorphic processes and agents.

Due to changes in climatic conditions and vertical or horizontal movements of land-masses, either the intensity of processes or the processes themselves might change leading to new modifications in the landforms. Evolution here implies stages of transformation of either a part of the earth's surface from one landform into another or transformation of individual landforms after they are once formed. That means, each and every landform has a history of development and changes through time. A landmass passes through stages of development somewhat comparable to the stages of life — youth, mature and old age.

What are the two important aspects of the evolution of landforms?

Running Water

In humid regions, which receive heavy rainfall running water is considered the most important of the geomorphic agents in bringing about the degradation of the land surface. There are two components of running water. One is overland flow on general land surface as a sheet. Another is linear flow as streams and rivers in valleys. Most of the erosional landforms made by running water are associated with vigorous and youthful rivers flowing over steep gradients. With time, stream channels over steep gradients turn gentler due to continued erosion, and as a consequence, lose their velocity, facilitating active deposition. There may be depositional forms associated with streams flowing over steep slopes. But these phenomena will be on a small scale compared to those associated with rivers flowing over medium to gentle slopes. The gentler the river channels in gradient or slope, the greater is the deposition. When the stream beds turn gentler due to continued erosion, downward cutting becomes less dominant and lateral erosion of banks increases and as a consequence the hills and valleys are reduced to plains.

Is complete reduction of relief of a high land mass possible?

Overland flow causes sheet erosion. Depending upon irregularities of the land surface, the overland flow may concentrate into narrow to wide paths. Because of the sheer friction of the column of flowing water, minor or major quantities of materials from the surface of the land are removed in the direction of flow and gradually small and narrow rills will form. These rills will gradually develop into long and wide gullies; the gullies will further deepen, widen, lengthen and unite to give rise to a network of valleys. In the early stages, down-cutting dominates during which irregularities such as waterfalls and cascades will be removed. In the middle stages, streams cut their beds slower, and lateral erosion of valley sides becomes severe. Gradually, the valley sides are reduced to lower and lower slopes. The divides between drainage basins are likewise lowered until they are almost completely flattened leaving finally, a lowland of faint relief with some low resistant remnants called *monadnocks* standing out here and there. This type of plain forming as a result of stream erosion is called a *peneplain* (an almost plain). The characteristics of each of the stages of landscapes developing in running water regimes may be summarised as follows:

Youth

Streams are few during this stage with poor integration and flow over original slopes showing shallow V-shaped valleys with no floodplains or with very narrow floodplains along trunk streams. Streams divides are broad and flat with marshes, swamp and lakes. Meanders if present develop over these broad upland surfaces. These meanders may eventually entrench themselves into the uplands. Waterfalls and rapids may exist where local hard rock bodies are exposed.

Mature

During this stage streams are plenty with good integration. The valleys are still V-shaped but deep; trunk streams are broad enough to have wider floodplains within which streams may flow in meanders confined within the valley. The flat and broad inter stream areas and swamps and marshes of youth disappear and the stream divides turn sharp. Waterfalls and rapids disappear.

Old

Smaller tributaries during old age are few with gentle gradients. Streams meander freely over vast floodplains showing natural levees, oxbow lakes, etc. Divides are broad and flat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level.

EROSIONAL LANDFORMS

Valleys

Valleys start as small and narrow rills; the rills will gradually develop into long and wide gullies; the gullies will further deepen, widen and lengthen to give rise to valleys. Depending upon dimensions and shape, many types of valleys like *V-shaped valley, gorge, canyon*, etc. can be recognised. A gorge is a deep valley with very steep to straight sides (Figure 6.1) and a canyon is characterised by steep step-like side slopes (Figure 6.2) and may be as deep as a gorge. A gorge is almost equal in width at its top as well as its bottom. In contrast, a canyon is wider at its top than at its bottom. In fact, a canyon is a variant of gorge. Valley types depend upon the type and structure of rocks in which they form. For example, canyons commonly form in horizontal bedded sedimentary rocks and gorges form in hard rocks.

Potholes and Plunge Pools

Over the rocky beds of hill-streams more or less circular depressions called *potholes* form because of stream erosion aided by the abrasion of rock fragments. Once a small and

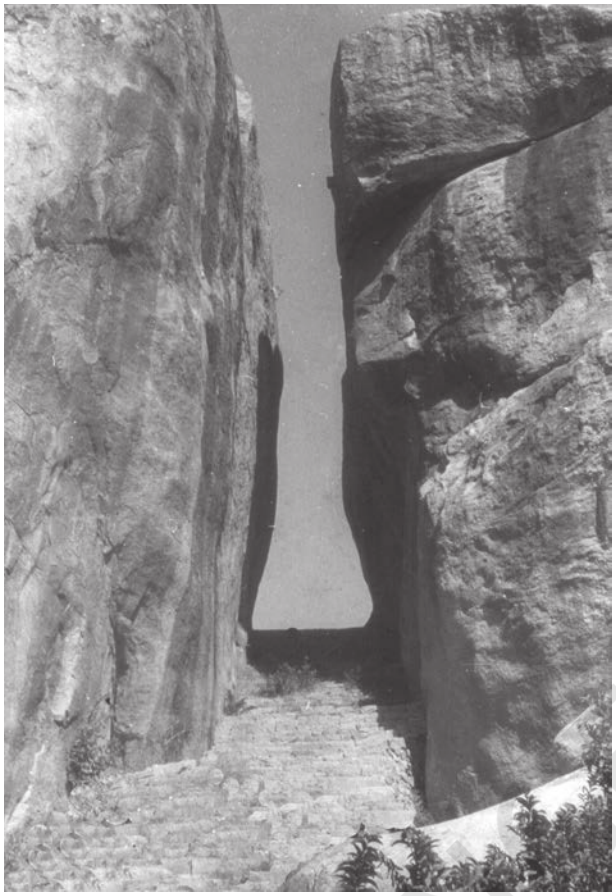

Figure 6.1 : The Valley of Kaveri river near Hogenekal, Dharmapuri district, Tamil Nadu in the form of gorge

Figure 6.2 : An entrenched meander loop of river Colorado in USA showing step-like side slopes of its valley typical of a canyon

shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water and consequently the depressions grow in dimensions. A series of such depressions eventually join and the stream valley gets deepened. At the foot of waterfalls also, large potholes, quite deep and wide, form because of the sheer impact of water and rotation of boulders. Such large and deep holes at the base of waterfalls are called *plunge pools*.

Incised or Entrenched Meanders

In streams that flow rapidly over steep gradients, normally erosion is concentrated on the bottom of the stream channel. Also, in the case of steep gradient streams, lateral erosion on the sides of the valleys is not much when compared to the streams flowing on low and gentle slopes. Because of active lateral erosion, streams flowing over gentle slopes, develop sinuous or meandering courses. It is common to find meandering courses over floodplains and delta plains where stream gradients are very gentle. But very deep and wide meanders can also be found cut in hard rocks. Such meanders are called *incised or entrenched meanders* (Figure 6.2).

River Terraces

River terraces are surfaces marking old valley floor or floodplain levels. They may be bedrock surfaces without any alluvial cover or alluvial terraces consisting of stream deposits. River terraces are basically products of erosion as they result due to vertical erosion by the stream into its own depositional floodplain. There can be a number of such terraces at different heights indicating former river bed levels. The river terraces may occur at the same elevation on either side of the rivers in which case they are called *paired terraces.*

Depositional Landforms

Alluvial Fans

Alluvial fans (Figure 6.3) are formed when streams flowing from higher levels break into foot slope plains of low gradient. Normally very coarse load is carried by streams flowing over mountain slopes. This load becomes too heavy for the streams to be carried over gentler gradients and gets dumped and spread as a broad low to high cone shaped deposit called *alluvial fan*. Usually, the streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called *distributaries*. Alluvial fans in humid areas show normally low cones with gentle slope from head to toe and they appear as high cones with steep slope in arid and semi-arid climates.

Figure 6.3 : An alluvial fan deposited by a hill stream on the way to Amarnath, Jammu and Kashmir

Deltas

Deltas are like alluvial fans but develop at a different location. The load carried by the rivers is dumped and spread into the sea. If this load is not carried away far into the sea or distributed along the coast, it spreads and accumulates as a low cone. Unlike in alluvial fans, the deposits making up deltas are very well sorted with clear stratification. The coarsest materials settle out first and the finer fractions like silts and clays are carried out into the sea. As the delta grows, the river distributaries continue to increase in length (Figure 6.4) and delta continues to build up into the sea.

Figure 6.4 : A satellite view of part of Krishna river delta, Andhra Pradesh

Floodplains, Natural Levees and Point Bars

Deposition develops a floodplain just as erosion makes valleys. Floodplain is a major landform of river deposition. Large sized materials are deposited first when stream channel breaks into a gentle slope. Thus, normally, fine sized materials like sand, silt and clay are carried by relatively slow moving waters in gentler channels usually found in the plains and deposited over the bed and when the waters spill over the banks during flooding above the bed. A river bed made of river deposits is the active floodplain. The floodplain above the bank is inactive floodplain. Inactive floodplain above the banks basically contain two types of deposits — flood deposits and channel deposits. In plains, channels shift laterally and change their courses occasionally leaving cut-off courses which get filled up gradually. Such areas over flood plains built up by abandoned or cut-off channels contain coarse deposits. The flood deposits of spilled waters carry relatively finer materials like silt and clay. The flood plains in a delta are called *delta plains*.

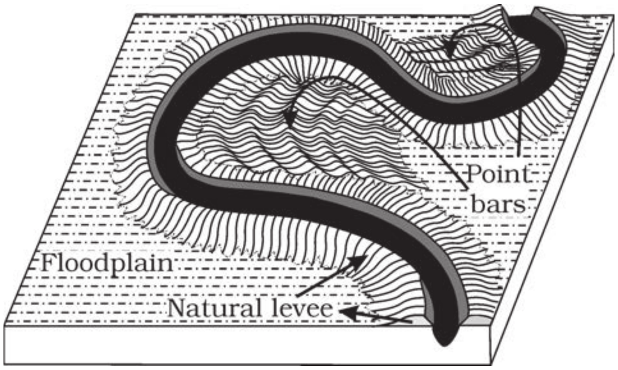

Figure 6.5 : Natural levee and point bars

Natural levees and point bars (Figure 6.5) are some of the important landforms found associated with floodplains. *Natural levees* are found along the banks of large rivers. They are low, linear and parallel ridges of coarse deposits along the banks of rivers, quite often cut into individual mounds. *Point bars* are also known as *meander bars*. They are found on the concave side of meanders of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank. They are almost uniform in profile and in width and contain mixed sizes of sediments.

In what way do natural levees differ from point bars?

Meanders

In large flood and delta plains, rivers rarely flow in straight courses. Loop-like channel patterns called *meanders* develop over flood and delta plains (Figure 6.6).

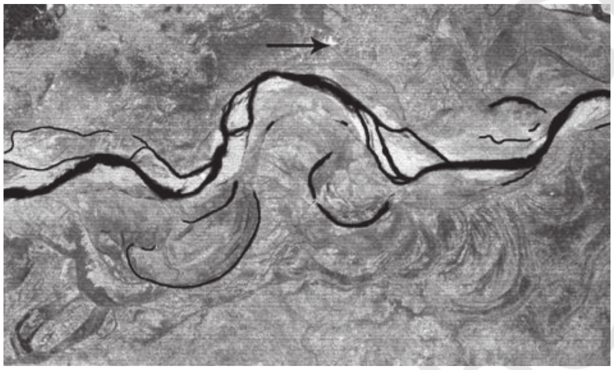

Figure 6.6 : A satellite scene showing meandering Burhi Gandak river near Muzaffarpur, Bihar, showing a number of oxbow lakes and cut-offs

Meander is not a landform but is only a type of channel pattern. This is because of (i) propensity of water flowing over very gentle gradients to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the banks with many irregularities which can be used by water exerting pressure laterally; (iii) coriolis force acting on the fluid water deflecting it like it deflects the wind. When the gradient of the channel becomes extremely low, water flows leisurely and starts working laterally. Slight irregularities along

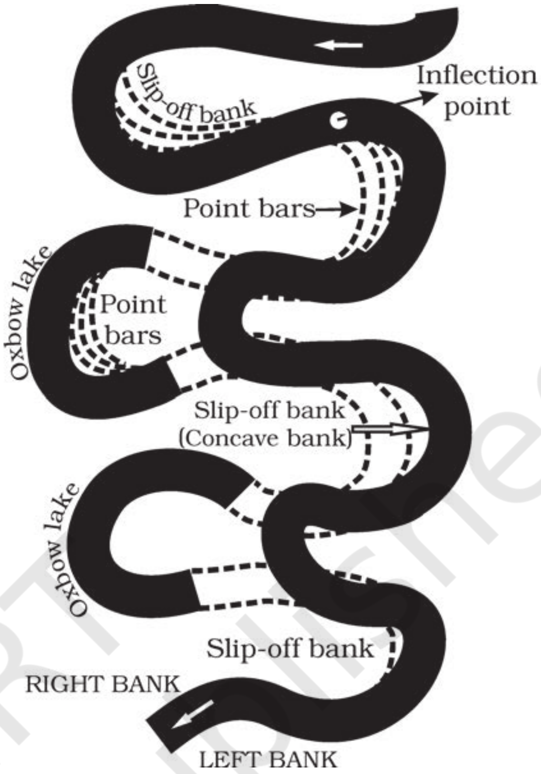

Figure 6.7 : Meander growth and cut-off loops and slip-off and undercut banks

the banks slowly get transformed into a small curvature in the banks; the curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside. If there is no deposition and no erosion or undercutting, the tendency to meander is reduced. Normally, in meanders of large rivers, there is active deposition along the concave bank and undercutting along the convex bank. The concave bank is known as cut-off bank which shows up as a steep scarp and the convex bank presents a long, gentle profile (Figure 6.7). As meanders grow into deep loops, the same may get cut-off due to erosion at the inflection points and are left as *ox-bow lakes*.

Groundwater

Here the interest is not on groundwater as a resource. Our focus is on the work of groundwater in the erosion of landmasses and evolution of landforms. The surface water

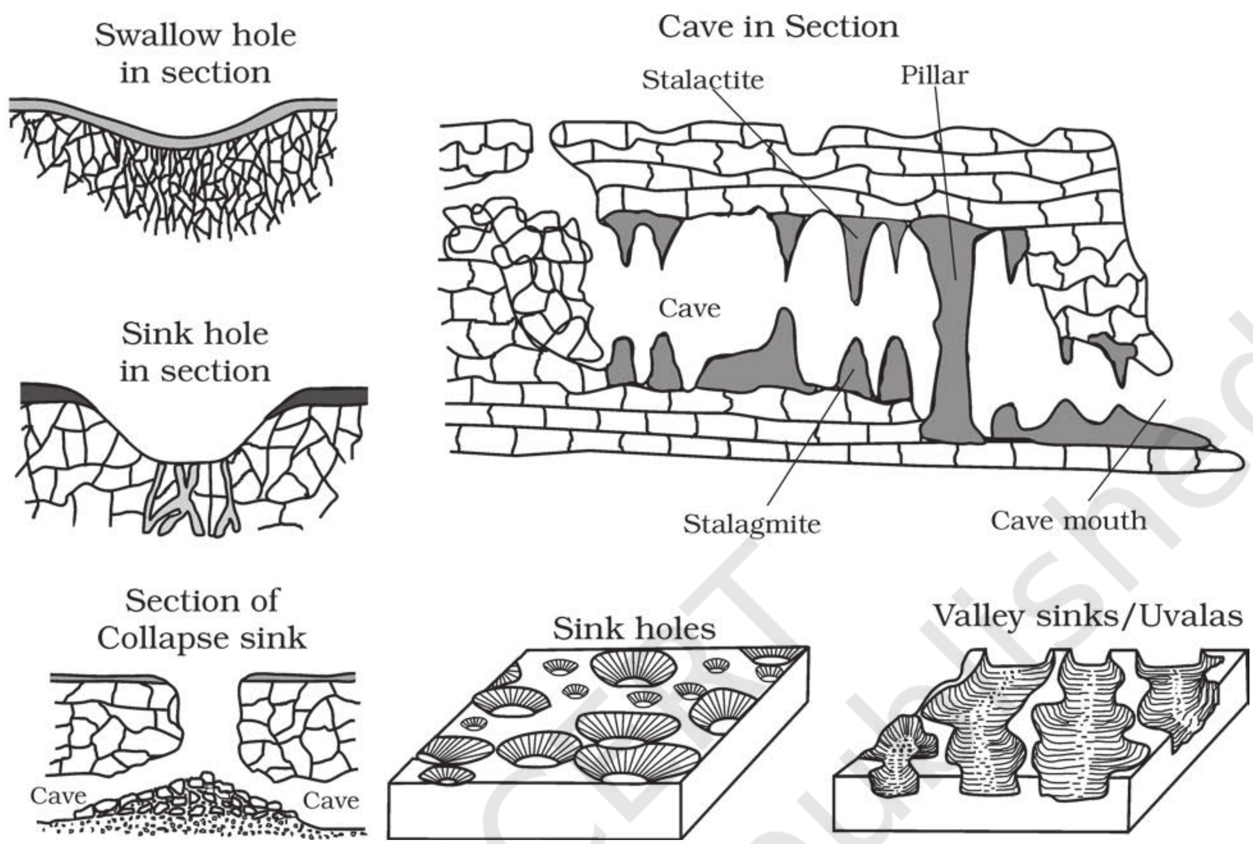

Figure 6.8 : Various karst features

percolates well when the rocks are permeable, thinly bedded and highly jointed and cracked. After vertically going down to some depth, the water under the ground flows horizontally through the bedding planes, joints or through the materials themselves. It is this downward and horizontal movement of water which causes the rocks to erode. Physical or mechanical removal of materials by moving groundwater is insignificant in developing landforms. That is why, the results of the work of groundwater cannot be seen in all types of rocks. But in rocks like limestones or dolomites rich in calcium carbonate, the surface water as well as groundwater through the chemical process of solution and precipitation deposition develop varieties of landforms. These two processes of solution and precipitation are active in limestones or dolomites occurring either exclusively or interbedded with other rocks. Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called *Karst topography* after the typical topography developed in limestone rocks of Karst region in the Balkans adjacent to Adriatic sea.

The karst topography is also characterised by erosional and depositional landforms.

Erosional Landforms

Pools, Sinkholes, Lapies and Limestone Pavements

Small to medium sized round to sub-rounded shallow depressions called *swallow holes* form on the surface of limestones through solution. Sinkholes are very common in limestone/ karst areas. *A sinkhole* is an opening more or less circular at the top and funnel-shapped towards the bottom with sizes varying in area from a few sq. m to a hectare and with depth from a less than half a metre to thirty metres or more. Some of these form solely through solution action (solution sinks) and others might start as solution forms first and if the bottom of a sinkhole forms the roof of a void or cave underground, it might collapse leaving a large hole opening into a cave or a void below (collapse sinks). Quite often, sinkholes are covered up with soil mantle and appear as shallow water pools. Anybody stepping over such pools would go down like it happens in quicksands in deserts. The term *doline* is sometimes used to refer the collapse sinks. Solution sinks are more common than collapse sinks. Quite often the surface run-off simply goes down swallow and sink holes and flow as underground streams and re-emerge at a distance downstream through a cave opening. When sink holes and dolines join together because of slumping of materials along their margins or due to roof collapse of caves, long, narrow to wide trenches called *valley sinks* or *Uvalas* form. Gradually, most of the surface of the limestone is eaten away by these pits and trenches, leaving it extremely irregular with a maze of points, grooves and *ridges* or *lapies*. Especially, these ridges or lapies form due to differential solution activity along parallel to sub-parallel joints. The lapie field may eventually turn into somewhat smooth *limestone pavements*.

Caves

In areas where there are alternating beds of rocks (shales, sandstones, quartzites) with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds, cave formation is prominent. Water percolates down either through the materials or through cracks and joints and moves horizontally along bedding planes. It is along these bedding planes that the limestone dissolves and long and narrow to wide gaps called *caves* result. There can be a maze of caves at different elevations depending upon the limestone beds and intervening rocks. Caves normally have an opening through which cave streams are discharged. Caves having openings at both the ends are called tunnels.

Depositional Landforms

Many depositional forms develop within the limestone caves. The chief chemical in limestone is calcium carbonate which is easily soluble in carbonated water (carbon dioxide absorbed rainwater). This calcium carbonate is deposited when the water carrying it in solution evaporates or loses its carbon dioxide as it trickles over rough rock surfaces.

Stalactites, Stalagmites and Pillars

Stalactites hang as icicles of different diameters. Normally they are broad at their bases and taper towards the free ends showing up in a variety of forms. *Stalagmites* rise up from the floor of the caves. In fact, stalagmites form due to dripping water from the surface or through the thin pipe, of the stalactite, immediately below it (Figure 6.9).

Stalagmites may take the shape of a column, a disc, with either a smooth, rounded bulging end or a miniature crater like

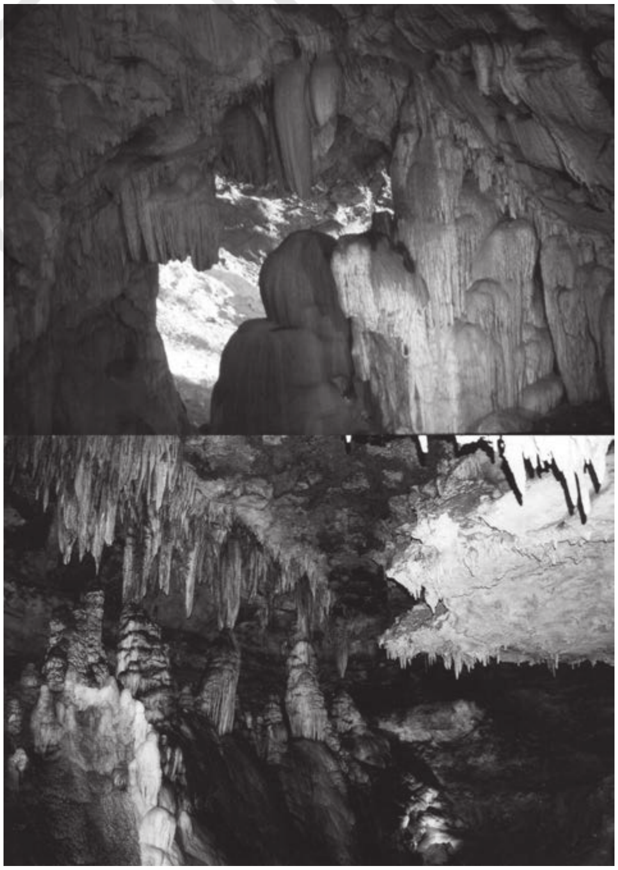

Figure 6.9 : Stalactites and stalagmites in limestone caves

depression. The stalagmite and stalactites eventually fuse to give rise to *columns and pillars* of different diameters.

Glaciers

Masses of ice moving as sheets over the land (continental glacier or piedmont glacier if a vast sheet of ice is spread over the plains at the foot of mountains) or as linear flows down the slopes of mountains in broad trough-like valleys (mountain and valley glaciers) are called *glaciers* (Figure 6.10). The movement of glaciers is slow unlike water flow. The movement could be a few centimetres to a few metres a day or even less or more. Glaciers move basically because of the force of gravity.

Figure 6.10 : A glacier in its valley

> We have many glaciers in our country moving down the slopes and valleys in Himalayas. Higher reaches of Uttaranchal, Himachal Pradesh and Jammu and Kashmir, are places to see some of them. Do you know where one can see river Bhagirathi is basically fed by meltwaters from under the snout (Gaumukh) of the Gangotri glacier. In fact, Alkapuri glacier feeds waters to Alakananda river. Rivers Alkananda and Bhagirathi join to make river Ganga near Deoprayag.

Erosion by glaciers is tremendous because of friction caused by sheer weight of the ice. The material plucked from the land by glaciers (usually large-sized angular blocks and fragments) get dragged along the floors or sides of the valleys and cause great damage through abrasion and plucking. Glaciers can cause significant damage to even un-weathered rocks and can reduce high mountains into low hills and plains.

As glaciers continue to move, debris gets removed, divides get lowered and eventually the slope is reduced to such an extent that glaciers will stop moving leaving only a mass of low hills and vast outwash plains along with other depositional features. Figures 6.11 and 6.12 show various glacial erosional and depositional forms described in the text.

Erosional Landforms

Cirque

Cirques are the most common of landforms in glaciated mountains. The cirques quite often are found at the heads of glacial valleys. The accumulated ice cuts these cirques while moving down the mountain tops. They are deep, long and wide troughs or basins with very steep concave to vertically dropping high walls at its head as well as sides. A lake of water can be seen quite often within the cirques after the glacier disappears. Such lakes are called *cirque or tarn lakes*. There can be two or more cirques one leading into another down below in a stepped sequence.

Horns and Serrated Ridges

Horns form through head ward erosion of the cirque walls. If three or more radiating glaciers cut headward until their cirques meet, high, sharp pointed and steep sided peaks called *horns* form. The divides between cirque side walls or head walls get narrow because of progressive erosion and turn into serrated or saw-toothed ridges sometimes referred to as *arêtes* with very sharp crest and a zig-zag outline.

> The highest peak in the Alps, Matterhorn and the highest peak in the Himalayas, Everest are in fact horns formed through headward erosion of radiating cirques.

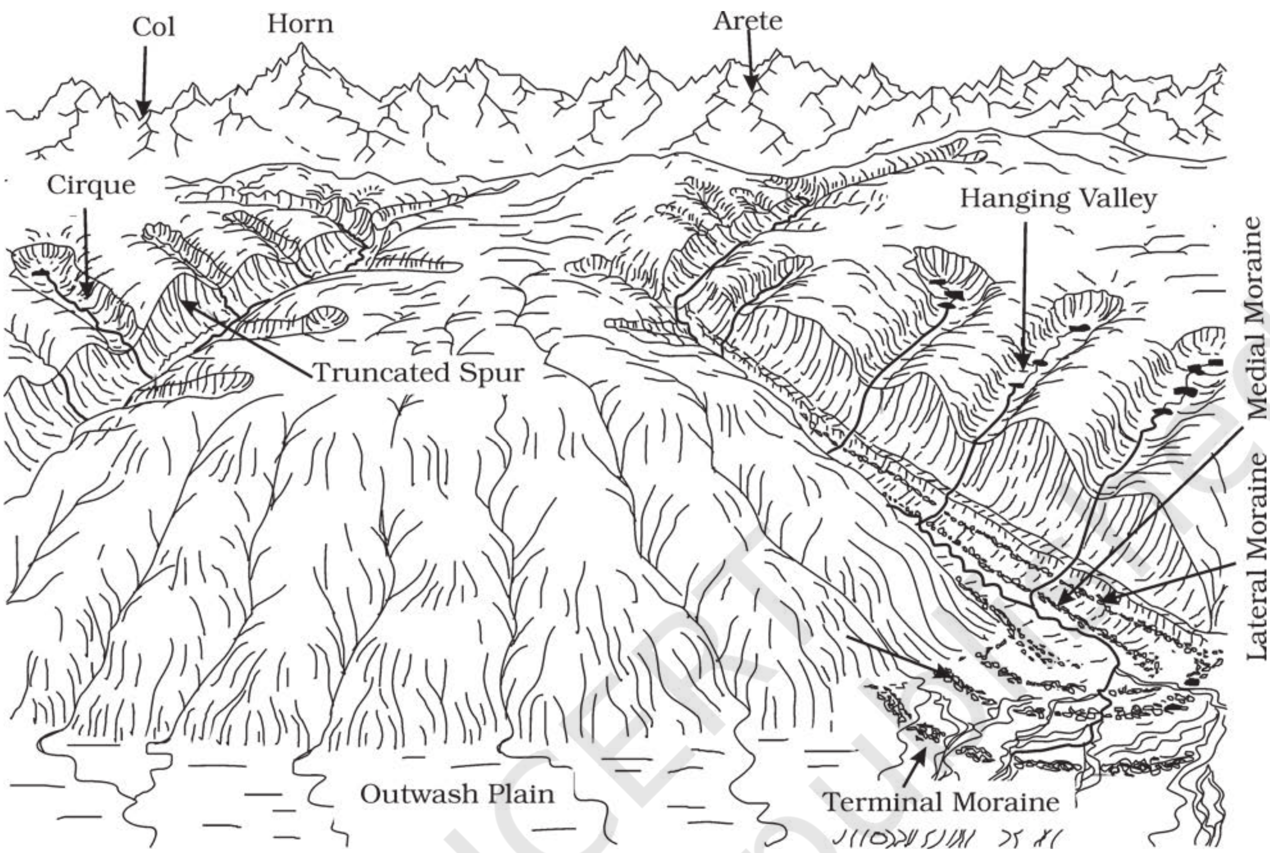

Figure 6.11 : Some glacial erosional and depositional forms (adapted and modified from Spencer, 1962)

Glacial Valleys/Troughs

Glaciated valleys are trough-like and *U-shaped* with broad floors and relatively smooth, and steep sides. The valleys may contain littered debris or debris shaped as *moraines* with swampy appearance. There may be lakes gouged out of rocky floor or formed by debris within the valleys. There can be hanging valleys at an elevation on one or both sides of the main glacial valley. The faces of divides or spurs of such hanging valleys opening into main glacial valleys are quite often truncated to give them an appearance like triangular facets. Very deep glacial troughs filled with sea water and making up shorelines (in high latitudes) are called *fjords/fiords*.

What are the basic differences between glacial valleys and river valleys?

Depositional Landforms

The unassorted coarse and fine debris dropped by the melting glaciers is called *glacial till*. Most of the rock fragments in till are angular to sub-angular in form. Streams form by melting ice at the bottom, sides or lower ends of glaciers. Some amount of rock debris small enough to be carried by such melt-water streams is washed down and deposited. Such glacio-fluvial deposits are called *outwash deposits*. Unlike till deposits, the outwash deposits are roughly stratified and assorted. The rock fragments in outwash deposits are somewhat rounded at their edges. Figure 6.12 shows a few depositional landforms commonly found in glaciated areas.

Moraines

They are long ridges of deposits of glacial till. Terminal moraines are long ridges of debris

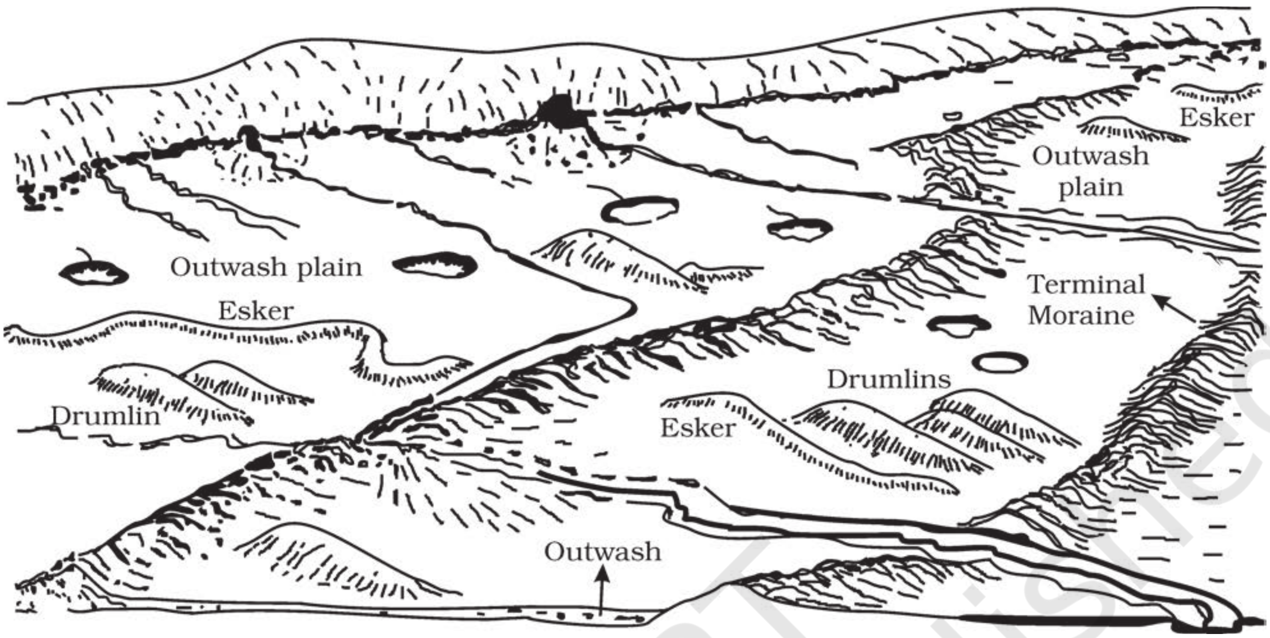

Figure 6.12 : A panoramic diagram of glacial landscape with various depositional landforms (adapted and modified from Spencer, 1962)

deposited at the end (toe) of the glaciers. *Lateral moraines* form along the sides parallel to the glacial valleys. The lateral moraines may join a terminal moraine forming a horse-shoe shaped ridge (Fig. 6.11). There can be many lateral moraines on either side in a glacial valley. These moraines partly or fully owe their origin to glacio-fluvial waters pushing up materials to the sides of glaciers. Many valley glaciers retreating rapidly leave an irregular sheet of till over their valley floors. Such deposits varying greatly in thickness and in surface topography are called *ground moraines*. The moraine in the centre of the glacial valley flanked by lateral moraines is called *medial moraine*. They are imperfectly formed as compared to lateral moraines. Sometimes medial moraines are indistinguishable from ground moraines.

Eskers

When glaciers melt in summer, the water flows on the surface of the ice or seeps down along the margins or even moves through holes in the ice. These waters accumulate beneath the glacier and flow like streams in a channel beneath the ice. Such streams flow over the ground (not in a valley cut in the ground) with ice forming its banks. Very coarse materials like boulders and blocks along with some minor fractions of rock debris carried into this stream settle in the valley of ice beneath the glacier and after the ice melts can be found as a sinuous ridge called *esker*.

Outwash Plains

The plains at the foot of the glacial mountains or beyond the limits of continental ice sheets are covered with glacio-fluvial deposits in the form of broad flat alluvial fans which may join to form outwash plains of gravel, silt, sand and clay.

> Distinguish between river alluvial plains and glacial outwash plains.

Drumlins

Drumlins are smooth oval shaped ridge-like features composed mainly of glacial till with some masses of gravel and sand. The long axes of drumlins are parallel to the direction of ice movement. They may measure up to 1 km in length and 30 m or so in height. One end of the drumlins facing the glacier called the *stoss* end is blunter and steeper than the other end called *tail*. The drumlins form due to dumping of rock debris beneath heavily loaded ice through fissures in the glacier. The stoss end gets blunted due to pushing by moving ice. Drumlins give an indication of direction of glacier movement.

> What is the difference between till and alluvium?

Waves and Currents

Coastal processes are the most dynamic and hence most destructive. So, don't you think it is important to know about the coastal processes and forms?

Some of the changes along the coasts take place very fast. At one place, there can be erosion in one season and deposition in another. Most of the changes along the coasts are accomplished by waves. When waves break, the water is thrown with great force onto the shore, and simultaneously, there is a great churning of sediments on the sea bottom. Constant impact of breaking waves drastically affects the coasts. Storm waves and tsunami waves can cause far-reaching changes in a short period of time than normal breaking waves. As wave environment changes, the intensity of the force of breaking waves changes.

> Do you know about the generating forces behind waves and currents? If not, refer to the chapter on movements in ocean waters.

Other than the action of waves, the coastal landforms depend upon (i) the configuration of land and sea floor; (ii) whether the coast is advancing (emerging) seaward or retreating (submerging) landward. Assuming sea level to be constant, two types of coasts are considered to explain the concept of evolution of coastal landforms: (i) high, rocky coasts (submerged coasts); (ii) low, smooth and gently sloping sedimentary coasts (emerged coasts).

High Rocky Coasts

Along the high rocky coasts, the rivers appear to have been drowned with highly irregular coastline. The coastline appears highly indented with extension of water into the land where glacial valleys *(fjords)* are present. The hill sides drop off sharply into the water. Shores do not show any depositional landforms initially. Erosion features dominate.

Along high rocky coasts, waves break with great force against the land shaping the hill sides into cliffs. With constant pounding by waves, the cliffs recede leaving a *wave-cut platform* in front of the sea cliff. Waves gradually minimise the irregularities along the shore.

The materials which fall off, and removed from the sea cliffs, gradually break into smaller fragments and roll to roundness, will get deposited in the offshore. After a considerable period of cliff development and retreat when coastline turns somewhat smooth, with the addition of some more material to this deposit in the offshore, a wave-built terrace would develop in front of wave-cut terrace. As the erosion along the coast takes place a good supply material becomes available to longshore currents and waves to deposit them as beaches along the shore and as bars (long ridges of sand and/ or shingle parallel to the coast) in the nearshore zone. Bars are submerged features and when bars show up above water, they are called *barrier bars*. Barrier bar which get keyed up to the headland of a bay is called a *spit*. When barrier bars and spits form at the mouth of a bay and block it, a *lagoon* forms. The lagoons would gradually get filled up by sediments from the land giving rise to a coastal plain.

Low Sedimentary Coasts

Along low sedimentary coasts the rivers appear to extend their length by building coastal plains and deltas. The coastline appears smooth with occasional incursions of water in the form of *lagoons and tidal creeks*. The land slopes gently into the water. Marshes and swamps may abound along the coasts. Depositional features dominate.

When waves break over a gently sloping sedimentary coast, the bottom sediments get churned and move readily building *bars, barrier bars, spits and lagoons*. Lagoons would eventually turn into a swamp which would subsequently turn into a coastal plain. The maintenance of these depositional features depends upon the steady supply of materials. Storm and tsunami waves cause drastic changes irrespective of supply of sediments. Large rivers which bring lots of sediments build deltas along low sedimentary coasts.

> The west coast of our country is a high rocky retreating coast. Erosional forms dominate in the west coast. The east coast of India is a low sedimentary coast. Depositional forms dominate in the east coast.

> What are the various differences between a high rocky coast and a low sedimentary coast in terms of processes and landforms?

Erosional Landforms

Cliffs, Terraces, Caves and Stacks

Wave-cut cliffs and terraces are two forms usually found where erosion is the dominant shore process. Almost all sea cliffs are steep and may range from a few m to 30 m or even more. At the foot of such cliffs there may be a flat or gently sloping platform covered by rock debris derived from the sea cliff behind. Such platforms occurring at elevations above the average height of waves is called a *wave-cut terrace*. The lashing of waves against the base of the cliff and the rock debris that gets smashed against the cliff along with lashing waves create hollows and these hollows get widened and deepened to form *sea caves*. The roofs of caves collapse and the sea cliffs recede further inland. Retreat of the cliff may leave some remnants of rock standing isolated as small islands just off the shore. Such resistant masses of rock, originally parts of a cliff or hill are called *sea stacks*. Like all other features, sea stacks are also temporary and eventually coastal hills and cliffs will disappear because of wave erosion giving rise to narrow coastal plains, and with onrush of deposits from over the land behind may get covered up by alluvium or may get covered up by shingle or sand to form a wide beach.

Depositional Landforms

Beaches and Dunes

Beaches are characteristic of shorelines that are dominated by deposition, but may occur as patches along even the rugged shores. Most of the sediment making up the beaches comes from land carried by the streams and rivers or from wave erosion. Beaches are temporary features. The sandy beach which appears so permanent may be reduced to a very narrow strip of coarse pebbles in some other season. Most of the beaches are made up of sand sized materials. Beaches called shingle beaches contain excessively small pebbles and even cobbles.

Just behind the beach, the sands lifted and winnowed from over the beach surfaces will be deposited as sand dunes. Sand dunes forming long ridges parallel to the coastline are very common along low sedimentary coasts.

Bars, Barriers and Spits

A ridge of sand and shingle formed in the sea in the off-shore zone lying approximately parallel to the coast is called an *off-shore bar*. An off-shore bar which is exposed due to further addition of sand is termed a *barrier bar*. The off-shore bars and barriers commonly form across the mouth of a river or at the entrance of a bay. Sometimes such barrier bars get keyed up to one end of the bay when they are called *spits* (Figure 6.13). Spits may also develop attached to headlands/hills. The barriers, bars and spits at the mouth of the bay gradually extend leaving only a small opening of the bay into the sea and the bay

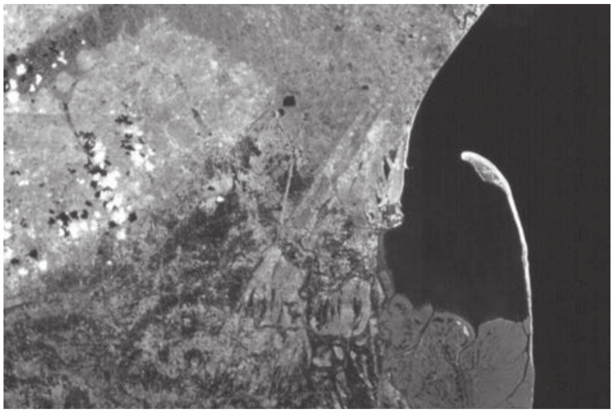

Figure 6.13 : A satellite picture of a part of Godavari river delta showing a spit

will eventually develop into a lagoon. The lagoons get filled up gradually by sediment coming from the land or from the beach itself (aided by wind) and a broad and wide coastal plain may develop replacing a lagoon.

> Do you know, the coastal off-shore bars offer the first buffer or defence against storm or tsunami by absorbing most of their destructive force. Then come the barriers, beaches, beach dunes and mangroves, if any, to absorb the destructive force of storm and tsunami waves. So, if we do anything which disturbs the 'sediment budget' and the mangroves along the coast, these coastal forms will get eroded away leaving human habitations to bear first strike of storm and tsunami waves.

WINDS

Wind is one of the two dominant agents in hot deserts. The desert floors get heated up too much and too quickly because of being dry and barren. The heated floors heat up the air directly above them and result in upward movements in the hot lighter air with turbulence, and any obstructions in its path sets up eddies, whirlwinds, updrafts and downdrafts. Winds also move along the desert floors with great speed and the obstructions in their path create turbulence. Of course, there are storm winds which are very destructive. Winds cause deflation, abrasion and impact. Deflation includes lifting and removal of dust and smaller particles from the surface of rocks. In the transportation process sand and silt act as effective tools to abrade the land surface. The impact is simply sheer force of momentum which occurs when sand is blown into or against a rock surface. It is similar to sand-blasting operation. The wind action creates a number of interesting erosional and depositional features in the deserts.

In fact, many features of deserts owe their formation to mass wasting and running water as sheet floods. Though rain is scarce in deserts, it comes down torrentially in a short period of time. The desert rocks devoid of vegetation, exposed to mechanical and chemical weathering processes due to drastic diurnal temperature changes, decay faster and the torrential rains help in removing the weathered materials easily. That means, the weathered debris in deserts is moved by not only wind but also by rain/sheet wash. The wind moves fine materials and general mass erosion is accomplished mainly through sheet floods or sheet wash. Stream channels in desert areas are broad, smooth and indefinite and flow for a brief time after rains.

EROSIONAL LANDFORMS

Pediments and Pediplains

Landscape evolution in deserts is primarily concerned with the formation and extension of pediments. Gently inclined rocky floors close to the mountains at their foot with or without a thin cover of debris, are called *pediments*. Such rocky floors form through the erosion of mountain front through a combination of lateral erosion by streams and sheet flooding.

Erosion starts along the steep margins of the landmass or the steep sides of the tectonically controlled steep incision features over the landmass. Once, pediments are formed with a steep wash slope followed by cliff or free face above it, the steep wash slope and free face retreat backwards. This method of erosion is termed as parallel retreat of slopes through backwasting. So, through parallel retreat of slopes, the pediments extend backwards at the expense of mountain front, and gradually, the mountain gets reduced leaving an *inselberg* which is a remnant of the mountain. That's how the high relief in desert areas is reduced to low featureless plains called *pediplains*.

Playas

Plains are by far the most prominent landforms in the deserts. In basins with mountains and hills around and along, the drainage is towards the centre of the basin and due to gradual deposition of sediment from basin margins, a nearly level plain forms at the centre of the basin. In times of sufficient water, this plain is covered up by a shallow water body. Such types of shallow lakes are called as *playas* where water is retained only for short duration due to evaporation and quite often the playas contain good deposition of salts. The playa plain covered up by salts is called *alkali flats*.

Deflation Hollows and Caves

Weathered mantle from over the rocks or bare soil, gets blown out by persistent movement of wind currents in one direction. This process may create shallow depressions called *deflation hollows*. Deflation also creates numerous small pits or cavities over rock surfaces. The rock faces suffer impact and abrasion of wind-borne sand and first shallow depressions called blow outs are created, and some of the *blow outs* become deeper and wider fit to be called *caves*.

Mushroom, Table and Pedestal Rocks

Many rock-outcrops in the deserts easily susceptible to wind deflation and abrasion are worn out quickly leaving some remnants of resistant rocks polished beautifully in the shape of mushroom with a slender stalk and a broad and rounded pear shaped cap above. Sometimes, the top surface is broad like a table top and quite often, the remnants stand out like pedestals.

List the erosional features carved out by wind action and action of sheet floods.

Depositional Landforms

Wind is a good sorting agent. Depending upon the velocity of wind, different sizes of grains are moved along the floors by rolling or saltation and carried in suspension and in this process of transportation itself, the materials get sorted. When the wind slows or begins to die down, depending upon sizes of grains and their critical velocities, the grains will begin to settle. So, in depositional landforms made by wind, good sorting of grains can be found. Since wind is there everywhere and wherever there is good source of sand and with constant wind directions, depositional features in arid regions can develop anywhere.

Sand Dunes

Dry hot deserts are good places for sand dune formation. Obstacles to initiate dune formation are equally important. There can be a great variety of dune forms (Figure 6.14).

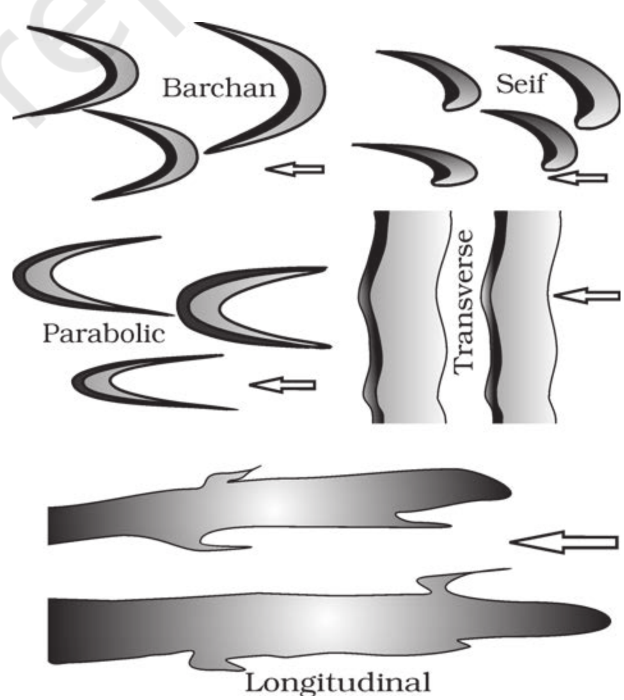

Figure 6.14 : Various types of sand dunes
Arrows indicate wind direction

Crescent shaped dunes called *barchans* with the points or wings directed away from wind direction i.e., downwind, form where the wind direction is constant and moderate and where the original surface over which sand is moving is almost uniform. *Parabolic dunes* form when sandy surfaces are partially covered with vegetation. That means parabolic dunes are reversed barchans with wind direction being the same. *Seif* is similar to barchan with a small difference. Seif has only one wing or point. This happens when there is shift in wind conditions. The lone wings of seifs can grow very long and high. Longitudinal dunes form when supply of sand is poor and wind direction is constant. They appear as long ridges of considerable length but low in height. *Transverse dunes* are aligned perpendicular to wind direction. These dunes form when the wind direction is constant and the source of sand is an elongated feature at right angles to the wind direction. They may be very long and low in height. When sand is plenty, quite often, the regular shaped dunes coalesce and lose their individual characteristics. Most of the dunes in the deserts shift and a few of them will get stabilised especially near human habitations.

EXERCISES

1. Multiple choice questions.

(i) In which of the following stages of landform development, downward cutting is dominated?

(a) Youth stage
(b) Late mature stage
(c) Early mature stage
(d) Old stage

(ii) A deep valley characterised by steep step-like side slopes is known as

(a) U-shaped valley
(b) Gorge
(c) Blind valley
(d) Canyon

(iii) In which one of the following regions the chemical weathering process is more dominant than the mechanical process?

(a) Humid region
(b) Limestone region
(c) Arid region
(d) Glacier region

(iv) Which one of the following sentences best defines the term 'Lapies'?

(a) A small to medium sized shallow depression
(b) A landform whose opening is more or less circular at the top and funnel shaped towards bottom
(c) A landform formed due to dripping water from surface
(d) An irregular surface with sharp pinnacles, grooves and ridges

(v) A deep, long and wide trough or basin with very steep concave high walls at its head as well as in sides is known as:

(a) Cirque
(b) Glacial valley
(c) Lateral Moraine
(d) Esker

2. Answer the following questions in about 30 words.

(i) What do incised meanders in rocks and meanders in plains of alluvium indicate?

(ii) Explain the evolution of valley sinks or uvalas.

(iii) Underground flow of water is more common than surface run-off in limestone areas. Why?

(iv) Glacial valleys show up many linear depositional forms. Give their locations and names.

(v) How does wind perform its task in desert areas? Is it the only agent responsible for the erosional features in the deserts?

3. Answer the following questions in about 150 words.

(i) Running water is by far the most dominating geomorphic agent in shaping the earth's surface in humid as well as in arid climates. Explain.

(ii) Limestones behave differently in humid and arid climates. Why? What is the dominant and almost exclusive geomorphic process in limestone areas and what are its results?

(iii) How do glaciers accomplish the work of reducing high mountains into low hills and plains?

Project Work

Identify the landforms, materials and processes around your area.

UNIT IV

CLIMATE

This unit deals with

- *Atmosphere — compositions and structure; elements of weather and climate*
- *Insolation — angle of incidence and distribution; heat budget of the earth — heating and cooling of atmosphere (conduction, convection, terrestrial radiation, advection); temperature — factors controlling temperature; distribution of temperature — horizontal and vertical; inversion of temperature*
- *Pressure — pressure belts; winds-planetary seasonal and local, air masses and fronts; tropical and extra tropical cyclones*
- *Precipitation — evaporation; condensation — dew, frost, fog, mist and cloud; rainfall — types and world distributon*
- *World climates — classification (Koeppen), greenhouse effect, global warming and climatic changes*

11092CH08

CHAPTER

7

Composition and Structure of Atmosphere

Can a person live without air? We eat food two - three times a day and drink water more frequently but breathe every few seconds. Air is essential to the survival of all organisms. Some organisms like humans may survive for some time without food and water but can't survive even a few minutes without breathing air. That shows the reason why we should understand the atmosphere in greater detail. Atmosphere is a mixture of different gases and it envelopes the earth all round. It contains life-giving gases like oxygen for humans and animals and carbon dioxide for plants. The air is an integral part of the earth's mass and 99 per cent of the total mass of the atmosphere is confined to the height of 32 km from the earth's surface. The air is colourless and odourless and can be felt only when it blows as wind.

> Can you imagine what will happen to us in the absence of ozone in the atmosphere?

Composition of the Atmosphere

The atmosphere is composed of gases, water vapour and dust particles. The proportion of gases changes in the higher layers of the atmosphere in such a way that oxygen will be almost in negligible quantity at the height of 120 km. Similarly, carbon dioxide and water vapour are found only up to 90 km from the surface of the earth.

Gases

Carbon dioxide is meteorologically a very important gas as it is transparent to the incoming solar radiation but opaque to the outgoing terrestrial radiation. It absorbs a part of terrestrial radiation and reflects back some part of it towards the earth's surface. It is largely responsible for the *green house effect*. The volume of other gases is constant but the volume of carbon dioxide has been rising in the past few decades mainly because of the burning of fossil fuels. This has also increased the temperature of the air. Ozone is another important component of the atmosphere found between 10 and 50 km above the earth's surface and acts as a filter and absorbs the *ultra-violet rays* radiating from the sun and prevents them from reaching the surface of the earth.

Water Vapour

Water vapour is also a variable gas in the atmosphere, which decreases with altitude. In the warm and wet tropics, it may account for four per cent of the air by volume, while in the dry and cold areas of desert and polar regions, it may be less than one per cent of the air. Water vapour also decreases from the equator towards the poles. It also absorbs parts of the insolation from the sun and preserves the earth's radiated heat. It thus, acts like a blanket allowing the earth neither to become too cold nor too hot. Water vapour also contributes to the stability and instability in the air.

Dust Particles

Atmosphere has a sufficient capacity to keep small solid particles, which may originate from different sources and include sea salts, fine soil, smoke-soot, ash, pollen, dust and disintegrated particles of meteors. Dust particles are generally concentrated in the lower layers of the atmosphere; yet, convectional air currents may transport them to great heights. The higher concentration of dust particles is found in subtropical and temperate regions due to dry winds in comparison to equatorial and polar regions. Dust and salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds.

Structure of the Atmosphere

The atmosphere consists of different layers with varying density and temperature. Density is highest near the surface of the earth and decreases with increasing altitude. The column of atmosphere is divided into five different layers depending upon the temperature condition. They are: troposphere, stratosphere, mesosphere, thermosphere and exosphere.

The troposphere is the lowermost layer of the atmosphere. Its average height is 13 km and extends roughly to a height of 8 km near the poles and about 18 km at the equator. Thickness of the troposphere is greatest at the equator because heat is transported to great heights by strong convectional currents. This layer contains dust particles and water vapour. All changes in climate and weather take place in this layer. The temperature in this layer decreases at the rate of 1 C for every 165m of height. This is the most important layer for all biological activity.

The zone separating the tropsophere from stratosphere is known as the *tropopause*. The air temperature at the tropopause is about minus 80^{0}C over the equator and about minus 45^{o}C over the poles. The temperature here is nearly constant, and hence, it is called the tropopause. *The stratosphere* is found above the tropopause and extends up to a height of 50 km. One important feature of the stratosphere is that it contains the *ozone layer*. This layer absorbs ultra-violet radiation and shields life on the earth from intense, harmful form of energy.

The mesosphere lies above the stratosphere, which extends up to a height of 80 km. In this layer, once again, temperature starts decreasing with the increase in altitude and reaches up to minus 100 C at the height of 80 km. The upper limit of mesosphere is known as the *mesopause*. *The ionosphere* is located between 80 and 400 km above the mesopause. It contains electrically charged particles known as ions, and hence, it is known as ionosphere. Radio waves transmitted from the earth are reflected back to the earth by this layer. Temperature here starts increasing with height. The uppermost layer of the atmosphere above the thermosphere

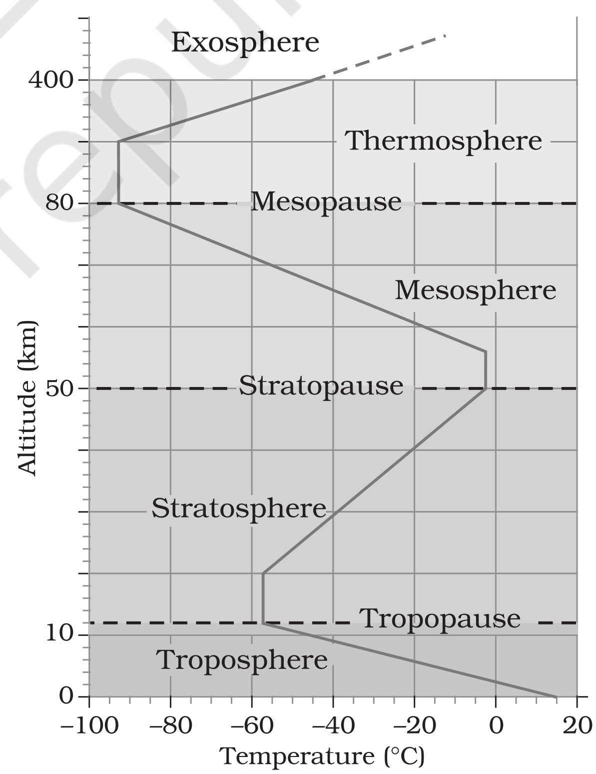

Figure 7.1 : Structure of atmosphere

is known as the *exosphere*. This is the highest layer but very little is known about it. Whatever contents are there, these are extremely rarefied in this layer, and it gradually merges with the outer space. Although all layers of the atmosphere must be exercising influence on us, geographers are concerned with the first two layers of the atmosphere.

Elements of Weather and Climate

The main elements of atmosphere which are subject to change and which influence human life on earth are temperature, pressure, winds, humidity, clouds and precipitation. These elements have been dealt in detail in Chapters 8, 9 and 10.

EXERCISES

1. Multiple choice questions.

 (i) Which one of the following gases constitutes the major portion of the atmosphere?

 (a) Oxygen (c) Argon

 (b) Nitrogen (d) Carbon dioxide

 (ii) Atmospheric layer important for human beings is:

 (a) Stratosphere (c) Troposphere

 (b) Mesosphere (d) Ionosphere

 (iii) Sea salt, pollen, ash, smoke soot, fine soil — these are associated with:

 (a) Gases (c) Water vapour

 (b) Dust particles (d) Meteors

 (iv) Oxygen gas is in negligible quantity at the height of atmosphere:

 (a) 90 km (c) 100 km

 (b) 120 km (d) 150 km

 (v) Which one of the following gases is transparent to incoming solar radiation and opaque to outgoing terrestrial radiation?

 (a) Oxygen (c) Helium

 (b) Nitrogen (d) Carbon dioxide

2. Answer the following questions in about 30 words.

 (i) What do you understand by atmosphere?

 (ii) What are the elements of weather and climate?

 (iii) Describe the composition of atmosphere.

 (iv) Why is troposphere the most important of all the layers of the atmosphere?

3. Answer the following questions in about 150 words.

 (i) Describe the composition of the atmosphere.

 (ii) Draw a suitable diagram for the structure of the atmosphere and label it and describe it.

11092CH09

CHAPTER

8

SOLAR RADIATION, HEAT BALANCE AND TEMPERATURE

Do you feel air around you? Do you know that we live at the bottom of a huge pile of air? We inhale and exhale but we feel the air when it is in motion. It means air in motion is wind. You have already learnt about the fact that earth is surrounded by air all around. This envelop of air is atmosphere which is composed of numerous gases. These gases support life over the earth's surface.

The earth receives almost all of its energy from the sun. The earth in turn radiates back to space the energy received from the sun. As a result, the earth neither warms up nor does it get cooled over a period of time. Thus, the amount of heat received by different parts of the earth is not the same. This variation causes pressure differences in the atmosphere. This leads to transfer of heat from one region to the other by winds. This chapter explains the process of heating and cooling of the atmosphere and the resultant temperature distribution over the earth's surface.

SOLAR RADIATION

The earth's surface receives most of its energy in short wavelengths. The energy received by the earth is known as incoming solar radiation which in short is termed as *insolation*.

As the earth is a geoid resembling a sphere, the sun's rays fall obliquely at the top of the atmosphere and the earth intercepts a very small portion of the sun's energy. On an average the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere. The solar output received at the top of the atmosphere varies slightly in a year due to the variations in the distance between the earth and the sun. During its revolution around the sun, the earth is farthest from the sun (152 million km) on 4th July. This position of the earth is called *aphelion*. On 3rd January, the earth is the nearest to the sun (147 million km). This position is called *perihelion*. Therefore, the annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July. However, the effect of this variation in the solar output is masked by other factors like the distribution of land and sea and the atmospheric circulation. Hence, this variation in the solar output does not have great effect on daily weather changes on the surface of the earth.

Variability of Insolation at the Surface of the Earth

The amount and the intensity of insolation vary during a day, in a season and in a year. The factors that cause these variations in insolation are : (i) the rotation of earth on its axis; (ii) the angle of inclination of the sun's rays; (iii) the length of the day; (iv) the transparency of the atmosphere; (v) the configuration of land in terms of its aspect. The last two however, have less influence.

The fact that the earth's axis makes an angle of 66½ with the plane of its orbit round the sun has a greater influence on the amount of insolation received at different latitudes.

The second factor that determines the amount of insolation received is the angle of inclination of the rays. This depends on the latitude of a place. The higher the latitude the less is the angle they make with the surface of the earth resulting in slant sun rays. The area covered by vertical rays is always less than the slant rays. If more area is covered, the energy gets distributed and the net energy received per unit area decreases. Moreover, the slant rays are required to pass through greater depth of the atmosphere resulting in more absorption, scattering and diffusion.

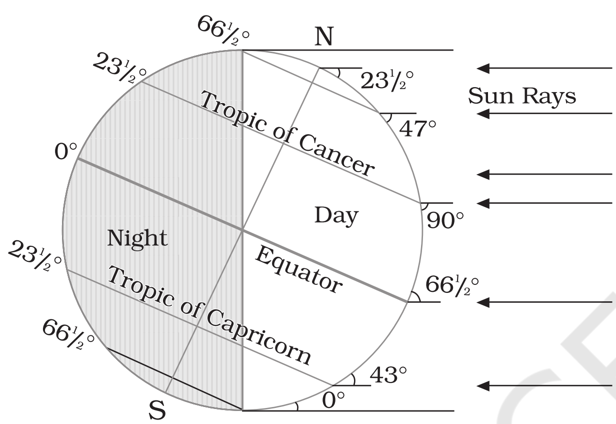

Figure 8.1 : Summer Solstice

The Passage of Solar Radiation through the Atmosphere

The atmosphere is largely transparent to short wave solar radiation. The incoming solar radiation passes through the atmosphere before striking the earth's surface. Within the troposphere water vapour, ozone and other gases absorb much of the near infrared radiation.

Very small-suspended particles in the troposphere scatter visible spectrum both to the space and towards the earth surface. This process adds colour to the sky. The red colour of the rising and the setting sun and the blue colour of the sky are the result of scattering of light within the atmosphere.

Spatial Distribution of Insolation at the Earth's Surface

The insolation received at the surface varies from about 320 Watt/m^2 in the tropics to about 70 Watt/m^2 in the poles. Maximum insolation is received over the subtropical deserts, where the cloudiness is the least. Equator receives comparatively less insolation than the tropics. Generally, at the same latitude the insolation is more over the continent than over the oceans. In winter, the middle and higher latitudes receive less radiation than in summer.

Heating and Cooling of Atmosphere

There are different ways of heating and cooling of the atmosphere.

The earth after being heated by insolation transmits the heat to the atmospheric layers near to the earth in long wave form. The air in contact with the land gets heated slowly and the upper layers in contact with the lower layers also get heated. This process is called *conduction*. Conduction takes place when two bodies of unequal temperature are in contact with one another, there is a flow of energy from the warmer to cooler body. The transfer of heat continues until both the bodies attain the same temperature or the contact is broken. Conduction is important in heating the lower layers of the atmosphere.

The air in contact with the earth rises vertically on heating in the form of currents and further transmits the heat of the atmsphere. This process of vertical heating of the atmosphere is known as *convection*. The convective transfer of energy is confined only to the troposphere.

The transfer of heat through horizontal movement of air is called *advection*. Horizontal movement of the air is relatively more important than the vertical movement. In middle latitudes, most of dirunal (day and night) variation in daily weather are caused by advection alone. In tropical regions particularly in northern India during summer season local winds called 'loo' is the outcome of advection process.

Terrestrial Radiation

The insolation received by the earth is in short waves forms and heats up its surface. The earth after being heated itself becomes a radiating body and it radiates energy to the atmosphere in long wave form. This energy heats up the atmosphere from below. This process is known as terrestrial radiation.

The long wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and the other green house gases. Thus, the atmosphere is indirectly heated by the earth's radiation.

The atmosphere in turn radiates and transmits heat to the space. Finally the amount of heat received from the sun is returned to space, thereby maintaining constant temperature at the earth's surface and in the atmosphere.

Heat Budget of the Planet Earth

Figure 9.2 depicts the heat budget of the planet earth. The earth as a whole does not accumulate or loose heat. It maintains its temperature. This can happen only if the amount of heat received in the form of insolation equals the amount lost by the earth through terrestrial radiation.

Consider that the insolation received at the top of the atmosphere is 100 per cent. While passing through the atmosphere some amount of energy is reflected, scattered and absorbed. Only the remaining part reaches the earth surface. Roughly 35 units are reflected back to space even before reaching the earth's surface. Of these, 27 units are reflected back from the top of the clouds and 2 units from the snow and ice-covered areas of the earth. The reflected amount of radiation is called the *albedo of the earth*.

The remaining 65 units are absorbed, 14 units within the atmosphere and 51 units by the earth's surface. The earth radiates back 51 units in the form of terrestrial radiation. Of these, 17 units are radiated to space directly and the remaining 34 units are absorbed by the atmosphere (6 units absorbed directly by the atmosphere, 9 units through convection and turbulence and 19 units through latent heat of condensation). 48 units absorbed by the atmosphere (14 units from insolation +34 units from terrestrial radiation) are also radiated back into space. Thus, the total radiation returning from the earth and the atmosphere respectively is 17+48=65 units which balance the total of 65 units received from the sun. This is termed the heat budget or heat balance of the earth.

This explains, why the earth neither warms up nor cools down despite the huge transfer of heat that takes place.

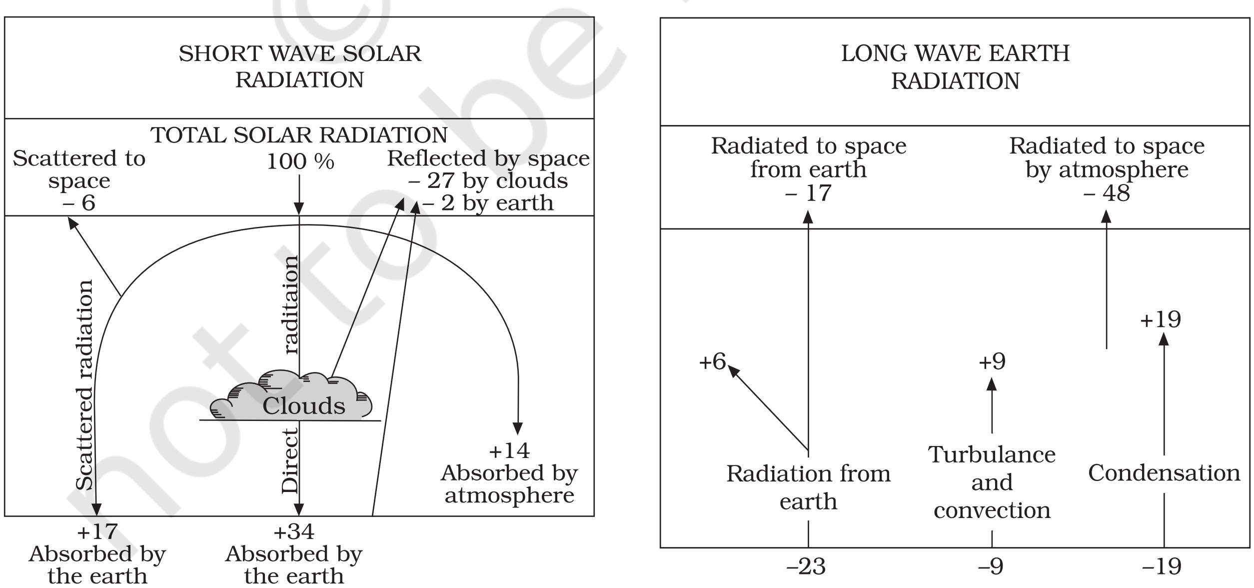

Figure 8.2 : Heat budget of the earth

Variation in the Net Heat Budget at the Earth's Surface

As explained earlier, there are variations in the amount of radiation received at the earth's surface. Some part of the earth has surplus radiation balance while the other part has deficit.

Figure 8.3 depicts the latitudinal variation in the net radiation balance of the earth — the atmosphere system. The figure shows that there is a surplus of net radiation balance between 40 degrees north and south and the regions near the poles have a deficit. The surplus heat energy from the tropics is redistributed pole wards and as a result the tropics do not get progressively heated up due to the accumulation of excess heat or the high latitudes get permanently frozen due to excess deficit.

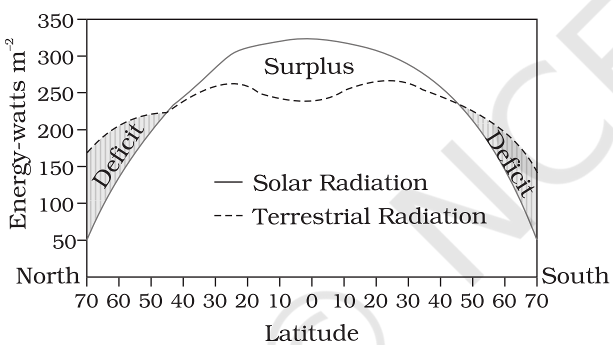

Figure 8.3 : Latitudinal variation in net radiation balance

Temperature

The interaction of insolation with the atmosphere and the earth's surface creates heat which is measured in terms of temperature. While heat represents the molecular movement of particles comprising a substance, the temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is.

Factors Controlling Temperature Distribution

The temperature of air at any place is influenced by (i) the latitude of the place; (ii) the altitude of the place; (iii) distance from the sea, the air-mass circulation; (iv) the presence of warm and cold ocean currents; (v) local aspects.

The latitude : The temperature of a place depends on the insolation received. It has been explained earlier that the insolation varies according to the latitude hence the temperature also varies accordingly.

The altitude : The atmosphere is indirectly heated by terrestrial radiation from below. Therefore, the places near the sea-level record higher temperature than the places situated at higher elevations. In other words, the temperature generally decreases with increasing height. The rate of decrease of temperature with height is termed as the normal lapse rate. It is 6.5 C per 1,000 m.

Distance from the sea : Another factor that influences the temperature is the location of a place with respect to the sea. Compared to land, the sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly. Therefore, the variation in temperature over the sea is less compared to land. The places situated near the sea come under the moderating influence of the sea and land breezes which moderate the temperature.

Air-mass and Ocean currents : Like the land and sea breezes, the passage of air masses also affects the temperature. The places, which come under the influence of warm air-masses experience higher temperature and the places that come under the influence of cold air-masses experience low temperature. Similarly, the places located on the coast where the warm ocean currents flow record higher temperature than the places located on the coast where the cold currents flow.

Distribution of Temperature

The global distribution of temperature can well be understood by studying the temperature distribution in January and July. The temperature distribution is generally shown on the map with the help of isotherms. The *Isotherms* are lines joining places having equal temperature. Figure 8.4 (a) and (b) show the distribution of surface air temperature in the month of January and July.

In general the effect of the latitude on temperature is well pronounced on the map, as the isotherms are generally parallel to the latitude. The deviation from this general trend is more pronounced in January than in July, especially in the northern hemisphere. In the northern hemisphere the land surface area is much larger than in the southern hemisphere. Hence, the effects of land mass and the ocean currents are well pronounced. In January the isotherms deviate to the north over the ocean and to the south over the continent. This can be seen on the North Atlantic Ocean. The presence of warm ocean currents, Gulf Stream and North Atlantic drift, make the Northern Atlantic Ocean warmer and the isotherms bend towards the north. Over the land the temperature decreases sharply and the isotherms bend towards south in Europe.

It is much pronounced in the Siberian plain. The mean January temperature along 60 E longitude is minus 20 C both at 80 N and 50 N latitudes. The mean monthly temperature for January is over 27 C, in equatorial oceans over 24 C in the tropics and 2 C - 0 C in the middle latitudes and –18 C to –48 C in the Eurasian continental interior.

The effect of the ocean is well pronounced in the southern hemisphere. Here the isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere. The isotherm of 20 C, 10 C, and 0 C runs parallel to 35 S, 45 S and 60 S latitudes respectively.

In July the isotherms generally run parallel to the latitude. The equatorial oceans record warmer temperature, more than 27 C.

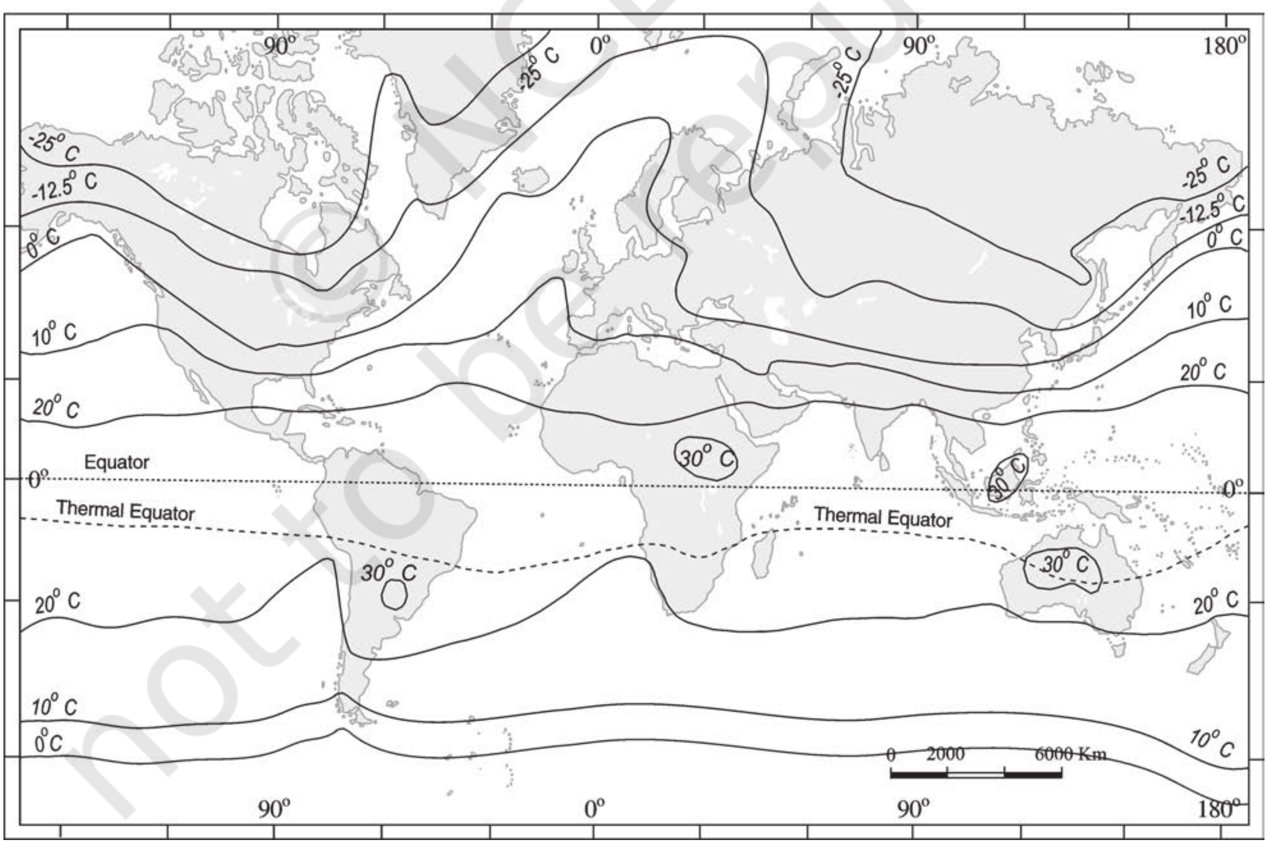

Figure 8.4 (a) : The distribution of surface air temperature in the month of January

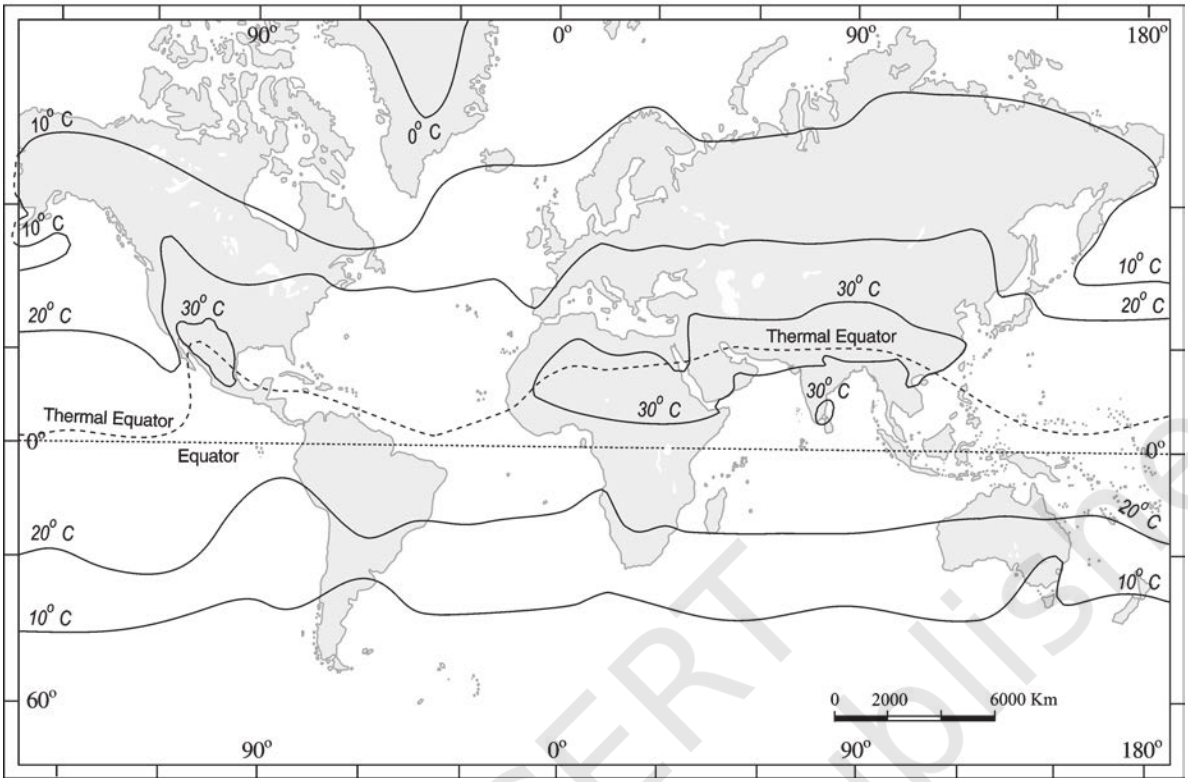

Figure 8.4 (b) : The distribution of surface air temperature in the month of July

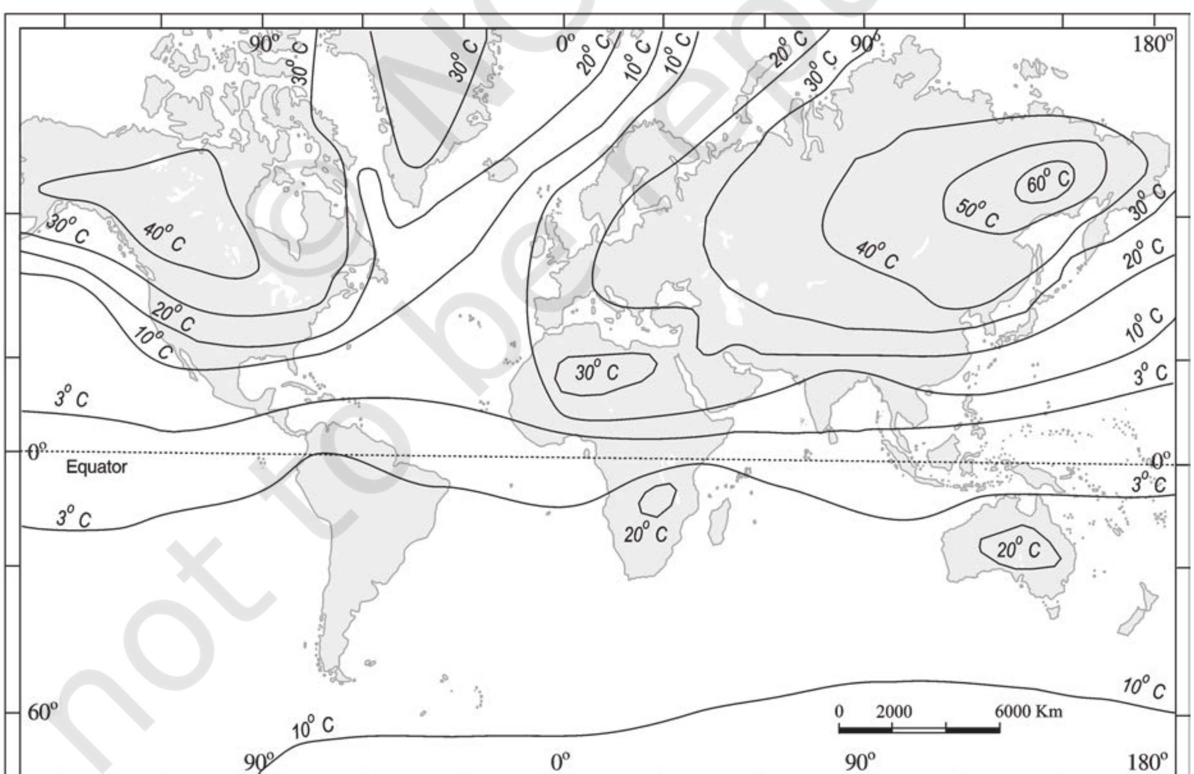

Figure 8.5 : The range of temperature between January and July

Over the land more than 30 C is noticed in the subtropical continental region of Asia, along the 30 N latitude. Along the 40 N runs the isotherm of 10 C and along the 40 S the temperature is 10 C.

Figure 8.5 shows the range of temperature between January and July. The highest range of temperature is more than 60 C over the north-eastern part of Eurasian continent. This is due to continentality. The least range of temperature, 3 C, is found between 20 S and 15 N.

Inversion of Temperature

Normally, temperature decreases with increase in elevation. It is called normal lapse rate. At times, the situations is reversed and the normal lapse rate is inverted. It is called Inversion of temperature. Inversion is usually of short duration but quite common nonetheless. A long winter night with clear skies and still air is ideal situation for inversion. The heat of the day is radiated off during the night, and by early morning hours, the earth is cooler than the air above. Over polar areas, temperature inversion is normal throughout the year.

Surface inversion promotes stability in the lower layers of the atmosphere. Smoke and dust particles get collected beneath the inversion layer and spread horizontally to fill the lower strata of the atmosphere. Dense fogs in mornings are common occurrences especially during winter season. This inversion commonly lasts for few hours until the sun comes up and beings to warm the earth.

The inversion takes place in hills and mountains due to air drainage. Cold air at the hills and mountains, produced during night, flows under the influence of gravity. Being heavy and dense, the cold air acts almost like water and moves down the slope to pile up deeply in pockets and valley bottoms with warm air above. This is called *air drainage.* It protects plants from frost damages.

- Plank's law states that hotter a body, the more energy it will radiate and shorter the wavelength of that radiation.
- Specific heat is the energy needed to raise the temperature of one gram of substance by one Celsius.

EXERCISES

1. Multiple choice questions.

   (i) The sun is directly overhead at noon on 21st June at:

   (a) The equator (c) 23.5 N

   (b) 23.5 S (d) 66.5 N

   (ii) In which one of the following cities, are the days the longest?

   (a) Tiruvanantpuram (c) Hyderabad

   (b) Chandigarh (d) Nagpur

   (iii) The atmosphere is mainly heated by the:

   (a) Short wave solar radiation (c) Long wave terrestrial radiation

   (b) Reflected solar radiation (d) Scattered solar radiation

(iv) Make correct pairs from the following two columns.

(i) Insolation	(a) The difference between the mean temperature of the warmest and the coldest months
(ii) Albedo	(b) The lines joining the places of equal temperature
(iii) Isotherm	(c) The incoming solar radiation
(iv) Annual range	(d) The percentage of visible light reflected by an object

(v) The main reason that the earth experiences highest temperatures in the subtropics in the northern hemisphere rather than at the equator is :

(a) Subtropical areas tend to have less cloud cover than equatorial areas.

(b) Subtropical areas have longer day hours in the summer than the equatorial.

(c) Subtropical areas have an enhanced "green house effect" compared to equatorial areas.

(d) Subtropical areas are nearer to the oceanic areas than the equatorial locations.

2. Answer the following questions in about 30 words.

(i) How does the unequal distribution of heat over the planet earth in space and time cause variations in weather and climate?

(ii) What are the factors that control temperature distribution on the surface of the earth?

(iii) In India, why is the day temperature maximum in May and why not after the summer solstice?

(iv) Why is the annual range of temperature high in the Siberian plains?

3. Answer the following questions in about 150 words.

(i) How do the latitude and the tilt in the axis of rotation of the earth affect the amount of radiation received at the earth's surface?

(ii) Discuss the processes through which the earth-atmosphere system maintains heat balance.

(iii) Compare the global distribution of temperature in January over the northern and the southern hemisphere of the earth.

Project Work

Select a meteorological observatory located in your city or near your town. Tabulate the temperature data as given in the climatological table of observatories :

(i) Note the altitude, latitude of the observatory and the period for which the mean is calculated.

(ii) Define the terms related to temperature as given in the table.

(iii) Calculate the daily mean monthly temperature.

(iv) Draw a graph to show the daily mean maximum, the daily mean minimum and the mean temperature.

(v) Calculate the annual range of temperature.

(vi) Find out in which months the daily range of temperature is the highest and the lowest.

(vii) List out the factors that determine the temperature of the place and explain the possible causes for temperature variation in the months of January, May, July and October.

Example

Observatory	:	New Delhi (Safdarjung)
Latitude	:	28 35 ' N
Based on observations	:	1951 - 1980
Altitude above mean sea level	:	216 m

Month	*Mean of Daily Max.(C)*	*Mean of Daily Min.(C)*	*Highest Recorded (C)*	*Lowest Recorded (C)*
January	21.1	7.3	29.3	0.6
May	39.6	25.9	47.2	17.5

Daily mean monthly temperature

January $\frac{21.1+7.3}{2} = 14.2^{o}C$

May $\frac{39.6+25.9}{2} = 32.75^{o}C$

Annual range of temperature

Mean Max. Temperature in May - Mean Temperature in January

Annual range of temperature = 32.75 C – 14.2 C = 18.55 C

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CHAPTER

9

Atmospheric Circulation and Weather Systems

Earlier Chapter 8 described the uneven distribution of temperature over the surface of the earth. Air expands when heated and gets compressed when cooled. This results in variations in the atmospheric pressure. The result is that it causes the movement of air from high pressure to low pressure, setting the air in motion. You already know that air in horizontal motion is wind. Atmospheric pressure also determines when the air will rise or sink. The wind redistributes the heat and moisture across the planet, thereby, maintaining a constant temperature for the planet as a whole. The vertical rising of moist air cools it down to form the clouds and bring precipitation. This chapter has been devoted to explain the causes of pressure differences, the forces that control the atmospheric circulation, the turbulent pattern of wind, the formation of air masses, the disturbed weather when air masses interact with each other and the phenomenon of violent tropical storms.

Atmospheric Pressure

Do you realise that our body is subjected to a lot of air pressure. As one moves up the air gets varified and one feels breathless.

The weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere is called the *atmospheric pressure*. The atmospheric pressure is expressed in units of milibar. At sea level the average atmospheric pressure is 1,013.2 milibar. Due to gravity the air at the surface is denser and hence has higher pressure. Air pressure is measured with the help of a mercury barometer or the aneroid barometer. Consult your book, *Practical Work in Geography — Part I* (NCERT, 2006) and learn about these instruments. The pressure decreases with height. At any elevation it varies from place to place and its variation is the primary cause of air motion, i.e. wind which moves from high pressure areas to low pressure areas.

Vertical Variation of Pressure

In the lower atmosphere the pressure decreases rapidly with height. The decrease amounts to about 1 mb for each 10 m increase in elevation. It does not always decrease at the same rate. Table 9.1 gives the average pressure and temperature at selected levels of elevation for a standard atmosphere.

Table 9.1 : Standard Pressure and Temperature at Selected Levels

Level	Pressure in mb	Temperature C
Sea Level	1,013.25	15.2
1 km	898.76	8.7
5 km	540.48	–17. 3
10 km	265.00	– 49.7

The vertical pressure gradient force is much larger than that of the horizontal pressure gradient. But, it is generally balanced by a nearly equal but opposite gravitational force. Hence, we do not experience strong upward winds.

Horizontal Distribution of Pressure

Small differences in pressure are highly significant in terms of the wind direction and velocity. Horizontal distribution of pressure is studied by drawing isobars at constant levels. Isobars are lines connecting places having equal pressure. In order to eliminate the effect of altitude on pressure, it is measured at any station after being reduced to sea level for purposes of comparison. The sea level pressure distribution is shown on weather maps.

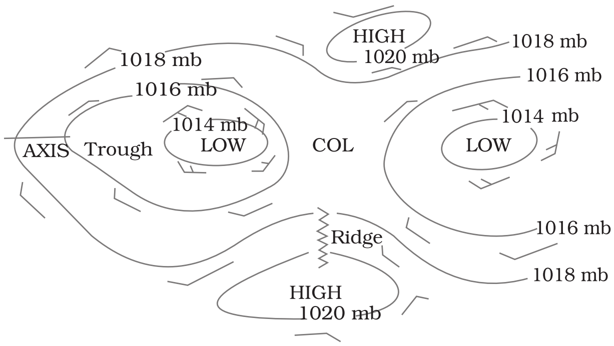


Figure 9.1 : Isobars, pressure and wind systems in Northern Hemisphere

Figure 9.1 shows the patterns of isobars corresponding to pressure systems. Low-pressure system is enclosed by one or more isobars with the lowest pressure in the centre. High-pressure system is also enclosed by one or more isobars with the highest pressure in the centre.

World Distribution of Sea Level Pressure

The world distribution of sea level pressure in January and July has been shown in Figures 9.2 and 9.3. Near the equator the sea level pressure is low and the area is known as *equatorial low*. Along 30 N and 30° S are found the high-pressure areas known as the subtropical highs. Further pole wards along 60° N and 60° S, the low-pressure belts are termed as the sub polar lows. Near the poles the pressure is high and it is known as the *polar high*. These pressure belts are not permanent

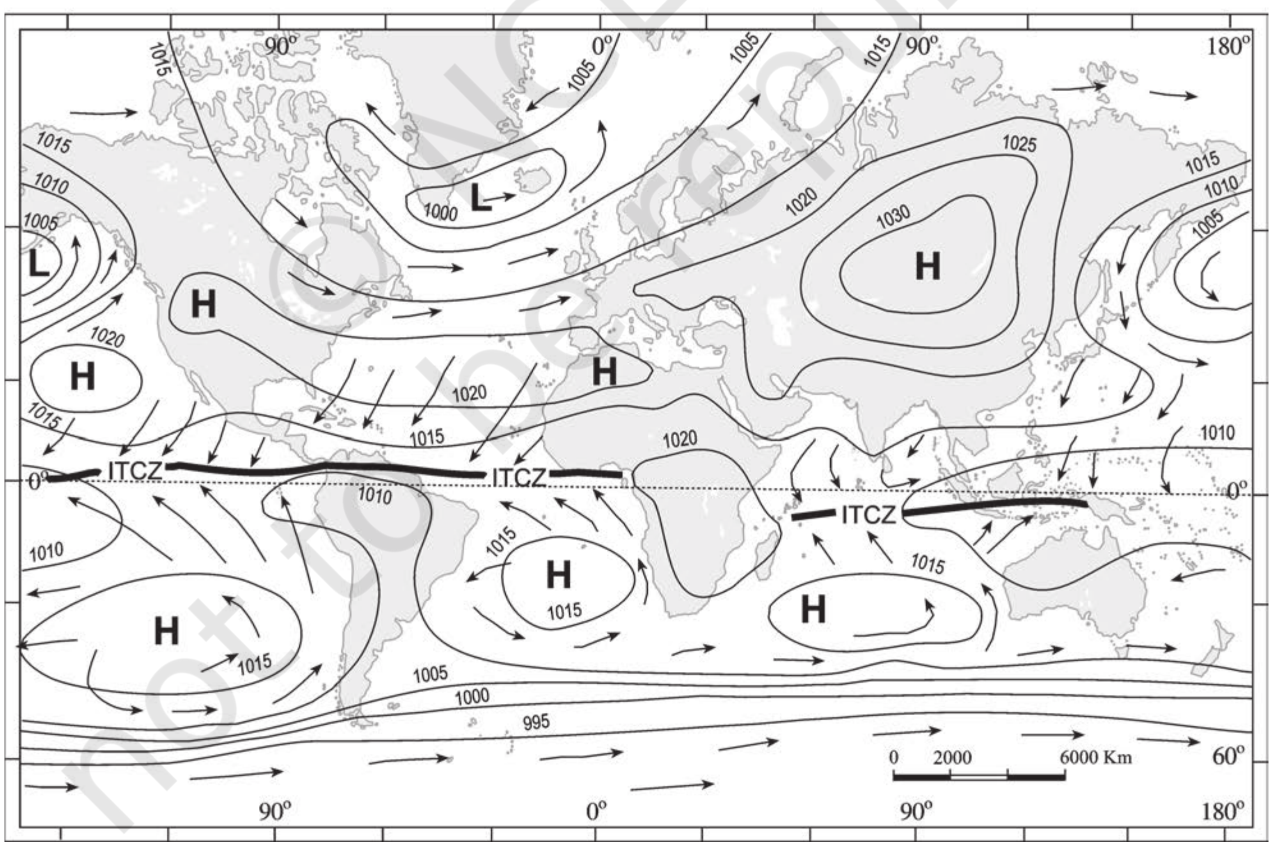


Figure 9.2 : Distribution of pressure (in millibars) — January

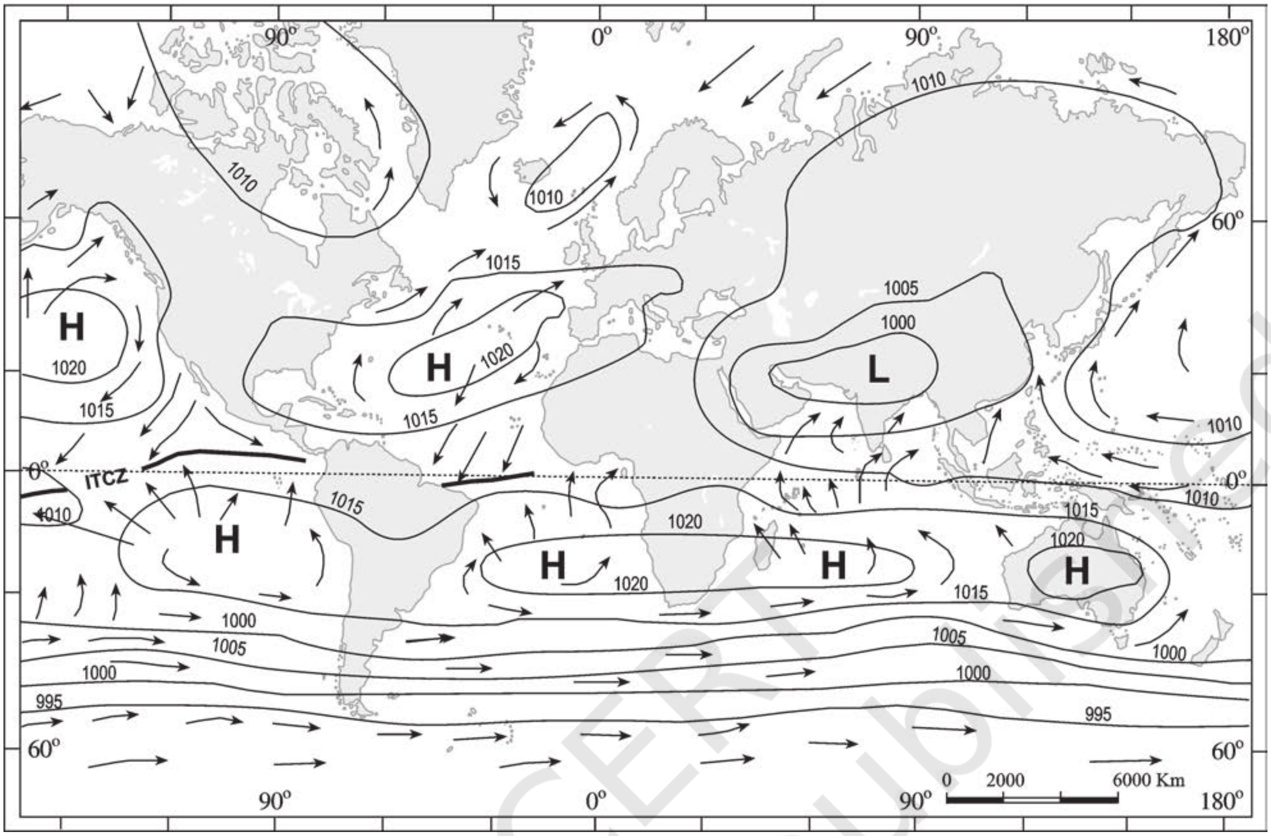


Figure 9.3 : Distribution of pressure (in millibars) — July

in nature. They oscillate with the apparent movement of the sun. In the northern hemisphere in winter they move southwards and in the summer northwards.

Forces Affecting the Velocity and Direction of Wind

You already know that the air is set in motion due to the differences in atmospheric pressure. The air in motion is called wind. The wind blows from high pressure to low pressure. The wind at the surface experiences friction. In addition, rotation of the earth also affects the wind movement. The force exerted by the rotation of the earth is known as the Coriolis force. Thus, the horizontal winds near the earth surface respond to the combined effect of three forces – the pressure gradient force, the frictional force and the Coriolis force. In addition, the gravitational force acts downward.

Pressure Gradient Force

The differences in atmospheric pressure produces a force. The rate of change of pressure with respect to distance is the pressure gradient. The pressure gradient is strong where the isobars are close to each other and is weak where the isobars are apart.

Frictional Force

It affects the speed of the wind. It is greatest at the surface and its influence generally extends upto an elevation of 1 - 3 km. Over the sea surface the friction is minimal.

Coriolis Force

The rotation of the earth about its axis affects the direction of the wind. This force is called the Coriolis force after the French physicist who described it in 1844. It deflects the wind to the right direction in the northern hemisphere and to the left in the southern hemisphere. The deflection is more when the wind velocity is high. The Coriolis force is directly proportional to the angle of latitude. It is maximum at the poles and is absent at the equator.

The Coriolis force acts perpendicular to the pressure gradient force. The pressure gradient force is perpendicular to an isobar. The higher the pressure gradient force, the more is the velocity of the wind and the larger is the deflection in the direction of wind. As a result of these two forces operating perpendicular to each other, in the low-pressure areas the wind blows around it. At the equator, the Coriolis force is zero and the wind blows perpendicular to the isobars. The low pressure gets filled instead of getting intensified. That is the reason why tropical cyclones are not formed near the equator.

Pressure and Wind

The velocity and direction of the wind are the net result of the wind generating forces. The winds in the upper atmosphere, 2 - 3 km above the surface, are free from frictional effect of the surface and are controlled mainly by the pressure gradient and the Coriolis force. When isobars are straight and when there is no friction, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar. This wind is known as the geostrophic wind (Figure 9.4).

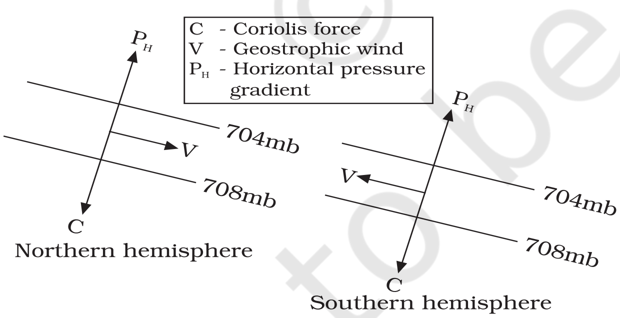


Figure 9.4 : Geostropic Wind

The wind circulation around a low is called *cyclonic circulation*. Around a high it is called *anti cyclonic circulation*. The direction of winds around such systems changes according to their location in different hemispheres (Table 9.2).

The wind circulation at the earth's surface around low and high on many occasions is closely related to the wind circulation at higher level. Generally, over low pressure area the air will converge and rise. Over high pressure area the air will subside from above and diverge at the surface (Figure 9.5). Apart from convergence, some eddies, convection currents, orographic uplift and uplift along fronts cause the rising of air, which is essential for the formation of clouds and precipitation.

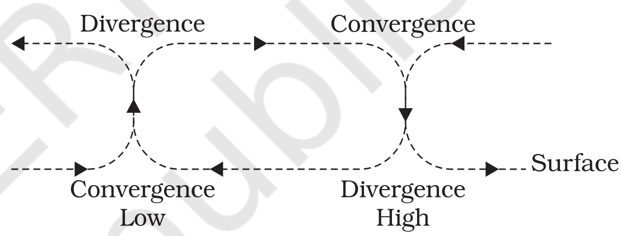


Figure 9.5 : Convergence and divergence of winds

General circulation of the atmosphere

The pattern of planetary winds largely depends on : (i) latitudinal variation of atmospheric heating; (ii) emergence of pressure belts; (iii) the migration of belts following apparent path of the sun; (iv) the distribution of continents and oceans; (v) the rotation of earth. The pattern of the movement of the planetary winds is called the general circulation of the atmosphere. The general circulation of the atmosphere also sets in motion the ocean water circulation which influences the earth's

Table 9.2 : Pattern of Wind Direction in Cyclones and Anticyclones

Pressure System	*Pressure Condition at the Centre*	*Pattern of Wind Direction*	
		Northern Hemisphere	*Southern Hemisphere*
Cyclone	Low	Anticlockwise	Clockwise
Anticyclone	High	Clockwise	Anticlockwise

climate. A schematic description of the general circulation is shown in Figure 9.6.

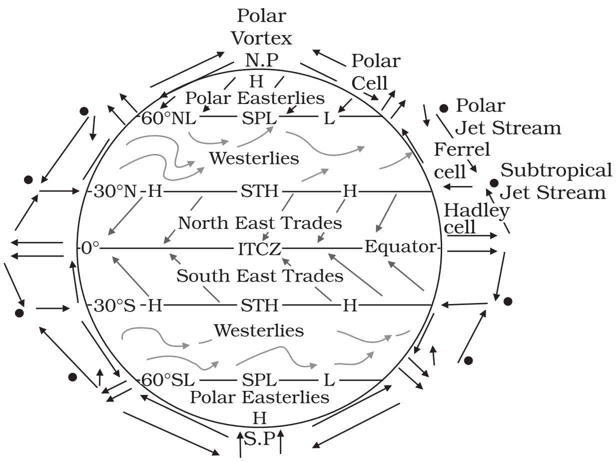


Figure 9. 6 : Simplified general circulation of the atmosphere

The air at the Inter Tropical Convergence Zone (ITCZ) rises because of convection caused by high insolation and a low pressure is created. The winds from the tropics converge at this low pressure zone. The converged air rises along with the convective cell. It reaches the top of the troposphere up to an altitude of 14 km. and moves towards the poles. This causes accumulation of air at about 30° N and S. Part of the accumulated air sinks to the ground and forms a subtropical high. Another reason for sinking is the cooling of air when it reaches 30° N and S latitudes. Down below near the land surface the air flows towards the equator as the easterlies. The easterlies from either side of the equator converge in the Inter Tropical Convergence Zone (ITCZ). Such circulations from the surface upwards and *vice-versa* are called cells. Such a cell in the tropics is called *Hadley Cell*. In the middle latitudes the circulation is that of sinking cold air that comes from the poles and the rising warm air that blows from the subtropical high. At the surface these winds are called westerlies and the cell is known as the *Ferrel cell*. At polar latitudes the cold dense air subsides near the poles and blows towards middle latitudes as the polar easterlies. This cell is called the polar cell. These three cells set the pattern for the general circulation of the atmosphere. The transfer of heat energy from lower latitudes to higher latitudes maintains the general circulation.

The general circulation of the atmosphere also affects the oceans. The large-scale winds of the atmosphere initiate large and slow moving currents of the ocean. Oceans in turn provide input of energy and water vapour into the air. These interactions take place rather slowly over a large part of the ocean.

General Atmospheric Circulation and its Effects on Oceans

Warming and cooling of the Pacific Ocean is most important in terms of general atmospheric circulation. The warm water of the central Pacific Ocean slowly drifts towards South American coast and replaces the cool Peruvian current. Such appearance of warm water off the coast of Peru is known as the El Nino. The El Nino event is closely associated with the pressure changes in the Central Pacific and Australia. This change in pressure condition over Pacific is known as the southern oscillation. The combined phenomenon of southern oscillation and El Nino is known as ENSO. In the years when the ENSO is strong, large-scale variations in weather occur over the world. The arid west coast of South America receives heavy rainfall, drought occurs in Australia and sometimes in India and floods in China. This phenomenon is closely monitored and is used for long range forecasting in major parts of the world.

Seasonal Wind

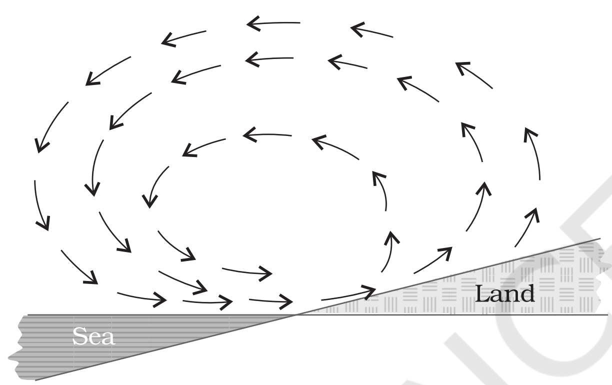
The pattern of wind circulation is modified in different seasons due to the shifting of regions of maximum heating, pressure and wind belts. The most pronounced effect of such a shift is noticed in the monsoons, especially over southeast Asia. You would be studying the details of monsoon in the book *India : Physical Environment* (NCERT, 2006). The other local deviations from the general circulation system are as follows.

Local Winds

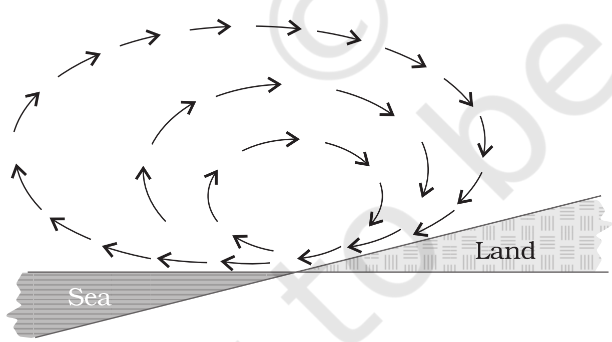
Differences in the heating and cooling of earth surfaces and the cycles those develop daily or annually can create several common, local or regional winds.

Land and Sea Breezes

As explained earlier, the land and sea absorb and transfer heat differently. During the day the land heats up faster and becomes warmer than the sea. Therefore, over the land the air rises giving rise to a low pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high. Thus, pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze. In the night the reversal of condition takes place. The land loses heat faster and is cooler than the sea. The pressure gradient is from the land to the sea and hence land breeze results (Figure 9.7).



Sea Breeze



Land Breeze

Figure 9.7 : Land and sea breezes

Mountain and Valley Winds

In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the valley breeze. During the night the slopes get cooled and the dense air descends into the valley as the mountain wind. The cool air, of the high plateaus and ice fields draining into the valley is called katabatic wind. Another type of warm wind occurs on the leeward side of the mountain ranges. The moisture in these winds, while crossing the mountain ranges condense and precipitate. When it descends down the leeward side of the slope the dry air gets warmed up by adiabatic process. This dry air may melt the snow in a short time.

Air Masses

When the air remains over a homogenous area for a sufficiently longer time, it acquires the characteristics of the area. The homogenous regions can be the vast ocean surface or vast plains. The air with distinctive characteristics in terms of temperature and humidity is called an airmass. It is defined as a large body of air having little horizontal variation in temperature and moisture. The homogenous surfaces, over which air masses form, are called the source regions.

The air masses are classified according to the source regions. There are five major source regions. These are: (i) Warm tropical and subtropical oceans; (ii) The subtropical hot deserts; (iii) The relatively cold high latitude oceans; (iv) The very cold snow covered continents in high latitudes; (v) Permanently ice covered continents in the Arctic and Antarctica. Accordingly, following types of air-masses are recognised: (i) Maritime tropical (mT); (ii) Continental tropical (cT); (iii) Maritime polar (mP); (iv) Continental polar (cP); (v) Continental arctic (cA). Tropical air masses are warm and polar air masses are cold.

Fronts

When two different air masses meet, the boundary zone between them is called a *front*. The process of formation of the fronts is known as *frontogenesis*. There are four types of fronts: (a) Cold; (b) Warm; (c) Stationary; (d) Occluded. When the front remains stationary, it is called a *stationary front*. When the cold air moves

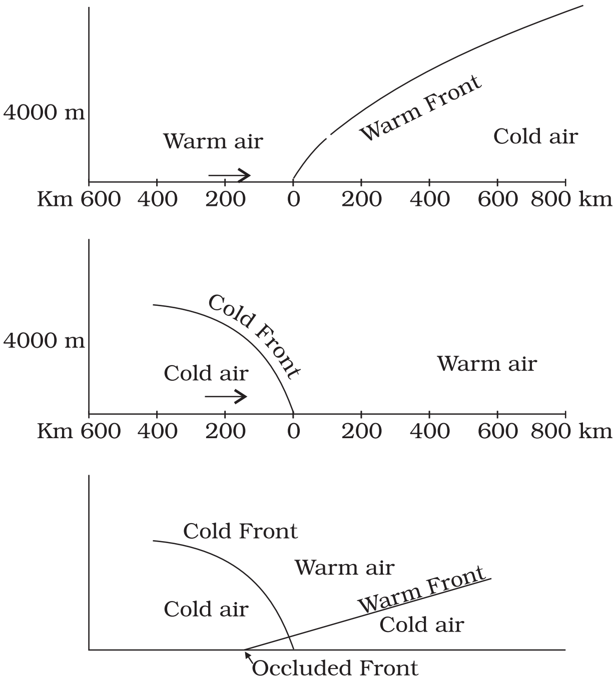


Figure 9.8 : Vertical Sections of : (a) Warm Front; (b) Cold Front; (c) Occluded Front

towards the warm air mass, its contact zone is called the *cold front*, whereas if the warm air mass moves towards the cold air mass, the contact zone is a warm front. If an air mass is fully lifted above the land surface, it is called the *occluded front*. The fronts occur in middle latitudes and are characterised by steep gradient in temperature and pressure. They bring abrupt changes in temperature and cause the air to rise to form clouds and cause precipitation.

Extra Tropical Cyclones

The systems developing in the mid and high latitude, beyond the tropics are called the *middle latitude or extra tropical cyclones*. The passage of front causes abrupt changes in the weather conditions over the area in the middle and high latitudes.

Extra tropical cyclones form along the polar front. Initially, the front is stationary. In the northern hemisphere, warm air blows from the south and cold air from the north of the front. When the pressure drops along the front, the warm air moves northwards and the cold air move towards, south setting in motion an anticlockwise cyclonic circulation. The cyclonic circulation leads to a well developed extra tropical cyclone, with a warm front and a cold front. The plan and cross section of a well developed cyclone is given in Figure 9.9. There are pockets of warm air or warm sector wedged between the forward and the rear cold air or cold sector. The warm air glides over the cold air and a sequence of clouds appear over the sky ahead of the warm front and cause precipitation. The cold front approaches the warm air from behind and pushes the warm air up. As a result, cumulus clouds develop along the cold front. The cold front moves faster than the warm front ultimately overtaking the warm front. The warm air is completely lifted up and the front is occluded and the cyclone dissipates.

The processes of wind circulation both at the surface and aloft are closely interlinked. The extra tropical cyclone differs from the tropical cyclone in number of ways. The extra tropical cyclones have a clear frontal system

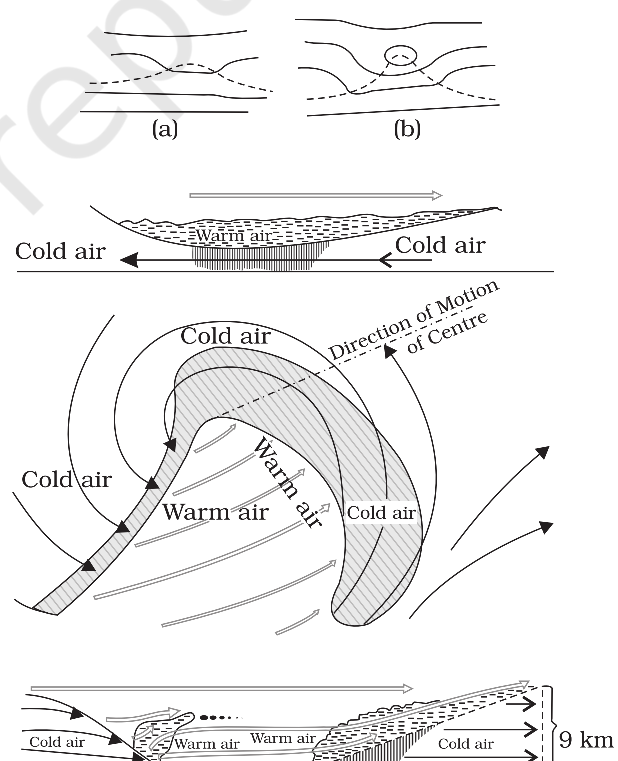


Figure 9. 9 : Extra tropical cyclones

which is not present in the tropical cyclones. They cover a larger area and can originate over the land and sea. Whereas the tropical cyclones originate only over the seas and on reaching the land they dissipate. The extra tropical cyclone affects a much larger area as compared to the tropical cyclone. The wind velocity in a tropical cyclone is much higher and it is more destructive. The extra tropical cyclones move from west to east but tropical cyclones, move from east to west.

Tropical Cyclones

Tropical cyclones are violent storms that originate over oceans in tropical areas and move over to the coastal areas bringing about large scale destruction caused by violent winds, very heavy rainfall and storm surges. This is one of the most devastating natural calamities. They are known as *Cyclones* in the Indian Ocean, *Hurricanes* in the Atlantic, *Typhoons* in the Western Pacific and South China Sea, and *Willy-willies* in the Western Australia.

Tropical cyclones originate and intensify over warm tropical oceans. The conditions favourable for the formation and intensification of tropical storms are: (i) Large sea surface with temperature higher than 27 C; (ii) Presence of the Coriolis force; (iii) Small variations in the vertical wind speed; (iv) A pre-existing weak-low-pressure area or low-level-cyclonic circulation; (v) Upper divergence above the sea level system.

The energy that intensifies the storm, comes from the condensation process in the towering cumulonimbus clouds, surrounding the centre of the storm. With continuous supply of moisture from the sea, the storm is further strengthened. On reaching the land the moisture supply is cut off and the storm dissipates. The place where a tropical cyclone crosses the coast is called the landfall of the cyclone. The cyclones, which cross 20° N latitude generally, recurve and they are more destructive.

A schematic representation of the vertical structure of a mature tropical cyclonic storm is shown in Figure 9.10.

A mature tropical cyclone is characterised by the strong spirally circulating wind around the centre, called the eye. The diameter of the circulating system can vary between 150 and 250 km.

The eye is a region of calm with subsiding air. Around the eye is the eye wall, where there is a strong spiralling ascent of air to greater height reaching the tropopause. The wind reaches maximum velocity in this region, reaching as high as 250 km per hour. Torrential rain occurs here. From the eye wall rain bands may radiate and trains of cumulus and cumulonimbus clouds may drift into the outer region. The diameter of the storm over the Bay of Bengal, Arabian sea and Indian ocean is between 600 - 1200 km. The system moves slowly about 300 - 500 km per day. The cyclone creates storm surges and they inundate the coastal low lands. The storm peters out on the land.

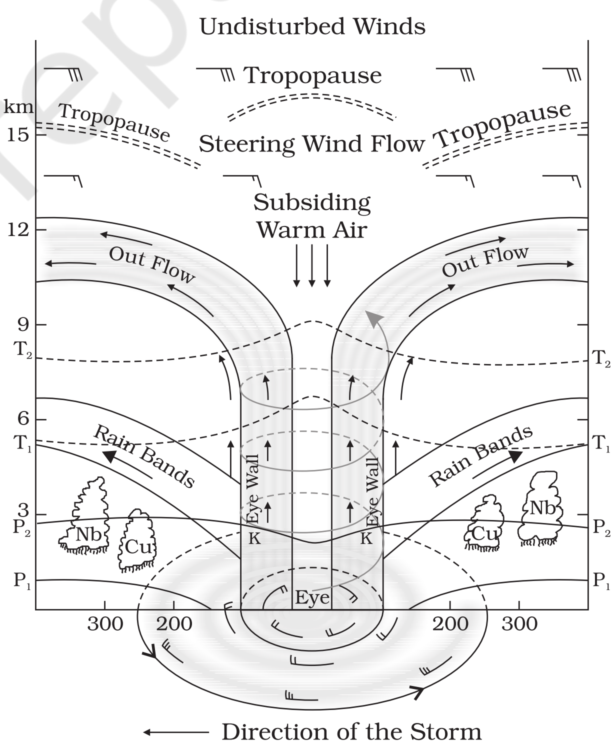


Figure 9.10 : Vertical section of the tropical cyclone (after Rama Sastry)

Thunderstorms and Tornadoes

Other severe local storms are thunderstorms and tornadoes. They are of short duration, occurring over a small area but are violent. *Thunderstorms* are caused by intense convection on moist hot days. A thunderstorm is a well-grown cumulonimbus cloud producing thunder and lightening. When the clouds extend to heights where sub-zero temperature prevails, hails are formed and they come down as hailstorm. If there is insufficient moisture, a thunderstorm can generate dust-storms. A thunderstorm is characterised by intense updraft of rising warm air, which causes the clouds to grow bigger and rise to greater height. This causes precipitation. Later, downdraft brings down to earth the cool air and the rain. From severe thunderstorms sometimes spiralling wind descends like a trunk of an elephant with great force, with very low pressure at the centre, causing massive destruction on its way. Such a phenomenon is called a *tornado*. Tornadoes generally occur in middle latitudes. The tornado over the sea is called *water spouts*.

These violent storms are the manifestation of the atmosphere's adjustments to varying energy distribution. The potential and heat energies are converted into kinetic energy in these storms and the restless atmosphere again returns to its stable state.

EXERCISES

1. Multiple choice questions.

   (i) If the surface air pressure is 1,000 mb, the air pressure at 1 km above the surface will be:

   (a) 700 mb (c) 900 mb

   (b) 1,100 mb (d) 1,300 mb

   (ii) The Inter Tropical Convergence Zone normally occurs:

   (a) near the Equator (b) near the Tropic of Cancer

   (c) near the Tropic of Capricorn (d) near the Arctic Circle

   (iii) The direction of wind around a low pressure in northern hemisphere is:

   (a) clockwise (c) anti-clock wise

   (b) perpendicular to isobars (d) parallel to isobars

   (iv) Which one of the following is the source region for the formation of air masses?

   (a) the Equatorial forest (c) the Siberian Plain

   (b) the Himalayas (d) the Deccan Plateau

2. Answer the following questions in about 30 words.

   (i) What is the unit used in measuring pressure? Why is the pressure measured at station level reduced to the sea level in preparation of weather maps?

   (ii) While the pressure gradient force is from north to south, i.e. from the subtropical high pressure to the equator in the northern hemisphere, why are the winds north easterlies in the tropics?

   (iii) What are the geotrophic winds?

   (iv) Explain the land and sea breezes.

3. Answer the following questions in about 150 words.
   (i) Discuss the factors affecting the speed and direction of wind.
   (ii) Draw a simplified diagram to show the general circulation of the atmosphere over the globe. What are the possible reasons for the formation of subtropical high pressure over 30° N and S latitudes?
   (iii) Why does tropical cyclone originate over the seas? In which part of the tropical cyclone do torrential rains and high velocity winds blow and why?

Project Work

(i) Collect weather information over media such as newspaper, TV and radio for understanding the weather systems.

(ii) Read the section on weather in any newspaper, preferably, one having a map showing a satellite picture. Mark the area of cloudiness. Attempt to infer the atmospheric circulation from the distribution of clouds. Compare the forecast given in the newspaper with the TV coverage, if you have access to TV. Estimate, how many days in a week was the forecast were accurate.

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CHAPTER

10

WATER IN THE ATMOSPHERE

You have already learnt that the air contains water vapour. It varies from zero to four per cent by volume of the atmosphere and plays an important role in the weather phenomena. Water is present in the atmosphere in three forms namely – gaseous, liquid and solid. The moisture in the atmosphere is derived from water bodies through evaporation and from plants through transpiration. Thus, there is a continuous exchange of water between the atmosphere, the oceans and the continents through the processes of evaporation, transpiration, condensation and precipitation.

Water vapour present in the air is known as humidity. It is expressed quantitatively in different ways. The actual amount of the water vapour present in the atmosphere is known as the *absolute humidity*. It is the weight of water vapour per unit volume of air and is expressed in terms of grams per cubic metre. The ability of the air to hold water vapour depends entirely on its temperature. The absolute humidity differs from place to place on the surface of the earth. The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the *relative humidity*. With the change of air temperature, the capacity to retain moisture increases or decreases and the relative humidity is also affected. It is greater over the oceans and least over the continents.

The air containing moisture to its full capacity at a given temperature is said to be *saturated*. It means that the air at the given temperature is incapable of holding any additional amount of moisture at that stage. The temperature at which saturation occurs in a given sample of air is known as *dew point*.

EVAPORATION AND CONDENSATION

The amount of water vapour in the atmosphere is added or withdrawn due to evaporation and condensation respectively. Evaporation is a process by which water is transformed from liquid to gaseous state. Heat is the main cause for evaporation. The temperature at which the water starts evaporating is referred to as the *latent heat of vapourisation*.

Increase in temperature increases water absorption and retention capacity of the given parcel of air. Similarly, if the moisture content is low, air has a potentiality of absorbing and retaining moisture. Movement of air replaces the saturated layer with the unsaturated layer. Hence, the greater the movement of air, the greater is the evaporation.

The transformation of water vapour into water is called *condensation*. Condensation is caused by the loss of heat. When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid form. If it directly condenses into solid form, it is known as *sublimation*. In free air, condensation results from cooling around very small particles termed as hygroscopic condensation nuclei. Particles of dust, smoke and salt from the ocean are particularly good nuclei because they absorb water. Condensation also takes place when the moist air comes in contact with some colder object and it may also take place when the temperature is close to the dew point. Condensation, therefore, depends upon the amount of cooling and the relative humidity of the air. Condensation is influenced by the volume of air, temperature, pressure and humidity. Condensation takes place: (i) when the temperature of the air is reduced to dew point with its volume remaining constant; (ii) when both the volume and the temperature are reduced; (iv) when moisture is added to the air through evaporation. However, the most favourable condition for condensation is the decrease in air temperature.

After condensation the water vapour or the moisture in the atmosphere takes one of the following forms — dew, frost, fog and clouds. Forms of condensation can be classified on the basis of temperature and location. Condensation takes place when the dew point is lower than the freezing point as well as higher than the freezing point.

Dew

When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects (rather than nuclei in air above the surface) such as stones, grass blades and plant leaves, it is known as *dew*. The ideal conditions for its formation are clear sky, calm air, high relative humidity, and cold and long nights. For the formation of dew, it is necessary that the dew point is above the freezing point.

Frost

Frost forms on cold surfaces when condensation takes place below freezing point (0^0C), i.e. the dew point is at or below the freezing point. The excess moisture is deposited in the form of minute ice crystals instead of water droplets. The ideal conditions for the formation of white frost are the same as those for the formation of dew, except that the air temperature must be at or below the freezing point.

Fog and Mist

When the temperature of an air mass containing a large quantity of water vapour falls all of a sudden, condensation takes place within itself on fine dust particles. So, the *fog* is a cloud with its base at or very near to the ground. Because of the fog and mist, the visibility becomes poor to zero. In urban and industrial centres smoke provides plenty of nuclei which help the formation of fog and mist. Such a condition when fog is mixed with smoke, is described as *smog*. The only difference between the mist and fog is that mist contains more moisture than the fog. In mist each nuceli contains a thicker layer of moisture. Mists are frequent over mountains as the rising warm air up the slopes meets a cold surface. Fogs are drier than mist and they are prevalent where warm currents of air come in contact with cold currents. Fogs are mini clouds in which condensation takes place around nuclei provided by the dust, smoke, and the salt particles.

Clouds

Cloud is a mass of minute water droplets or tiny crystals of ice formed by the condensation of the water vapour in free air at considerable elevations. As the clouds are formed at some height over the surface of the earth, they take various shapes. According to their height, expanse, density and transparency or opaqueness clouds are grouped under four types : (i) cirrus; (ii) cumulus; (iii) stratus; (iv) nimbus.

Cirrus

Cirrus clouds are formed at high altitudes (8,000 - 12,000m). They are thin and detatched clouds having a feathery appearance. They are always white in colour.

Cumulus

Cumulus clouds look like cotton wool. They are generally formed at a height of 4,000 - 7,000 m. They exist in patches and can be seen scattered here and there. They have a flat base.

Stratus

As their name implies, these are layered clouds covering large portions of the sky. These clouds are generally formed either due to loss of heat or the mixing of air masses with different temperatures.

Nimbus

Nimbus clouds are black or dark gray. They form at middle levels or very near to the surface of the earth. These are extremely dense and opaque to the rays of the sun. Sometimes, the clouds are so low that they seem to touch the ground. Nimbus clouds are shapeless masses of thick vapour.

Figure 10.1

Figure 10.2

Identify these cloud types which are shown in Figure 10.1 and 10.2.

A combination of these four basic types can give rise to the following types of clouds: *high clouds* – cirrus, cirrostratus, cirrocumulus; *middle clouds* – altostratus and altocumulus; *low clouds* – stratocumulus and nimbostratus and *clouds with extensive vertical development* – cumulus and cumulonimbus.

Precipitation

The process of continuous condensation in free air helps the condensed particles to grow in size. When the resistance of the air fails to hold them against the force of gravity, they fall on to the earth's surface. So after the condensation of water vapour, the release of moisture is known as *precipitation*. This may take place in liquid or solid form. The precipitation in the form of water is called *rainfall*, when the temperature is lower than the 0^0C, precipitation takes place in the form of fine flakes of snow and is called *snowfall*. Moisture is released in the form of hexagonal crystals. These crystals form flakes of snow. Besides rain and snow, other forms of precipitation are *sleet* and *hail*, though the latter are limited in occurrence and are sporadic in both time and space.

Sleet is frozen raindrops and refrozen melted snow-water. When a layer of air with the temperature above freezing point overlies a subfreezing layer near the ground, precipitation takes place in the form of sleet. Raindrops, which leave the warmer air, encounter the colder air below. As a result, they solidify and reach the ground as small pellets of ice not bigger than the raindrops from which they are formed.

Sometimes, drops of rain after being released by the clouds become solidified into small rounded solid pieces of ice and which reach the surface of the earth are called *hailstones*. These are formed by the rainwater passing through the colder layers. Hailstones have several concentric layers of ice one over the other.

Types of Rainfall

On the basis of origin, rainfall may be classified into three main types – the convectional, orographic or relief and the cyclonic or frontal.

Convectional Rain

The, air on being heated, becomes light and rises up in convection currents. As it rises, it expands and loses heat and consequently, condensation takes place and cumulous clouds are formed. With thunder and lightening, heavy rainfall takes place but this does not last long. Such rain is common in the summer or in the hotter part of the day. It is very common in the equatorial regions and interior parts of the continents, particularly in the northern hemisphere.

Orographic Rain

When the saturated air mass comes across a mountain, it is forced to ascend and as it rises, it expands; the temperature falls, and the moisture is condensed. The chief characteristic of this sort of rain is that the windward slopes receive greater rainfall. After giving rain on the windward side, when these winds reach the other slope, they descend, and their temperature rises. Then their capacity to take in moisture increases and hence, these leeward slopes remain rainless and dry. The area situated on the leeward side, which gets less rainfall is known as the *rain-shadow area*. It is also known as the *relief rain*.

Cyclonic Rain

You have already read about extra tropical cyclones and cyclonic rain in Chapter 9. Please consult Chapter 9 to understand cyclonic rainfall.

World Distribution of Rainfall

Different places on the earth's surface receive different amounts of rainfall in a year and that too in different seasons.

In general, as we proceed from the equator towards the poles, rainfall goes on decreasing steadily. The coastal areas of the world receive greater amounts of rainfall than the interior of the continents. The rainfall is more over the oceans than on the landmasses of the world because of being great sources of water. Between the latitudes 35^0 and 40^0 N and S of the equator, the rain is heavier on the eastern coasts and goes on decreasing towards the west. But, between 45^0 and 65^0 N and S of equator, due to the westerlies, the rainfall is first received on the western margins of the continents and it goes on decreasing towards the east. Wherever mountains run parallel to the coast, the rain is greater on the coastal plain, on the windward side and it decreases towards the leeward side.

On the basis of the total amount of annual precipitation, major precipitation regimes of the world are identified as follows.

The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone and the coastal areas of the monsoon land receive heavy rainfall of over 200 cm per annum. Interior continental areas receive moderate rainfall varying from 100 - 200 cm per annum. The coastal areas of the continents receive moderate amount of rainfall. The central parts of the tropical land and the eastern and interior parts of the temperate lands receive rainfall varying between 50 - 100 cm per annum. Areas lying in the rain shadow zone of the interior of the continents and high latitudes receive very low rainfall-less than 50 cm per annum. Seasonal distribution of rainfall provides an important aspect to judge its effectiveness. In some regions rainfall is distributed evenly throughout the year such as in the equatorial belt and in the western parts of cool temperate regions.

EXERCISES

1. Multiple choice questions.

   (i) Which one of the following is the most important constituent of the atmosphere for human beings?

   (a) Water vapour (c) Dust particle

   (b) Nitrogen (d) Oxygen

(ii) Which one of the following process is responsible for transforming liquid into vapour?

(a) Condensation (c) Evaporation

(b) Transpiration (d) Precipitation

(iii) The air that contains moisture to its full capacity :

(a) Relative humidity (c) Absolute humidity

(b) Specific humidity (d) Saturated air

(iv) Which one of the following is the highest cloud in the sky?

(a) Cirrus (c) Nimbus

(b) Stratus (d) Cumulus

2. Answer the following questions in about 30 words.

(i) Name the three types of precipitation.

(ii) Explain relative humidity.

(iii) Why does the amount of water vapour decreases rapidly with altitude?

(iv) How are clouds formed? Classify them.

3. Answer the following questions in about 150 words.

(i) Discuss the salient features of the world distribution of precipitation.

(ii) What are forms of condensation? Describe the process of dew and frost formation.

Project Work

Browse through the newspaper from 1st June to 31st December and note the news about extreme rainfall in different parts of the country.

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CHAPTER

11

World Climate and Climate Change

The world climate can be studied by organising information and data on climate and synthesising them in smaller units for easy understanding, description and analysis. Three broad approaches have been adopted for classifying climate. They are empirical, genetic and applied. Empirical classification is based on observed data, particularly on temperature and precipitation. Genetic classification attempts to organise climates according to their causes. Applied classification is for specific purpose.

Koeppen's Scheme of Classification of Climate

The most widely used classification of climate is the empirical climate classification scheme developed by V. Koeppen. Koeppen identified a close relationship between the distribution of vegetation and climate. He selected certain values of temperature and precipitation and related them to the distribution of vegetation and used these values for classifying the climates. It is an empirical classification based on mean annual and mean monthly temperature and precipitation data. He introduced the use of capital and small letters to designate climatic groups and types. Although developed in 1918 and modified over a period of time, Koeppen's scheme is still popular and in use.

Koeppen recognised five major climatic groups, four of them are based on temperature and one on precipitation. Table 11.1 lists the climatic groups and their characteristics according to Koeppen. The capital letters : A,C, D and E delineate humid climates and B dry climates.

The climatic groups are subdivided into types, designated by small letters, based on seasonality of precipitation and temperature characteristics. The seasons of dryness are indicated by the small letters : f, m, w and s, where f corresponds to no dry season,

Table 11.1 : Climatic Groups According to Koeppen

Group	*Characteristics*
A - Tropical	Average temperature of the coldest month is 18 C or higher
B - Dry Climates	Potential evaporation exceeds precipitation
C - Warm Temperate	The average temperature of the coldest month of the (Mid-latitude) climates years is higher than minus 3 C but below 18 C
D - Cold Snow Forest Climates	The average temperature of the coldest month is minus 3 C or below
E - Cold Climates	Average temperature for all months is below 10 C
H - High Land	Cold due to elevation

m - monsoon climate, w- winter dry season and s - summer dry season. The small letters a, b, c and d refer to the degree of severity of temperature. The B- Dry Climates are subdivided using the capital letters S for steppe or semi-arid and W for deserts. The climatic types are listed in Table 11.2. The distribution of climatic groups and types is shown in Table 11.1.

Table 11.2 : Climatic Types According to Koeppen

Group	*Type*	*Letter Code*	*Characteristics*
A-Tropical Humid Climate	Tropical wet	Af	No dry season
	Tropical monsoon	Am	Monsoonal, short dry season
	Tropical wet and dry	Aw	Winter dry season
B-Dry Climate	Subtropical steppe	BSh	Low-latitude semi arid or dry
	Subtropical desert	BWh	Low-latitude arid or dry
	Mid-latitude steppe	BSk	Mid-latitude semi arid or dry
	Mid-latitude desert	BWk	Mid-latitude arid or dry
C-Warm temperate (Mid-latitude) Climates	Humid subtropical	Cfa	No dry season, warm summer
	Mediterranean	Cs	Dry hot summer
	Marine west coast	Cfb	No dry season, warm and cool summer
D-Cold Snow-forest Climates	Humid continental	Df	No dry season, severe winter
	Subarctic	Dw	Winter dry and very severe
E-Cold Climates	Tundra	ET	No true summer
	Polar ice cap	EF	Perennial ice
H-Highland	Highland	H	Highland with snow cover

Group A : Tropical Humid Climates

Tropical humid climates exist between Tropic of Cancer and Tropic of Capricorn. The sun being overhead throughout the year and the presence of Inter Tropical Convergence Zone (ITCZ) make the climate hot and humid. Annual range of temperature is very low and annual rainfall is high. The tropical group is divided into three types, namely (i) Af- Tropical wet climate; (ii) Am - Tropical monsoon climate; (iii) Aw- Tropical wet and dry climate.

Tropical Wet Climate (Af)

Tropical wet climate is found near the equator. The major areas are the Amazon Basin in South America, western equatorial Africa and the islands of East Indies. Significant amount of rainfall occurs in every month of the year as thunder showers in the afternoon. The temperature is uniformly high and the annual range of temperature is negligible. The maximum temperature on any day is around 30 C while the minimum temperature is around 20 C. Tropical evergreen forests with dense canopy cover and large biodiversity are found in this climate.

Tropical Monsoon Climate (Am)

Tropical monsoon climate (Am) is found over the Indian sub-continent, North Eastern part of South America and Northern Australia. Heavy rainfall occurs mostly in summer. Winter is dry. The detailed climatic account of this climatic type is given in the book on *India: Physical Environment*.

Tropical Wet and Dry Climate (Aw)

Tropical wet and dry climate occurs north and south of Af type climate regions. It borders with dry climate on the western part of the continent and Cf or Cw on the eastern part. Extensive Aw climate is found to the north and south of the Amazon forest in Brazil and adjoining parts of Bolivia and Paraguay in South America, Sudan and south of Central Africa. The annual rainfall in this climate is considerably less than that in Af and Am climate types and is variable also. The wet season is shorter and the dry season is longer with the drought being more severe. Temperature is high throughout the year and diurnal ranges of temperature are the greatest in the dry season. Deciduous forest and tree-shredded grasslands occur in this climate.

Dry Climates : B

Dry climates are characterised by very low rainfall that is not adequate for the growth of plants. These climates cover a very large area of the planet extending over large latitudes from 15 - 60 north and south of the equator. At low latitudes, from 15 - 30 , they occur in the area of subtropical high where subsidence and inversion of temperature do not produce rainfall. On the western margin of the continents, adjoining the cold current, particularly over the west coast of South America, they extend more equatorwards and occur on the coast land. In middle latitudes, from 35 - 60 north and south of equator, they are confined to the interior of continents where maritime-humid winds do not reach and to areas often surrounded by mountains.

Dry climates are divided into steppe or semi-arid climate (BS) and desert climate (BW). They are further subdivided as subtropical steppe (BSh) and subtropical desert (BWh) at latitudes from 15 - 35 and mid-latitude steppe (BSk) and mid-latitude desert (BWk) at latitudes between 35 - 60 .

Subtropical Steppe (BSh) and Subtropical Desert (BWh) Climates

Subtropical steppe (BSh) and subtropical desert (BWh) have common precipitation and temperature characteristics. Located in the transition zone between humid and dry climates, subtropical steppe receives slightly more rainfall than the desert, adequate enough for the growth of sparse grasslands. The rainfall in both the climates is highly variable. The variability in the rainfall affects the life in the steppe much more than in the desert, more often causing famine. Rain occurs in short intense thundershowers in deserts and is ineffective in building soil moisture. *Fog* is common in coastal deserts bordering cold currents. Maximum temperature in the summer is very high. The highest shade temperature of 58 C was recorded at *Al Aziziyah*, Libya on 13 September 1922. The annual and diurnal ranges of temperature are also high.

Warm Temperate (Mid-Latitude) Climates-C

Warm temperate (mid-latitude) climates extend from 30 - 50 of latitude mainly on the eastern and western margins of continents. These climates generally have warm summers with mild winters. They are grouped into four types: (i) Humid subtropical, i.e. dry in winter and hot in summer (Cwa); (ii) Mediterranean (Cs); (iii) Humid subtropical, i.e. no dry season and mild winter (Cfa); (iv) Marine west coast climate (Cfb).

Humid Subtropical Climate (Cwa)

Humid subtropical climate occurs poleward of Tropic of Cancer and Capricorn, mainly in North Indian plains and South China interior plains. The climate is similar to Aw climate except that the temperature in winter is warm.

Mediterranean Climate (Cs)

As the name suggests, Mediterranean climate occurs around Mediterranean sea, along the west coast of continents in subtropical latitudes between 30 - 40 latitudes e.g. — Central California, Central Chile, along the coast in south eastern and south western Australia. These areas come under the influence of sub tropical high in summer and westerly wind in winter. Hence, the climate is characterised by hot, dry summer and mild, rainy winter. Monthly average temperature in summer is around 25 C and in winter below 10 C. The annual precipitation ranges between 35 - 90 cm.

Humid Subtropical (Cfa) Climate

Humid subtropical climate lies on the eastern parts of the continent in subtropical latitudes. In this region the air masses are generally unstable and cause rainfall throughout the year. They occur in eastern United States of America, southern and eastern China, southern Japan, northeastern Argentina, coastal south Africa and eastern coast of Australia. The annual averages of precipitation vary from 75-150 cm. Thunderstorms in summer and frontal precipitation in winter are common. Mean monthly temperature in summer is around 27 C, and in winter it varies from 5 -12 C. The daily range of temperature is small.

Marine West Coast Climate (Cfb)

Marine west coast climate is located poleward from the Mediterranean climate on the west coast of the continents. The main areas are: Northwestern Europe, west coast of North America, north of California, southern Chile, southeastern Australia and New Zealand. Due to marine influence, the temperature is moderate and in winter, it is warmer than for its latitude. The mean temperature in summer months ranges from 15 -20 C and in winter 4 -10 C. The annual and daily ranges of temperature are small. Precipitation occurs throughout the year. Precipitation varies greatly from 50-250cm.

Cold Snow Forest Climates (D)

Cold snow forest climates occur in the large continental area in the northern hemisphere between 40 -70 north latitudes in Europe, Asia and North America. Cold snow forest climates are divided into two types: (i) Df- cold climate with humid winter; (ii) Dw- cold climate with dry winter. The severity of winter is more pronounced in higher latitudes.

Cold Climate with Humid Winters (Df)

Cold climate with humid winter occurs poleward of marine west coast climate and mid latitude steppe. The winters are cold and snowy. The frost free season is short. The annual ranges of temperature are large. The weather changes are abrupt and short. Poleward, the winters are more severe.

Cold Climate with Dry Winters (Dw)

Cold climate with dry winter occurs mainly over Northeastern Asia. The development of pronounced winter anti cyclone and its weakening in summer sets in monsoon like reversal of wind in this region. Poleward summer temperatures are lower and winter temperatures are extremely low with many locations experiencing below freezing point temperatures for up to seven months in a year. Precipitation occurs in summer. The annual precipitation is low from 12-15 cm.

Polar Climates (E)

Polar climates exist poleward beyond 70 latitude. Polar climates consist of two types: (i) Tundra (ET); (ii) Ice Cap (EF).

Tundra Climate (ET)

The tundra climate (ET) is so called after the types of vegetation, like low growing mosses, lichens and flowering plants. This is the region of permafrost where the sub soil is permanently frozen. The short growing season and water logging support only low growing plants. During summer, the tundra regions have very long duration of day light.

Ice Cap Climate (EF)

The ice cap climate (EF) occurs over interior Greenland and Antartica. Even in summer, the temperature is below freezing point. This area receives very little precipitation. The snow and ice get accumulated and the mounting pressure causes the deformation of the ice sheets and they break. They move as icebergs that float in the Arctic and Antarctic waters. Plateau Station , Antarctica ,79 S, portray this climate.

Highland Climates (H)

Highland climates are governed by topography. In high mountains, large changes in mean temperature occur over short distances. Precipitation types and intensity also vary spatially across high lands. There is vertical zonation of layering of climatic types with elevation in the mountain environment.

Climate Change

The earlier chapters on climate summarised our understanding of climate as it prevails now. The type of climate we experience now might be prevailing over the last 10,000 years with minor and occasionally wide fluctuations. The planet earth has witnessed many variations in climate since the beginning. Geological records show alteration of glacial and inter-glacial periods. The geomorphological features, especially in high altitudes and high latitudes, exhibit traces of advances and retreats of glaciers. The sediment deposits in glacial lakes also reveal the occurrence of warm and cold periods. The rings in the trees provide clues about wet and dry periods. Historical records describe the vagaries in climate. All these evidences indicate that change in climate is a natural and continuous process.

India also witnessed alternate wet and dry periods. Archaeological findings show that the Rajasthan desert experienced wet and cool climate around 8,000 B.C. The period 3,000-1,700 B.C. had higher rainfall. From about 2,000-1,700 B.C., this region was the centre of the Harappan civilisation. Dry conditions accentuated since then.

In the geological past, the earth was warm some 500-300 million years ago, through the Cambrian, Ordovician and Silurian periods. During the Pleistocene epoch, glacial and inter-glacial periods occurred, the last major peak glacial period was about 18,000 years ago. The present inter-glacial period started 10,000 years ago.

Climate in the recent past

Variability in climate occurs all the time. The nineties decade of the last century witnessed extreme weather events. The 1990s recorded the warmest temperature of the century and some of the worst floods around the world. The worst devastating drought in the Sahel region, south of the Sahara desert, from 1967-1977 is one such variability. During the 1930s, severe drought occurred in southwestern Great Plains of the United States, described as the *dust bowl*. Historical records of crop yield or crop failures, of floods and migration of people tell about the effects of changing climate. A number of times Europe witnessed warm, wet, cold and dry periods, the significant episodes were the warm and dry conditions in the tenth and eleventh centuries, when the Vikings settled in Greenland. Europe witnessed "Little Ice Age" from 1550 to about 1850. From about 1885-1940 world temperature showed an upward trend. After 1940, the rate of increase in temperature slowed down.

Causes of Climate Change

The causes for climate change are many. They can be grouped into astronomical and terrestrial causes. The astronomical causes are the changes in solar output associated with sunspot activities. Sunspots are dark and cooler patches on the sun which increase and decrease in a cyclical manner. According to some meteorologists, when the number of sunspots increase, cooler and wetter weather and greater storminess occur. A decrease in sunspot numbers is associated with warm and drier conditions. Yet, these findings are not statistically significant.

An another astronomical theory is Millankovitch oscillations, which infer cycles in the variations in the earth's orbital characteristics around the sun, the wobbling of the earth and the changes in the earth's axial tilt. All these alter the amount of insolation received from the sun, which in turn, might have a bearing on the climate.

Volcanism is considered as another cause for climate change. Volcanic eruption throws up lots of aerosols into the atmosphere. These aerosols remain in the atmosphere for a considerable period of time reducing the sun's radiation reaching the Earth's surface. After the recent Pinatoba and El Cion volcanic eruptions, the average temperature of the earth fell to some extent for some years.

The most important anthropogenic effect on the climate is the increasing trend in the concentration of greenhouse gases in the atmosphere which is likely to cause global warming.

Global Warming

Due to the presence of greenhouse gases, the atmosphere is behaving like a *greenhouse*. The atmosphere also transmits the incoming solar radiation but absorbs the vast majority of long wave radiation emitted upwards by the earth's surface. The gases that absorb long wave radiation are called greenhouse gases. The processes that warm the atmosphere are often collectively referred to as the *greenhouse effect*.

> The term *greenhouse* is derived from the analogy to a greenhouse used in cold areas for preserving heat. *A greenhouse* is made up of glass. The glass which is transparent to incoming short wave solar radiation is opaque to outgoing long wave radiation. The glass, therefore, allows in more radiation and prevents the long wave radiation going outside the glass house, causing the temperature inside the glasshouse structure warmer than outside. When you enter a car or a bus, during summers, where windows are closed, you feel more heat than outside. Likewise during winter the vehicles with closed doors and windows remain warmer than the temperature outside. This is another example of the greenhouse effect.

Greenhouse Gases(GHGs)

The primary GHGs of concern today are carbon dioxide (CO_2), Chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Some other gases such as nitric oxide (NO) and carbon monoxide (CO) easily react with GHGs and affect their concentration in the atmosphere.

The effectiveness of any given GHG molecule will depend on the magnitude of the increase in its concentration, its life time in the atmosphere and the wavelength of radiation that it absorbs. The chlorofluorocarbons (CFCs) are highly effective. *Ozone* which absorbs ultra violet radiation in the stratosphere is very effective in absorbing terrestrial radiation when it is present in the lower troposphere. Another important point to be noted is that the more time the GHG molecule remains in the atmosphere, the longer it will take for earth's atmospheric system to recover from any change brought about by the latter.

The *largest concentration* of GHGs in the atmosphere is *carbon dioxide*. The emission of CO_2 comes mainly from fossil fuel combustion (oil, gas and coal). Forests and oceans are the sinks for the carbon dioxide. Forests use CO_2 in their growth. So, deforestation due to changes in land use, also increases the concentration of Co_2. The time taken for atmospheric CO_2 to adjust to changes in sources to sinks is 20-50 years. It is rising at about 0.5 per cent annually. Doubling of concentration of CO_2 over pre-industrial level is used as an index for estimating the changes in climate in climatic models.

Chlorofluorocarbons (CFCs) are products of human activity. *Ozone* occurs in the stratosphere where ultra-violet rays convert oxygen into ozone. Thus, ultra violet rays do not reach the earth's surface. The CFCs which drift into the stratosphere destroy the ozone. Large depletion of ozone occurs over Antarctica. *The* depletion *of ozone concentration in the* stratosphere is called the *ozone hole*. This allows the ultra violet rays to pass through the troposphere.

International efforts have been initiated for reducing the emission of GHGs into the atmosphere. The most important one is the *Kyoto protocol* proclaimed in 1997. This protocol went into effect in 2005, ratified by 141 nations. Kyoto protocol bounds the 35 industrialised countries to reduce their emissions by the year 2012 to 5 per cent less than the levels prevalent in the year 1990.

The increasing trend in the concentration of GHGs in the atmosphere may, in the long run, warm up the earth. Once the global warming sets in, it will be difficult to reverse it. The effect of global warming may not be uniform everywhere. Nevertheless, the adverse effect due to global warming will adversely affect the life supporting system. Rise in the sea level due to melting of glaciers and ice-caps and thermal expansion of the sea may inundate large parts of the coastal area and islands, leading to social problems. This is another cause for serious concern for the world community. Efforts have already been initiated to control the emission of GHGs and to arrest the trend towards global warming. Let us hope the world community responds to this challenge and adopts a lifestyle that leaves behind a livable world for the generations to come.

One of the major concerns of the world today is global warming. Let us look at how much the planet has warmed up from the temperature records.

The annual average near-surface air temperature of the world is approximately 14°C.

An increasing trend in temperature was discernible in the 20th century. The greatest warming of the 20th century was during the two periods, 1901-44 and 1977-99. Over each of these two periods, global temperatures rose by about 0.4°C. In between, there was a slight cooling, which was more marked in the Northern Hemisphere.

The globally averaged annual mean temperature at the end of the 20th century was about 0.6°C above that recorded at the end of the 19th century. The seven warmest years during the 1856-2000 were recorded in the last decade. The year 1998 was the warmest year, probably not only for the 20th century but also for the whole millennium.

Write an explanatory note on "global warming".

EXERCISES

1. Multiple choice questions.

   (i) Which one of the following is suitable for Koeppen's "A" type of climate?

   (a) High rainfall in all the months

   (b) Mean monthly temperature of the coldest month more than freezing point

   (c) Mean monthly temperature of all the months more than 18^{o} C

   (d) Average temperature for all the months below 10 C

   (ii) Koeppen's system of classification of climates can be termed as :

   (a) Applied (b) Systematic (c) Genetic (d) Empirical

   (iii) Most of the Indian Peninsula will be grouped according to Koeppen's system under:

   (a) "Af" (b) "BSh" (c) "Cfb" (d) "Am"

   (iv) Which one of the following years is supposed to have recorded the warmest temperature the world over?

   (a) 1990 (b) 1998 (c) 1885 (d) 1950

   (v) Which one of the following groups of four climates represents humid conditions?

   (a) A—B—C—E

   (b) A—C—D—E

   (c) B—C—D—E

   (d) A—C—D—F

2. Answer the following questions in about 30 words.

   (i) Which two climatic variables are used by Koeppen for classification of the climate?

   (ii) How is the "genetic" system of classification different from the "empirical one"?

   (iii) Which types of climates have very low range of temperature?

   (iv) What type of climatic conditions would prevail if the sun spots increase?

3. Answer the following questions in about 150 words.

   (i) Make a comparison of the climatic conditions between the "A" and "B" types of climate.

   (ii) What type of vegetation would you find in the "C" and "A" type(s) of climate?

   (iii) What do you understand by the term "Greenhouse Gases"? Make a list of greenhouse gases.

Project Work

Collect information about Kyoto declaration related to global climate changes.

UNIT V

WATER (OCEANS)

This unit deals with

- *Hydrological Cycle*
- *Oceans — submarine relief; distribution of temperature and salinity; movements of ocean water-waves, tides and currents*

CHAPTER

12

Water (Oceans)

Can we think of life without water? It is said that the water is life. Water is an essential component of all life forms that exist over the surface of the earth. The creatures on the earth are lucky that it is a water planet, otherwise we all would have no existence. Water is a rare commodity in our solar system. There is no water on the sun or anywhere else in the solar system. The earth, fortunately has an abundant supply of water on its surface. Hence, our planet is called the *'Blue Planet'.*

Hydrological Cycle

Water is a cyclic resource. It can be used and re-used. Water also undergoes a cycle from the ocean to land and land to ocean. The hydrological cycle describes the movement of water on, in, and above the earth. The water cycle has been working for billions of years and all the life on earth depends on it. Next to air, water is the most important element required for the existence of life on earth. The distribution of water on earth is quite uneven. Many locations have plenty of water while others have very limited quantity. The *hydrological cycle*, is the circulation of water within the earth's hydrosphere in different forms i.e. the liquid, solid and the gaseous phases. It also refers to the continuous exchange of water between the oceans,

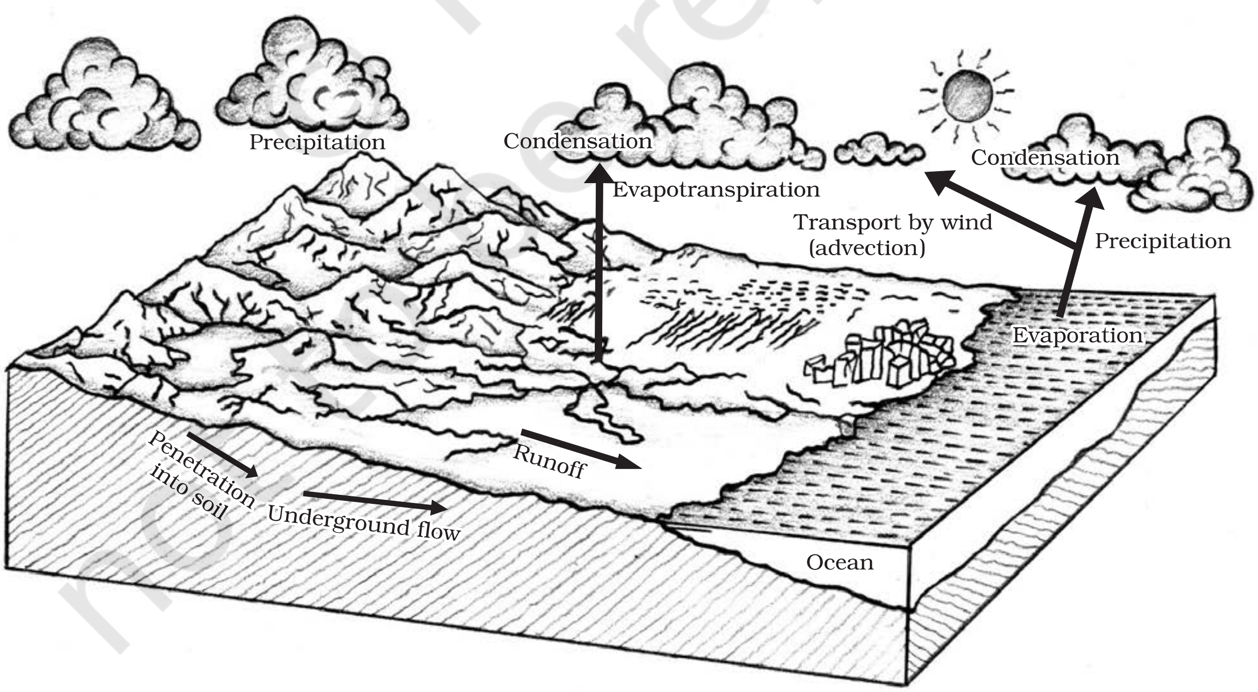

Figure 12.1 : Hydrological Cycle

Table 12.1 : Components and Processes of the Water Cycle

Components	*Processes*
Water storage in oceans	Evaporation Evapotranspiration Sublimation
Water in the atmosphere	Condensation Precipitation
Water storage in ice and snow	Snowmelt runoff to streams
Surface runoff	Stream flow freshwater storage infiltration
Groundwater storage	Groundwater discharge springs

atmosphere, landsurface and subsurface and the organisms.

About 71 per cent of the planetary water is found in the oceans. The remaining is held as freshwater in glaciers and icecaps, groundwater sources, lakes, soil moisture, atmosphere, streams and within life. Nearly 59 per cent of the water that falls on land returns to the atmosphere through evaporation from over the oceans as well as from other places. The remainder runs-off on the surface, infiltrates into the ground or a part of it becomes glacier.

It is to be noted that the renewable water on the earth is constant while the demand is increasing tremendously. This leads to water crisis in different parts of the world — spatially and temporally. The pollution of river waters has further aggravated the crisis. How can you intervene in improving the water quality and augmenting the available quantity of water?

Relief of the Ocean Floor

The oceans are confined to the great depressions of the earth's outer layer. In this section, we shall see the nature of the ocean basins of the earth and their topography. The oceans, unlike the continents, merge so naturally into one another that it is hard to demarcate them. The geographers have divided the oceanic part of the earth into five oceans, namely the Pacific, the Atlantic, the Indian, Southern ocean and the Arctic. The various seas, bays, gulfs and other inlets are parts of these four large oceans.

A major portion of the ocean floor is found between 3-6 km below the sea level. The 'land' under the waters of the oceans, that is, the ocean floor exhibits complex and varied features as those observed over the land (Figure 12.2). The floors of the oceans are rugged with the world's largest mountain ranges, deepest trenches and the largest plains. These features are formed, like those of the continents, by the factors of tectonic, volcanic and depositional processes.

Divisions of the Ocean Floors

The ocean floors can be divided into four major divisions: (i) the Continental Shelf; (ii) the Continental Slope; (iii) the Deep Sea Plain; (iv) the Oceanic Deeps. Besides, these divisions there are also major and minor relief features in the ocean floors like ridges, hills, sea mounts, guyots, trenches, canyons, etc.

Continental Shelf

The continental shelf is the extended margin of each continent occupied by relatively shallow seas and gulfs. It is the shallowest part of the ocean showing an average gradient of 1 or even less. The shelf typically ends at a very steep slope, called the shelf break.

The width of the continental shelves vary from one ocean to another. The average width of continental shelves is about 80 km. The shelves are almost absent or very narrow along some of the margins like the coasts of Chile, the west coast of Sumatra, etc. On the contrary, the Siberian shelf in the Arctic Ocean, the largest in the world, stretches to 1,500 km in width. The depth of the shelves also varies. It may be as shallow as 30 m in some areas while in some areas it is as deep as 600 m.

The continental shelves are covered with variable thicknesses of sediments brought down by rivers, glaciers, wind, from the land and distributed by waves and currents. Massive sedimentary deposits received over a long time by the continental shelves, become the source of fossil fuels.

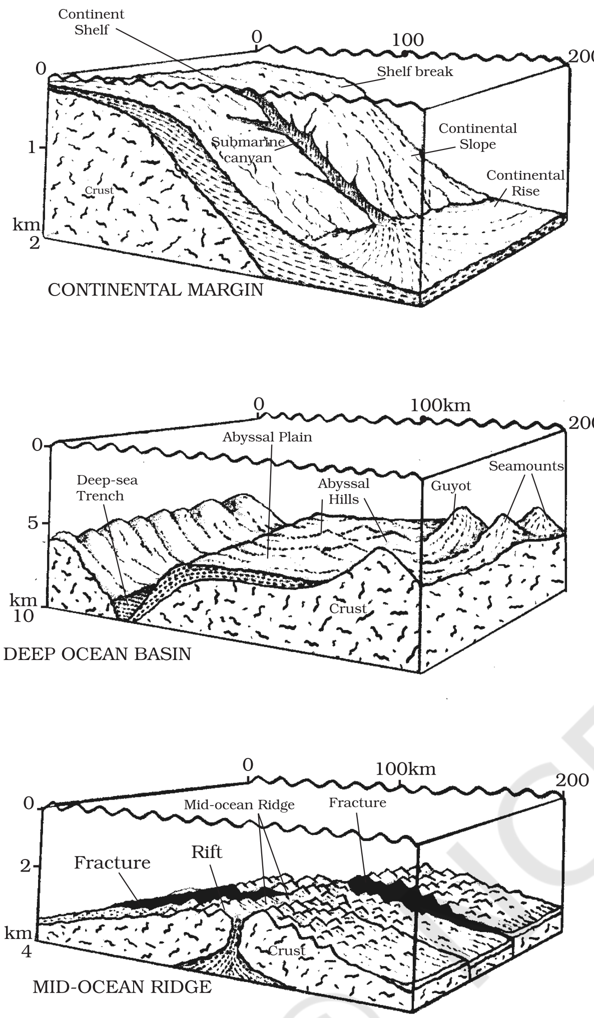

Figure 12.2 : Relief features of ocean floors

Continental Slope

The continental slope connects the continental shelf and the ocean basins. It begins where the bottom of the continental shelf sharply drops off into a steep slope. The gradient of the slope region varies between 2-5 . The depth of the slope region varies between 200 and 3,000 m. The slope boundary indicates the end of the continents. Canyons and trenches are observed in this region.

Deep Sea Plain

Deep sea plains are gently sloping areas of the ocean basins. These are the flattest and smoothest regions of the world. The depths vary between 3,000 and 6,000m. These plains are covered with fine-grained sediments like clay and silt.

Oceanic Deeps or Trenches

These areas are the deepest parts of the oceans. The trenches are relatively steep sided, narrow basins. They are some 3-5 km deeper than the surrounding ocean floor. They occur at the bases of continental slopes and along island arcs and are associated with active volcanoes and strong earthquakes. That is why they are very significant in the study of plate movements. As many as 57 deeps have been explored so far; of which 32 are in the Pacific Ocean; 19 in the Atlantic Ocean and 6 in the Indian Ocean.

Minor Relief Features

Apart from the above mentioned major relief features of the ocean floor, some minor but significant features predominate in different parts of the oceans.

Mid-Oceanic Ridges

A mid-oceanic ridge is composed of two chains of mountains separated by a large depression. The mountain ranges can have peaks as high as 2,500 m and some even reach above the ocean's surface. Iceland, a part of the mid-Atlantic Ridge, is an example.

Seamount

It is a mountain with pointed summits, rising from the seafloor that does not reach the surface of the ocean. Seamounts are volcanic in origin. These can be 3,000-4,500 m tall. The Emperor seamount, an extension of the Hawaiian Islands in the Pacific Ocean, is a good example.

Submarine Canyons

These are deep valleys, some comparable to the Grand Canyon of the Colorado river. They are sometimes found cutting across the continental shelves and slopes, often extending from the mouths of large rivers. The Hudson Canyon is the best known submarine canyon in the world.

Guyots

It is a flat topped seamount. They show evidences of gradual subsidence through stages to become flat topped submerged mountains. It is estimated that more than 10,000 seamounts and guyots exist in the Pacific Ocean alone.

Atoll

These are low islands found in the tropical oceans consisting of coral reefs surrounding a central depression. It may be a part of the sea (lagoon), or sometimes form enclosing a body of fresh, brackish, or highly saline water.

TEMPERATURE OF OCEAN WATERS

This section deals with the spatial and vertical variations of temperature in various oceans. Ocean waters get heated up by the solar energy just as land. The process of heating and cooling of the oceanic water is slower than land.

Factors Affecting Temperature Distribution

The factors which affect the distribution of temperature of ocean water are :

(i) *Latitude* : the temperature of surface water decreases from the equator towards the poles because the amount of insolation decreases poleward.

(ii) *Unequal distribution of land and water* : the oceans in the northern hemisphere receive more heat due to their contact with larger extent of land than the oceans in the southern hemisphere.

(iii) *Prevailing wind* : the winds blowing from the land towards the oceans drive warm surface water away form the coast resulting in the upwelling of cold water from below. It results into the longitudinal variation in the temperature. Contrary to this, the onshore winds pile up warm water near the coast and this raises the temperature.

(iv) *Ocean currents* : warm ocean currents raise the temperature in cold areas while the cold currents decrease the temperature in warm ocean areas. Gulf stream (warm current) raises the temperature near the eastern coast of North America and the West Coast of Europe while the Labrador current (cold current) lowers the temperature near the north-east coast of North America.

All these factors influence the temperature of the ocean currents locally. The enclosed seas in the low latitudes record relatively higher temperature than the open seas; whereas the enclosed seas in the high latitudes have lower temperature than the open seas.

Horizontal and Vertical Distribution of Temperature

The temperature-depth profile for the ocean water shows how the temperature decreases with the increasing depth. The profile shows a boundary region between the surface waters of the ocean and the deeper layers. The boundary usually begins around 100 - 400 m below the sea surface and extends several hundred of metres downward (Figure 12.3). This boundary region, from where there is a rapid decrease of temperature, is called the *thermocline*. About 90 per cent of the total volume of water is found below the thermocline in the deep ocean. In this zone, temperatures approach 0 C.

The temperature structure of oceans over middle and low latitudes can be described as a three-layer system from surface to the bottom.

The *first layer* represents the top layer of warm oceanic water and it is about 500m thick with temperatures ranging between 20 and 25 C. This layer, within the tropical region, is present throughout the year but in mid latitudes it develops only during summer.

The *second layer* called the thermocline layer lies below the first layer and is characterised by rapid decrease in temperature with increasing depth. The thermocline is 500 -1,000 m thick.

The *third layer* is very cold and extends upto the deep ocean floor. In the Arctic and

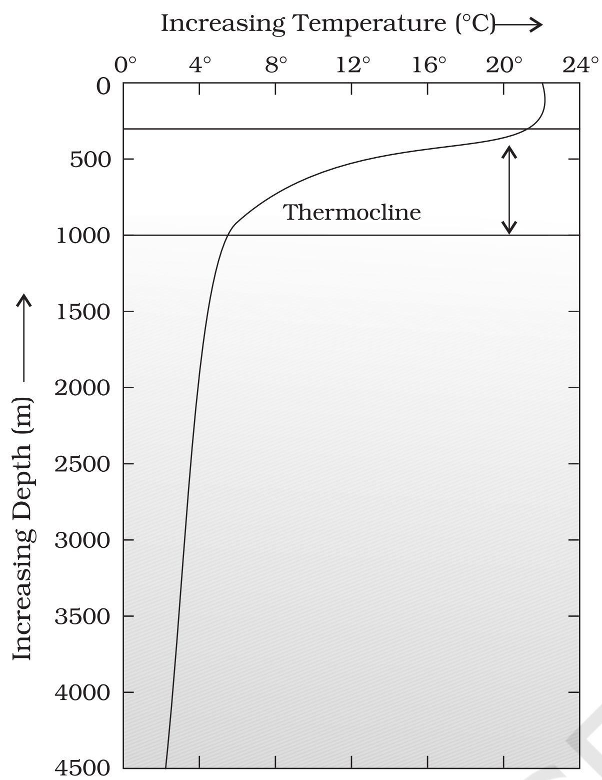

Figure 12.3 : Thermocline

Antartic circles, the surface water temperatures are close to 0 C and so the temperature change with the depth is very slight. Here, only one layer of cold water exists, which extends from surface to deep ocean floor.

The average temperature of surface water of the oceans is about 27 C and it gradually decreases from the equator towards the poles. The rate of decrease of temperature with increasing latitude is generally 0.5 C per latitude. The average temperature is around 22 C at 20 latitudes, 14 C at 40 latitudes and 0 C near poles. The oceans in the northern hemisphere record relatively higher temperature than in the southern hemisphere. The highest temperature is not recorded at the equator but slightly towards north of it. The average annual temperatures for the northern and southern hemisphere are around 19 C and 16 C respectively. This variation is due to the unequal distribution of land and water in the northern and southern hemispheres.

Figure 12.4 shows the spatial pattern of surface temperature of the oceans.

It is a well known fact that the maximum temperature of the oceans is always at their surfaces because they directly receive the heat from the sun and the heat is transmitted to the lower sections of the oceans through the process of convection. It results into decrease of temperature with the increasing depth, but the rate of decrease is not uniform throughout. The temperature falls very rapidly up to the depth of 200 m and thereafter, the rate of decrease of temperature is slowed down.

Salinity of Ocean Waters

All waters in nature, whether rain water or ocean water, contain dissolved mineral salts. Salinity is the term used to define the total content of dissolved salts in sea water (Table 12.4). It is calculated as the amount of salt (in gm) dissolved in 1,000 gm (1 kg) of seawater. It is usually expressed as parts per thousand ($^{o}/_{oo}$) or ppt. Salinity is an important property of sea water. Salinity of 24.7 $^{o}/_{oo}$ has been considered as the upper limit to demarcate 'brackish water'.

Factors affecting ocean salinity are mentioned below:

(i) The salinity of water in the surface layer of oceans depend mainly on evaporation and precipitation.
(ii) Surface salinity is greatly influenced in coastal regions by the fresh water flow from rivers, and in polar regions by the processes of freezing and thawing of ice.
(iii) Wind, also influences salinity of an area by transferring water to other areas.
(iv) The ocean currents contribute to the salinity variations. Salinity, temperature and density of water are interrelated. Hence, any change in the temperature or density influences the salinity of water in an area.

Highest salinity in water bodies
Lake Van in Turkey (330 $^{o}/_{oo}$),
Dead Sea (238 $^{o}/_{oo}$),
Great Salt Lake (220 $^{o}/_{oo}$)

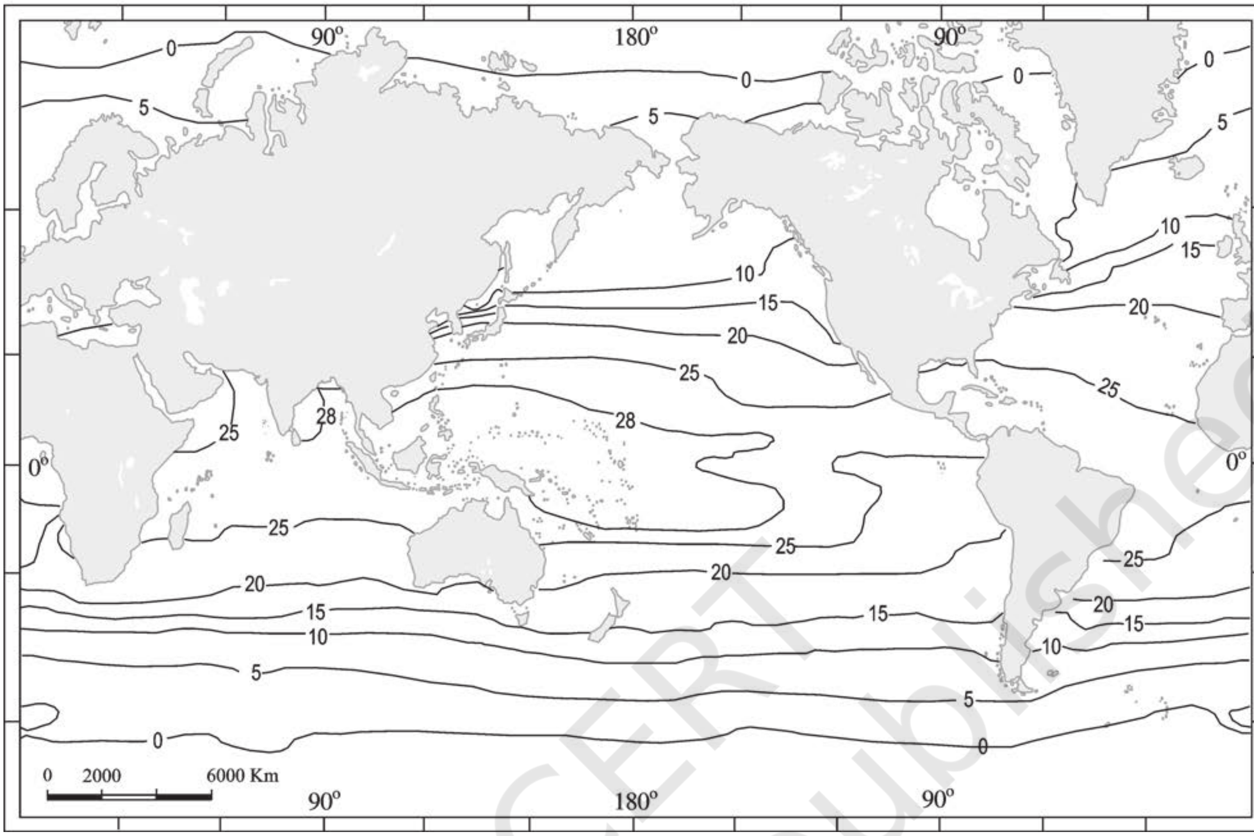

Figure 12.4 : Spatial pattern of surface temperature (C) of the oceans

Horizontal Distribution of Salinity

The salinity for normal open ocean ranges between $33^{o}/_{oo}$ and $37\ ^{o}/_{oo}$. In the land locked Red Sea, it is as high as $41^{o}/_{oo}$, while in the estuaries and the Arctic, the salinity fluctuates from 0 - $35\ ^{o}/_{oo}$, seasonally. In hot and dry regions, where evaporation is high, the salinity sometimes reaches to $70\ ^{o}/_{oo}$.

The salinity variation in the Pacific Ocean is mainly due to its shape and larger areal extent. Salinity decreases from $35\ ^{o}/_{oo}$ - $31\ ^{o}/_{oo}$ on the western parts of the northern hemisphere because of the influx of melted water from the Arctic region. In the same way, after 15 - 20 south, it decreases to $33\ ^{o}/_{oo}$.

The average salinity of the Atlantic Ocean is around $36\ ^{o}/_{oo.}$ The highest salinity is recorded between 15 and 20 latitudes. Maximum salinity ($37\ ^{o}/_{oo}$) is observed between 20 N and 30 N and 20 W - 60 W. It gradually decreases towards the north. The North Sea, in spite of its location in higher latitudes, records higher salinity due to more saline water brought by the North Atlantic Drift. Baltic Sea records low salinity due to influx of river waters in large quantity. The Mediterranean Sea records higher salinity due to high evaporation. Salinity is, however, very low in Black Sea due to enormous fresh water influx by rivers. See the atlas to find out the rivers joining Black Sea.

The average salinity of the Indian Ocean is $35\ ^{o}/_{oo.}$ The low salinity trend is observed in the Bay of Bengal due to influx of river water. On the contrary, the Arabian Sea shows higher salinity due to high evaporation and low influx of fresh water. Figure 12.5 shows the salinity of the World's oceans.

Vertical Distribution of Salinity

Salinity changes with depth, but the way it changes depends upon the location of the

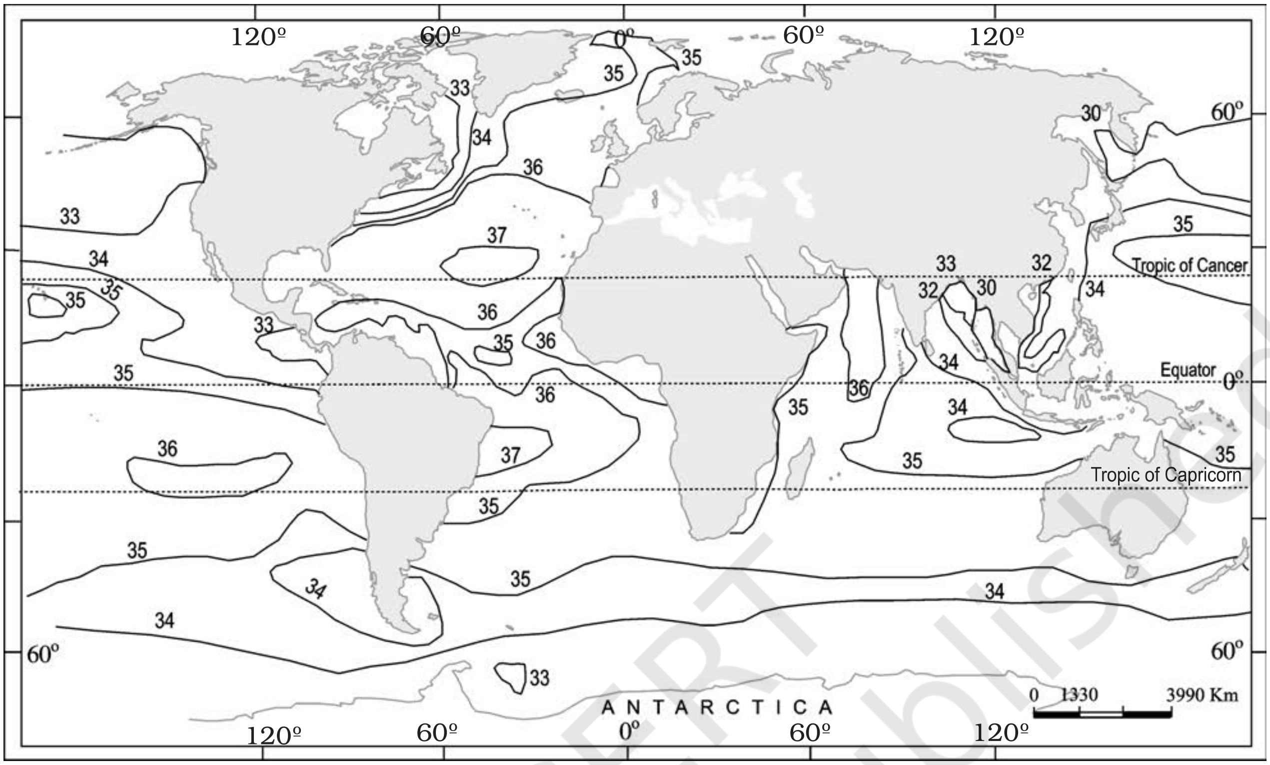

Figure12.5 : Surface salinity of the World's Oceans

sea. Salinity at the surface increases by the loss of water to ice or evaporation, or decreased by the input of fresh waters, such as from the rivers. Salinity at depth is very much fixed, because there is no way that water is 'lost', or the salt is 'added.' There is a marked difference in the salinity between the surface zones and the deep zones of the oceans. The lower salinity water rests above the higher salinity dense water. Salinity, generally, increases with depth and there is a distinct zone called the *halocline*, where salinity increases sharply. Other factors being constant, increasing salinity of seawater causes its density to increase. High salinity seawater, generally, sinks below the lower salinity water. This leads to stratification by salinity.

EXERCISES

1. Multiple choice questions.

(i) Identify the element which is not a part of the hydrological cycle

(a) Evaporation (c) Precipitation

(b) Hydration (d) Condensation

(ii) The average depth of continental slope varies between

(a) 2–20m (c) 20–200m

(b) 200–2,000m (d) 2,000–20,000m

(iii) Which one of the following is not a minor relief feature in the oceans:

(a) Seamount (c) Oceanic Deep

(b) Atoll (d) Guyot

(iv) Salinity is expressed as the amount of salt in grams dissolved in sea water per

(a) 10 gm (c) 100 gm

(b) 1,000 gm (d) 10,000 gm

(v) Which one of the following is the smallest ocean:

(a) Indian Ocean (c) Atlantic Ocean

(b) Arctic Ocean (d) Pacific Ocean

2. Answer the following questions in about 30 words.

(i) Why do we call the earth a Blue Planet?

(ii) What is a continental margin?

(iii) List out the deepest trenches of various oceans.

(iv) What is a thermocline?

(v) When you move into the ocean what thermal layers would you encounter? Why the temperature varies with depth?

(vi) What is salinity of sea water?

3. Answer the following questions in about 150 words.

(i) How are various elements of the hydrological cycle interrelated?

(ii) Examine the factors that influence the temperature distribution of the oceans.

Project Work

(i) Consult the atlas and show ocean floor relief on the outline of the world map.

(ii) Identify the areas of mid oceanic ridges from the Indian Ocean.

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CHAPTER

13

Movements of Ocean Water

The ocean water is dynamic. Its physical characteristics like temperature, salinity, density and the external forces like of the sun, moon and the winds influence the movement of ocean water. The horizontal and vertical motions are common in ocean water bodies. The horizontal motion refers to the ocean currents and waves. The vertical motion refers to tides. Ocean currents are the continuous flow of huge amount of water in a definite direction while the waves are the horizontal motion of water. Water moves ahead from one place to another through ocean currents while the water in the waves does not move, but the wave trains move ahead. The vertical motion refers to the rise and fall of water in the oceans and seas. Due to attraction of the sun and the moon, the ocean water is raised up and falls down twice a day. The upwelling of cold water from subsurface and the sinking of surface water are also forms of vertical motion of ocean water.

Waves

Waves are actually the energy, not the water as such, which moves across the ocean surface. Water particles only travel in a small circle as a wave passes. Wind provides energy to the waves. Wind causes waves to travel in the ocean and the energy is released on shorelines. The motion of the surface water seldom affects the stagnant deep bottom water of the oceans. As a wave approaches the beach, it slows down. This is due to the friction occurring between the dynamic water and the sea floor. And, when the depth of water is less than half the wavelength of the wave, the wave breaks. The largest waves are found in the open oceans. Waves continue to grow larger as they move and absorb energy from the wind.

Most of the waves are caused by the wind driving against water. When a breeze of two knots or less blows over calm water, small ripples form and grow as the wind speed increases until white caps appear in the breaking waves. Waves may travel thousands of km before rolling ashore, breaking and dissolving as surf.

A wave's size and shape reveal its origin. Steep waves are fairly young ones and are probably formed by local wind. Slow and steady waves originate from far away places, possibly from another hemisphere. The maximum wave height is determined by the strength of the wind, i.e. how long it blows and the area over which it blows in a single direction.

Waves travel because wind pushes the water body in its course while gravity pulls the crests of the waves downward. The falling water pushes the former troughs upward, and the

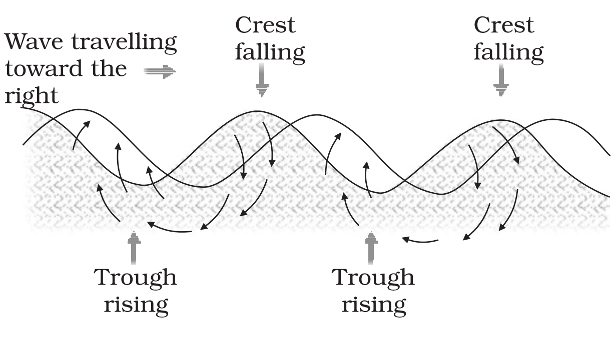

Figure13.1 : Motion of waves and water molecules

wave moves to a new position (Figure 13.1). The actual motion of the water beneath the waves is circular. It indicates that things are carried up and forward as the wave approaches, and down and back as it passes.

> **Characteristics of Waves**
>
> *Wave crest and trough* : The highest and lowest points of a wave are called the crest and trough respectively.
>
> *Wave height* : It is the vertical distance from the bottom of a trough to the top of a crest of a wave.
>
> *Wave amplitude :* It is one-half of the wave height.
>
> *Wave period* : It is merely the time interval between two successive wave crests or troughs as they pass a fixed point.
>
> *Wavelength* : It is the horizontal distance between two successive crests.
>
> *Wave speed* : It is the rate at which the wave moves through the water, and is measured in knots.
>
> *Wave frequency* : It is the number of waves passing a given point during a one-second time interval.

TIDES

The periodical rise and fall of the sea level, once or twice a day, mainly due to the attraction of the sun and the moon, is called a *tide*. Movement of water caused by meteorological effects (winds and atmospheric pressure changes) are called *surges*. Surges are not regular like tides. The study of tides is very complex, spatially and temporally, as it has great variations in frequency, magnitude and height.

The moon's gravitational pull to a great extent and to a lesser extent the sun's gravitational pull, are the major causes for the occurrence of tides. Another factor is centrifugal force, which is the force that acts to counter balance the gravity. Together, the gravitational pull and the centrifugal force are responsible for creating the two major tidal bulges on the earth. On the side of the earth facing the moon, a tidal bulge occurs while on the opposite side though the gravitational attraction of the moon is less as it is farther away, the centrifugal force causes tidal bulge on the other side (Figure 13.2).

The 'tide-generating' force is the difference between these two forces; i.e. the gravitational attraction of the moon and the centrifugal force. On the surface of the earth, nearest the moon, pull or the attractive force of the moon is greater than the centrifugal force, and so there is a net force causing a bulge towards the moon. On the opposite side of the earth, the attractive force is less, as it is farther away from the moon, the centrifugal force is dominant. Hence, there is a net force away from the moon. It creates the second bulge away from the moon. On the surface of the earth, the horizontal tide generating forces are more important than the vertical forces in generating the tidal bulges.

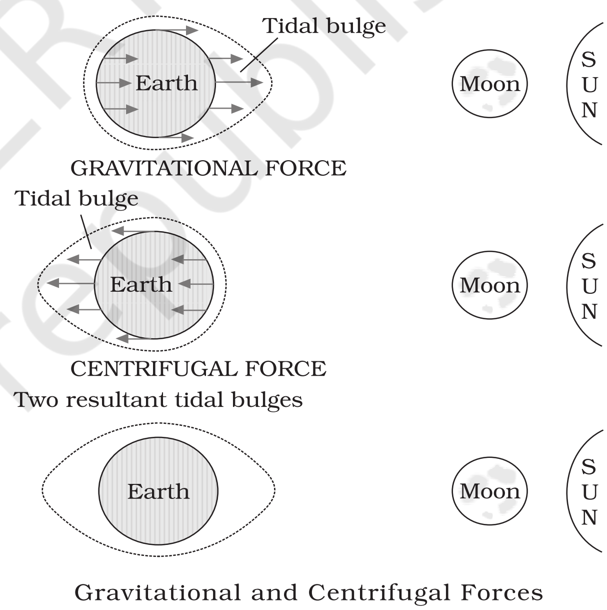

Figure13.2 : Relation between gravitational forces and tides

The tidal bulges on wide continental shelves, have greater height. When tidal bulges hit the mid-oceanic islands they become low. The shape of bays and estuaries along a coastline can also magnify the intensity of tides. Funnel-shaped bays greatly change tidal magnitudes. When the tide is channelled between islands or into bays and estuaries they are called *tidal currents*.

Tides of Bay of Fundy, Canada

The highest tides in the world occur in the Bay of Fundy in Nova Scotia, Canada. The tidal bulge is 15 - 16 m. Because there are two high tides and two low tides every day (roughly a 24 hour period); then a tide must come in within about a six hour period. As a rough estimate, the tide rises about 240 cm an hour (1,440 cm divided by 6 hours). If you have walked down a beach with a steep cliff alongside (which is common there), make sure you watch the tides. If you walk for about an hour and then notice that the tide is coming in, the water will be over your head before you get back to where you started!

Types of Tides

Tides vary in their frequency, direction and movement from place to place and also from time to time. Tides may be grouped into various types based on their frequency of occurrence in one day or 24 hours or based on their height.

Tides based on Frequency

Semi-diurnal tide : The most common tidal pattern, featuring two high tides and two low tides each day. The successive high or low tides are approximately of the same height.

Diurnal tide : There is only one high tide and one low tide during each day. The successive high and low tides are approximately of the same height.

Mixed tide : Tides having variations in height are known as mixed tides. These tides generally occur along the west coast of North America and on many islands of the Pacific Ocean.

Tides based on the Sun, Moon and the Earth Positions

The height of rising water (high tide) varies appreciably depending upon the position of sun and moon with respect to the earth. Spring tides and neap tides come under this category.

Spring tides : The position of both the sun and the moon in relation to the earth has direct bearing on tide height. When the sun, the moon and the earth are in a straight line, the height of the tide will be higher. These are called spring tides and they occur twice a month, one on full moon period and another during new moon period.

Neap tides : Normally, there is a seven day interval between the spring tides and neap tides. At this time the sun and moon are at right angles to each other and the forces of the sun and moon tend to counteract one another. The Moon's attraction, though more than twice as strong as the sun's, is diminished by the counteracting force of the sun's gravitational pull.

Once in a month, when the moon's orbit is closest to the earth *(perigee)*, unusually high and low tides occur. During this time the tidal range is greater than normal. Two weeks later, when the moon is farthest from earth *(apogee)*, the moon's gravitational force is limited and the tidal ranges are less than their average heights.

When the earth is closest to the sun *(perihelion)*, around 3rd January each year, tidal ranges are also much greater, with unusually high and unusually low tides. When the earth is farthest from the sun *(aphelion)*, around 4th July each year, tidal ranges are much less than average.

The time between the high tide and low tide, when the water level is falling, is called the *ebb*. The time between the low tide and high tide, when the tide is rising, is called the *flow* or *flood*.

Importance of Tides

Since tides are caused by the earth-moon-sun positions which are known accurately, the tides can be predicted well in advance. This helps the navigators and fishermen plan their activities. Tidal flows are of great importance in navigation. Tidal heights are very important, especially harbours near rivers and within estuaries having shallow 'bars' at the entrance, which prevent ships and boats from entering into the harbour. Tides are also helpful in desilting the sediments and in removing polluted water from river estuaries. Tides are used to generate electrical power (in Canada, France, Russia, and China). A 3 MW tidal power project at Durgaduani in Sunderbans of West Bengal is under way.

OCEAN CURRENTS

Ocean currents are like river flow in oceans. They represent a regular volume of water in a definite path and direction. Ocean currents are influenced by two types of forces namely : (i) primary forces that initiate the movement of water; (ii) secondary forces that influence the currents to flow.

The primary forces that influence the currents are: (i) heating by solar energy; (ii) wind; (iii) gravity; (iv) coriolis force. Heating by solar energy causes the water to expand. That is why, near the equator the ocean water is about 8 cm higher in level than in the middle latitudes. This causes a very slight gradient and water tends to flow down the slope. Wind blowing on the surface of the ocean pushes the water to move. Friction between the wind and the water surface affects the movement of the water body in its course. Gravity tends to pull the water down the pile and create gradient variation. The Coriolis force intervenes and causes the water to move to the right in the northern hemisphere and to the left in the southern hemisphere. These large accumulations of water and the flow around them are called *Gyres*. These produce large circular currents in all the ocean basins.

Characteristics of Ocean Currents

Currents are referred to by their "drift". Usually, the currents are strongest near the surface and may attain speeds over five knots. At depths, currents are generally slow with speeds less than 0.5 knots. We refer to the speed of a current as its "drift." Drift is measured in terms of knots. The strength of a current refers to the speed of the current. A fast current is considered strong. A current is usually strongest at the surface and decreases in strength (speed) with depth. Most currents have speeds less than or equal to 5 knots.

Differences in water density affect vertical mobility of ocean currents. Water with high salinity is denser than water with low salinity and in the same way cold water is denser than warm water. Denser water tends to sink, while relatively lighter water tends to rise. Cold-water ocean currents occur when the cold water at the poles sinks and slowly moves towards the equator. Warm-water currents travel out from the equator along the surface, flowing towards the poles to replace the sinking cold water.

Types of Ocean Currents

The ocean currents may be classified based on their depth as surface currents and deep water currents : (i) *surface currents* constitute about 10 per cent of all the water in the ocean, these waters are the upper 400 m of the ocean; (ii) *deep water currents* make up the other 90 per cent of the ocean water. These waters move around the ocean basins due to variations in the density and gravity. Deep waters sink into the deep ocean basins at high latitudes, where the temperatures are cold enough to cause the density to increase.

Ocean currents can also be classified based on temperature : as cold currents and warm currents: (i) *cold currents* bring cold water into warm water areas. These currents are usually found on the west coast of the continents in the low and middle latitudes (true in both hemispheres) and on the east coast in the higher latitudes in the Northern Hemisphere; (ii) *warm currents* bring warm water into cold water areas and are usually observed on the east coast of continents in the low and middle latitudes (true in both hemispheres). In the northern hemisphere they are found on the west coasts of continents in high latitudes.

Major Ocean Currents

Major ocean currents are greatly influenced by the stresses exerted by the prevailing winds and coriolis force. The oceanic circulation pattern roughly corresponds to the earth's atmospheric circulation pattern. The air circulation over the oceans in the middle latitudes is mainly anticyclonic (more pronounced in the southern hemisphere than in the northern hemisphere). The oceanic circulation pattern also corresponds with the same. At higher latitudes,

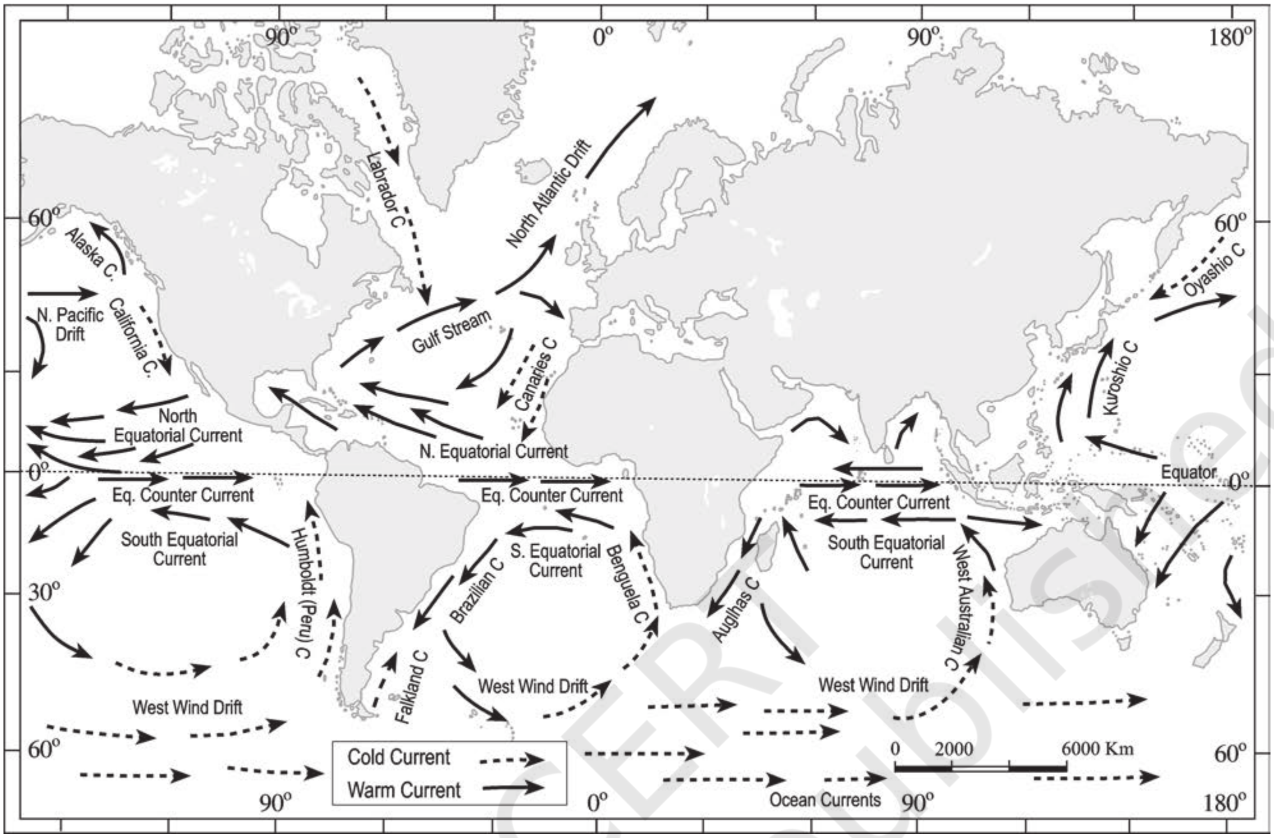

Fig.13.3 : Major currents in the Pacific, Atlantic and Indian oceans

where the wind flow is mostly cyclonic, the oceanic circulation follows this pattern. In regions of pronounced monsoonal flow, the monsoon winds influence the current movements. Due to the coriolis force, the warm currents from low latitudes tend to move to the right in the northern hemisphere and to their left in the southern hemisphere.

The oceanic circulation transports heat from one latitude belt to another in a manner similar to the heat transported by the general circulation of the atmosphere. The cold waters of the Arctic and Antarctic circles move towards warmer water in tropical and equatorial regions, while the warm waters of the lower latitudes move polewards. The major currents in the different oceans are shown in Figure13.3.

> Prepare a list of currents which are found in Pacific, Atlantic and Indian Oceans.
>
> How is the movement of currents influenced by prevailing winds? Give some examples from Figure13.3.

Effects of Ocean Currents

Ocean currents have a number of direct and indirect influences on human activities. West coasts of the continents in tropical and subtropical latitudes (except close to the equator) are bordered by cool waters. Their average temperatures are relatively low with a narrow diurnal and annual ranges. There is fog, but generally the areas are arid. West coasts of the continents in the middle and higher latitudes are bordered by warm waters which cause a distinct marine climate. They are characterised by cool summers and relatively mild winters with a narrow annual range of temperatures. Warm currents flow parallel to the east coasts of the continents in tropical and subtropical latitudes. This results in warm and rainy climates. These areas lie in the western margins of the subtropical anti-cyclones. The mixing of warm and cold currents help to replenish the oxygen and favour the growth of planktons, the primary food for fish population. The best fishing grounds of the world exist mainly in these mixing zones.

EXERCISES

1. Multiple choice questions.
   (i) Upward and downward movement of ocean water is known as the :
   (a) tide (c) wave
   (b) current (d) none of the above
   (ii) Spring tides are caused :
   (a) As result of the moon and the sun pulling the earth gravitationally in the same direction.
   (b) As result of the moon and the sun pulling the earth gravitationally in the opposite direction.
   (c) Indention in the coast line.
   (d) None of the above.
   (iii) The distance between the earth and the moon is minimum when the moon is in :
   (a) Aphelion (c) Perihelion
   (b) Perigee (d) Apogee
   (iv) The earth reaches its perihelion in:
   (a) October (c) July
   (b) September (d) January
2. Answer the following questions in about 30 words.
   (i) What are waves?
   (ii) Where do waves in the ocean get their energy from?
   (iii) What are tides?
   (iv) How are tides caused?
   (v) How are tides related to navigation?
3. Answer the following questions in about 150 words.
   (i) How do currents affect the temperature? How does it affect the temperature of coastal areas in the N. W. Europe?
   (ii) What are the causes of currents?

Project Work

(i) Visit a lake or a pond and observe the movement of waves. Throw a stone and notice how waves are generated.
(ii) Take a globe and a map showing the currents of the oceans. Discuss why certain currents are warm or cold and why they deflect in certain places and examine the reasons.

UNIT VI

LIFE ON THE EARTH

This unit deals with

- *Biosphere — biodiversity and conservation*

11092CH16

CHAPTER

14

BIODIVERSITY AND CONSERVATION

You have already learnt about the geomorphic processes particularly weathering and depth of weathering mantle in different climatic zones. See the Figure 5.2 in Chapter 5 in order to recapitulate. You should know that this weathering mantle is the basis for the diversity of vegetation and hence, the biodiversity. The basic cause for such weathering variations and resultant biodiversity is the input of solar energy and water. No wonder that the areas that are rich in these inputs are the areas of wide spectrum of biodiversity.

> Biodiversity as we have today is the result of 2.5-3.5 billion years of evolution. Before the advent of humans, our earth supported more biodiversity than in any other period. Since, the emergence of humans, however, biodiversity has begun a rapid decline, with one species after another bearing the brunt of extinction due to overuse. The number of species globally vary from 2 million to 100 million, with 10 million being the best estimate. New species are regularly discovered most of which are yet to be classified (an estimate states that about 40 per cent of fresh water fishes from South America are not classified yet). Tropical forests are very rich in bio-diversity.

Biodiversity is a system in constant evolution, from a view point of species, as well as from view point of an individual organism. The average half-life of a species is estimated at between one and four million years, and 99 per cent of the species that have ever lived on the earth are today extinct. Biodiversity is not found evenly on the earth. It is consistently richer in the tropics. As one approaches the polar regions, one finds larger and larger populations of fewer and fewer species.

Biodiversity itself is a combination of two words, *Bio* (life) and *diversity* (variety). In simple terms, biodiversity is the number and variety of organisms found within a specified geographic region. It refers to the varieties of plants, animals and micro-organisms, the genes they contain and the ecosystems they form. It relates to the variability among living organisms on the earth, including the variability within and between the species and that within and between the ecosystems. Biodiversity is our living wealth. It is a result of hundreds of millions of years of evolutionary history.

Biodiversity can be discussed at three levels : (i) Genetic diversity; (ii) Species diversity; (iii) Ecosystem diversity.

Genetic Diversity

Genes are the basic building blocks of various life forms. Genetic biodiversity refers to the variation of genes within species. Groups of individual organisms having certain similarities in their physical characteristics are called *species*. Human beings genetically belong to the *homo sapiens* group and also differ in their characteristics such as height, colour, physical appearance, etc., considerably. This is due to genetic diversity. This genetic diversity is essential for a healthy breeding of population of species.

Species Diversity

This refers to the variety of species. It relates to the number of species in a defined area. The diversity of species can be measured through its richness, abundance and types. Some areas are more rich in species than others. Areas rich in species diversity are called *hotspots* of diversity (Figure 14.5).

Ecosystem Diversity

You have studied about the ecosystem in the earlier chapter. The broad differences between ecosystem types and the diversity of habitats and ecological processes occurring within each ecosystem type constitute the ecosystem diversity. The 'boundaries' of communities (associations of species) and ecosystems are not very rigidly defined. Thus, the demarcation of ecosystem boundaries is difficult and complex.

Figure 14.1 : Grasslands and sholas in Indira Gandhi National Park, Annamalai, Western Ghats — an example of ecosystem diversity

Importance of Biodiversity

Biodiversity has contributed in many ways to the development of human culture and, in turn, human communities have played a major role in shaping the diversity of nature at the genetic, species and ecological levels. Biodiversity plays the following roles: ecological, economic and scientific.

Ecological Role of Biodiversity

Species of many kinds perform some function or the other in an ecosystem. Nothing in an ecosystem evolves and sustains without any reason. That means, every organism, besides extracting its needs, also contributes something of useful to other organisms. Can you think of the way we, humans contribute to the sustenance of ecosystems. Species capture and store energy, produce and decompose organic materials, help to cycle water and nutrients throughout the ecosystem, fix atmospheric gases and help regulate the climate. These functions are important for ecosystem function and human survival. The more diverse an ecosystem, better are the chances for the species to survive through adversities and attacks, and consequently, is more productive. Hence, the loss of species would decrease the ability of the system to maintain itself. Just like a species with a high genetic diversity, an ecosystem with high biodiversity may have a greater chance of adapting to environmental change. In other words, the more the variety of species in an ecosystem, the more stable the ecosystem is likely to be.

Economic Role of Biodiversity

For all humans, biodiversity is an important resource in their day-to-day life. One important part of biodiversity is 'crop diversity', which is also called agro-biodiversity. Biodiversity is seen as a reservoir of resources to be drawn upon for the manufacture of food, pharmaceutical, and cosmetic products. This concept of biological resources is responsible for the deterioration of biodiversity. At the same time, it is also the origin of new conflicts dealing with rules of division and appropriation of natural resources. Some of the important economic commodities that biodiversity supplies to humankind are: food crops, livestock, forests, fish, medicinal resources, etc.

Scientific Role of Biodiversity

Biodiversity is important because each species can give us some clue as to how life evolved and will continue to evolve. Biodiversity also helps in understanding how life functions and the role of each species in sustaining ecosystems of which we are also a species. This fact must be drawn upon every one of us so that we live and let other species also live their lives.

It is our ethical responsibility to consider that each and every species along with us have an intrinsic right to exist. Hence, it is morally wrong to voluntarily cause the extinction of any species. The level of biodiversity is a good indicator of the state of our relationships with other living species. In fact, the concept of biodiversity is an integral part of many human cultures.

Loss of Biodiversity

Since the last few decades, growth in human population has increased the rate of consumption of natural resources. It has accelerated the loss of species and habitation in different parts of the world. Tropical regions which occupy only about one-fourth of the total area of the world, contain about three-fourth of the world human population. Over-exploitation of resources and deforestation have become rampant to fulfil the needs of large population. As these tropical rain forests contain 50 per cent of the species on the earth, destruction of natural habitats have proved disastrous for the entire biosphere.

Natural calamities such as earthquakes, floods, volcanic eruptions, forest fires, droughts, etc. cause damage to the flora and fauna of the earth, bringing change the biodiversity of respective affected regions. Pesticides and other pollutants such as hydrocarbons and toxic heavy metals destroy the weak and sensitive species. Species which are not the natural inhabitants of the local habitat but are introduced into the system, are called *exotic species*. There are many examples when a natural biotic community of the ecosystem suffered extensive damage because of the introduction of exotic species. During the last few decades, some animals like tigers, elephants, rhinoceros, crocodiles, minks and birds were hunted mercilessly by poachers for their horn, tusks, hides, etc. It has resulted in the rendering of certain types of organisms as endangered category.

The International Union of Conservation of Nature and Natural Resources (IUCN) has classified the threatened species of plants and animals into three categories for the purpose of their conservation.

Endangered Species

It includes those species which are in danger of extinction. The IUCN publishes information about endangered species world-wide as the *Red List* of threatened species.

Figure 14.2 : Red Panda — an endangered species

Vulnerable Species

This includes the species which are likely to be in danger of extinction in near future if the factors threatening to their extinction continue. Survival of these species is not assured as their population has reduced greatly.

Rare Species

Population of these species is very small in the world; they are confined to limited areas or thinly scattered over a wider area.

Conservation of Biodiversity

Biodiversity is important for human existence. All forms of life are so closely interlinked that disturbance in one gives rise to imbalance in the others. If species of plants and animals become endangered, they cause degradation in the environment, which may threaten human being's own existence.

Figure 14.3 : Humbodtia decurrens Bedd — highly rare endemic tree of Southern Western Ghats (India)

There is an urgent need to educate people to adopt environment-friendly practices and reorient their activities in such a way that our development is harmonious with other life forms and is sustainable. There is an increasing consciousness of the fact that such conservation with sustainable use is possible only with the involvement and cooperation of local communities and individuals. For this, the development of institutional structures at local levels is necessary. The critical problem is not merely the conservation of species nor the habitat but the continuation of process of conservation.

The Government of India along with 155 other nations have signed the Convention of Biodiversity at the Earth Summit held at Rio de Janeiro, Brazil in June 1992. The world conservation strategy has suggested the following steps for biodiversity conservation:

(i) Efforts should be made to preserve the species that are endangered.
(ii) Prevention of extinction requires proper planning and management.
(iii) Varieties of food crops, forage plants, timber trees, livestock, animals and their wild relatives should be preserved;
(iv) Each country should identify habitats of wild relatives and ensure their protection.
(v) Habitats where species feed, breed, rest and nurse their young should be safeguarded and protected.
(vi) International trade in wild plants and animals be regulated.

To protect, preserve and propagate the variety of species within natural boundaries, the Government of India passed the *Wild Life (Protection) Act, 1972*, under which national parks and sanctuaries were established and biosphere reserves declared. Details of these biosphere reserves are given in the book *India: Physical Environment* (NCERT, 2006).

There are some countries which are situated in the tropical region; they possess a large number of the world's species diversity. They are called *mega diversity centres*. There are 12 such countries, namely Mexico, Columbia, Ecuador, Peru, Brazil, Democratic Republic of Congo, Madagascar, China, India, Malaysia, Indonesia and Australia in which these centres are located. In order to concentrate resources on those areas that are most vulnerable, the International Union for the Conservation of Nature and Natural Resources (IUCN) has identified certain areas as biodiversity hotspots (Figure 14.1). Hotspots are defined according to their vegetation. Plants are important because these determine the primary productivity of an ecosystem. Most, but not all, of the hotspots rely on species-rich ecosystems for food, firewood, cropland, and income from timber. In Madagascar, for example, about 85 per cent of the plants and animals are found nowhere else in the world, Other hotspots in wealthy countries are facing different types of pressures. The islands of Hawaii have many unique plants and animals that are threatened by introduced species and land development.

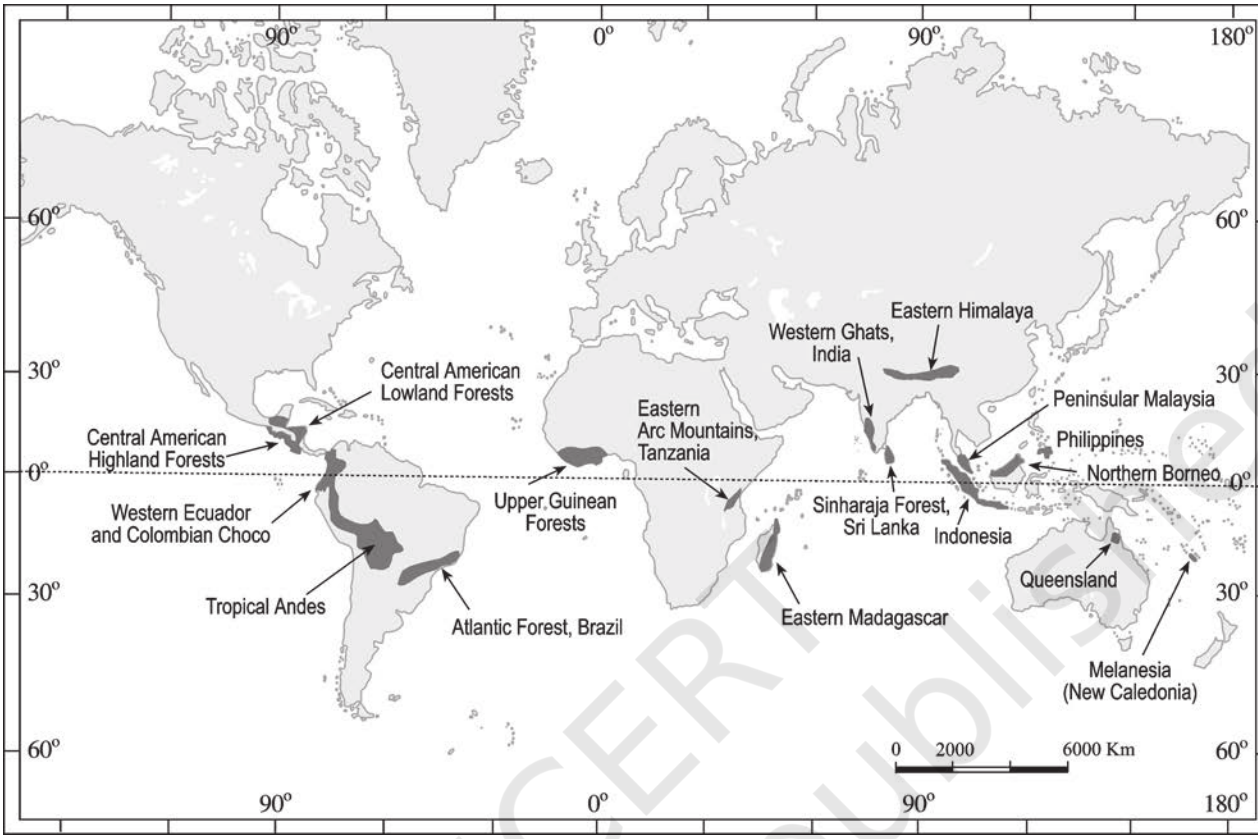

Figure 14.4 : Some ecological 'hotspots' in the world

EXERCISES

1. Multiple choice questions.

   (i) Conservation of biodiversity is important for :

   (a) Animals (c) Plants

   (b) Animals and plants (d) All organisms

   (ii) Threatened species are those which :

   (a) threaten others

   (b) Lion and tiger

   (c) are abundant in number

   (d) are suffering from the danger of extinction

   (iii) National parks and sanctuaries are established for the purpose of :

   (a) Recreation (c) Pets

   (b) Hunting (d) Conservation

(iv) Biodiversity is richer in :

(a) Tropical Regions (c) Temperate Regions

(b) Polar Regions (d) Oceans

(v) In which one of the following countries, the 'Earth Summit' was held?

(a) the UK (c) Brazil

(b) Mexico (d) China

2. Answer the following questions in about 30 words.

(i) What is biodiversity?

(ii) What are the different levels of biodiversity?

(iii) What do you understand by 'hotspots'?

(iv) Discuss briefly the importance of animals to human kind.

(v) What do you understand by 'exotic species'?

3. Answer the following questions in about 150 words.

(i) What are the roles played by biodiversity in the shaping of nature?

(ii) What are the major factors that are responsible for the loss of biodiversity? What steps are needed to prevent them?

Project Work

Collect the names of national parks, sanctuaries and biosphere reserves of the state where your school is located and show their location on the map of India.

PRACTICAL WORK IN GEOGRAPHY

PART I

TEXTBOOK FOR CLASS XI

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्
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NCERT Campus
Sri Aurobindo Marg
New Delhi 110 016 **Phone : 011-26562708**

108, 100 Feet Road
Hosdakere Halli Extension
Banashankari III Stage
Bengaluru 560 085 **Phone : 080-26725740**

Navjivan Trust Building
P.O.Navjivan
Ahmedabad 380 014 **Phone : 079-27541446**

CWC Campus
Opp. Dhankal Bus Stop
Panihati
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Assistant Editor	:	*R.N. Bhardwaj*
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FOREWORD

The National Curriculum Framework (NCF), 2005, recommends that children's life at school must be linked to their life outside the school. This principle marks a departure from the legacy of bookish learning which continues to shape our system and causes a gap between the school, home and community. The syllabi and textbooks developed on the basis of NCF signify an attempt to implement this basic idea. They also attempt to discourage rote learning and the maintenance of sharp boundaries between different subject areas. We hope these measures will take us significantly further in the direction of a child-centred system of education outlined in the National Policy on Education (1986).

The success of this effort depends on the steps that school principals and teachers will take to encourage children to reflect on their own learning and to pursue imaginative activities and questions. We must recognise that, given space, time and freedom, children generate new knowledge by engaging with the information passed on to them by adults. Treating the prescribed textbook as the sole basis of examination is one of the key reasons why other resources and sites of learning are ignored. Inculcating creativity and initiative is possible if we perceive and treat children as participants in learning, not as receivers of a fixed body of knowledge.

These aims imply considerable change in school routines and mode of functioning. Flexibility in the daily time-table is as necessary as rigour in implementing the annual calendar so that the required number of teaching days are actually devoted to teaching. The methods used for teaching and evaluation will also determine how effective this textbook proves for making children's life at school a happy experience, rather than a source of stress or boredom. Syllabus designers have tried to address the problem of curricular burden by restructuring and reorienting knowledge at different stages with greater consideration for child psychology and the time available for teaching. The textbook attempts to enhance this endeavour by giving higher priority and space to opportunities for contemplation and wondering, discussion in small groups, and activities requiring hands-on experience.

The National Council of Educational Research and Training (NCERT) appreciates the hard work done by the textbook development committee responsible for this book. We wish to thank the Chairperson of the advisory committee for textbooks in Social Sciences, at the higher secondary level, Professor Hari Vasudevan and the Chief Advisor for this book, Professor M.H. Qureshi for guiding the work of this committee. Several teachers contributed to the development of this textbook; we are grateful to their principals for making this possible. We are indebted to the institutions and organisations which have generously permitted us to draw upon their resources, material and personnel. We are especially grateful to the members of the National Monitoring Committee, appointed by the Department of Secondary and Higher Education, Ministry of Human Resource Development under the Chairpersonship of Professor Mrinal Miri and Professor G.P. Deshpande, for their valuable time and contribution. As an organisation committed to systemic reform and continuous improvement in the quality of its products, NCERT welcomes comments and suggestions which will enable us to undertake further revision and refinement.

Director
National Council of Educational
Research and Training

New Delhi
20 December 2005

RATIONALISATION OF CONTENT IN THE TEXTBOOKS

In view of the COVID-19 pandemic, it is imperative to reduce content load on students. The National Education Policy 2020, also emphasises reducing the content load and providing opportunities for experiential learning with creative mindset. In this background, NCERT has undertaken the exercise to rationalise the textbooks across all classes. Learning Outcomes already developed by the NCERT across classes have been taken into consideration in this exercise.

Contents of the textbooks have been rationalised in view of the following:

- Overlapping with similar content included in other subject areas in the same class
- Similar content included in the lower or higher class in same subject
- Difficulty level
- Content, which is easily accessible to students without much interventions from teachers and can be learned through children through self-learning or peer-learning
- Content, which is irrelevant in the present context

This present edition, is a reformatted version after carrying out the changes given above.

TEXTBOOK DEVELOPMENT COMMITTEE

Chairperson, Advisory Committee for Social Science Textbooks at Higher Secondary Level

Hari Vasudevan, *Professor,* Department of History, University of Calcutta, Kolkata

Chief Advisor

M. H. Qureshi*, Professor,* CSRD, Jawaharlal Nehru University, New Delhi

Members

Rupa Das, *PGT,* DPS, R.K. Puram, New Delhi

S.M. Rashid, *Professor,* Department of Geography, Jamia Millia Islamia, New Delhi

Sucharita Sen, *Asstt. Professor*, CSRD, Jawaharlal Nehru University, New Delhi

Y. Sreekanth, *Lecturer*, DEME, NCERT, New Delhi

Member-coordinator

Tannu Malik, *Lecturer,* DESSH, NCERT, New Delhi

The following are applicable to all the maps of India used in this book

1. The responsibility for the correctness of internal details rests with the publisher.
2. The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
3. The administrative headquarters of Chandigarh, Haryana and Punjab are at Chandigarh.
4. The interstate boundaries amongst Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the "North-Eastern Areas (Reorganisation) Act.1971," but have yet to be verified.
5. The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.
6. The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhattisgarh & Madhya Pradesh have not been verified by the Governments concerned.
7. The spellings of names in this map, have been taken from various sources.

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The National Council of Educational Research and Training acknowledges the contribution of Milap Chand Sharma, *Reader,* CSRD, JNU; Muzammil Husain Quasmi, *Lecturer*, IASE, Jamia Millia Islamia; Aruna Gordan, *PGT,* St. Thomas School, New Delhi and C. Pargi, *PGT*, KV, Neemuch in the development of this textbook.

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The Council is thankful to the Survey of India for certification of maps given in the textbook. It also gratefully acknowledges the support of individuals and organisations as listed below for providing various photographs and other materials used in the textbook-

Milap Chand Sharma, CSRD, JNU for photographs of gentle slope, steep slope, concave slope, convex slope, conical hill, plateau, V-shaped valley, U-shaped valley, gorge, spur, cliff, waterfall and rapids in Chapter 5; Narendra Kumar Saini, *Cartographer,* JMI for box 1.1, Figures 1.1 and 6.1; Concept Publishing Company (Book : Fundamentals of Cartography by R.P. Misra and A. Ramesh), New Delhi for Figures 1.4, 1.5 and 1.6 and NCERT textbook (Remote Sensing by Meenakshi) for Figures 6.3 and 6.6; Survey of India for Figures 1.2, 1.3 and parts of toposheet on page nos. 66 and 68; National Atlas and Thematic Mapping Organisation for Figures 1.7, 1.8, 1.9, 1.10, 1.11, 1.12 and 1.13; Regional Remote Sensing Service Centre, Jodhpur for Figures 6.4; National Remote Sensing Agency, Hyderabad for Figures 6.9, 6.11, 6.13, 6.14, 6.15, 6.16, 6.17 and image on page no. 91 and Digital Globe Agency for Figure 6.10.

The Council also gratefully acknowledges the contributions of Anil Sharma, *DTP Operator*; Sameer Khatana and Amar Kumar Prusty, *Copy Editors;* Shrestha and Deepti Sharma, *Proof Readers;* Dinesh Kumar, *Computer Station Incharge* who have helped in giving a final shape of this textbook. The efforts of Publication Department, NCERT are also duly acknowledged.

The Council acknowledges the valuable input for analysing syllabi, textbooks and the content, proposed to be rationalised for this edition by Kulprit Singh, PGT, Geography, Chanakyapuri, New Delhi, Pushpendra Singh, PGT, Geography, Prudence School, Ashok Vihar, Aparna Pandey, Associate Professor, DESS, NCERT, Tanu Malik, Assistant Professor, DESS, NCERT.

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity and to promote among them all;

FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)

CONTENTS

Constitution of India

Part IV A (Article 51 A)

Fundamental Duties

It shall be the duty of every citizen of India —

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wildlife and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;

*(k) who is a parent or guardian, to provide opportunities for education to his child or, as the case may be, ward between the age of six and fourteen years.

Note: The Article 51A containing Fundamental Duties was inserted by the Constitution (42nd Amendment) Act, 1976 (with effect from 3 January 1977).

*(k) was inserted by the Constitution (86th Amendment) Act, 2002 (with effect from 1 April 2010).

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Chapter 1

Introduction to Maps

Figure 1.1 India as it is seen on the globe

You may be familiar with maps that you have seen in most of your books of social sciences representing the earth or any of its parts. You may also know that the shape of the earth is geoid (three-dimensional) and a globe can best represent it (Fig. 1.1). A map, on the other hand, is a simplified depiction of whole or part of the earth on a piece of paper. In other words, it is a two-dimensional form of the three-dimensional earth. Hence, a map can be drawn using a system of map projections (see Chapter 4). As it is impossible to represent all features of the earth's surface in their true size and form, a map is drawn at a reduced scale. Imagine your school campus. If a plan/map of your school is to be drawn in its actual size, it will be as large as the campus itself. Hence, maps are drawn at a scale and projection so that each point on the paper corresponds to the actual ground position. Besides, the representation of different features is also simplified using symbols, colours and shades. A map is, therefore, defined as selective, symbolised and generalised representation of whole or a

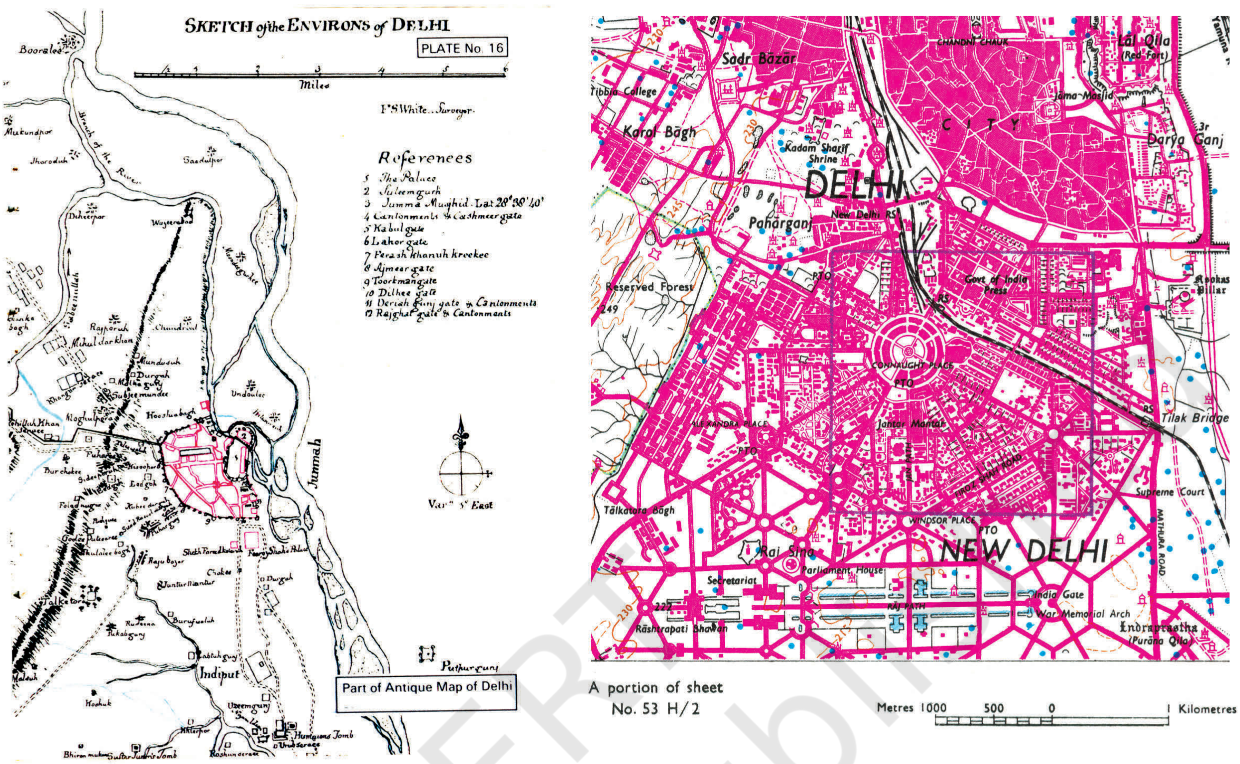


Figure 1.2 Sketch of the Environs of Delhi (Left) and a Map of Delhi (Right)

Glossary

Cadastral Map : A large-scale map drawn at a scale of 1 : 500 to 1 : 4000 to show property boundaries, designating each parcel of land with a number.
Cardinal Points : North (N), South (S), East (E) and West (W).
Cartography : Art, science and technology of making maps, charts, plans and other modes of graphical expression as well as their study and use.
Generalisation-Map : A simplified representation of the features on the map, appropriate to its scale or purpose, without affecting their visual form.
Geoid : An oblate spheroid whose shape resembles the actual shape of the Earth.
Map : A selective, symbolised and generalised representation of the whole or part of the earth at a reduced scale.
Map series : A group of maps produced at same scale, style and specifications for a country or a region.
Projection-Map : The system of the transformation of the spherical surface onto a plane surface.
Scale : The ratio between the distances of two points on the map, plan or photograph and the actual distance between the same two points on the ground.
Sketch Map : A simplified map drawn freehand which fails to preserve the true scale or orientation.

part of the earth's surface on a plane surface at a reduced scale. It may also be understood that a simple network of lines and polygons without a scale shall not be called a map. It is only referred to as “the sketch” (Fig. 1.2). In the present chapter, we will study the essential requirements of maps, their types and the uses.

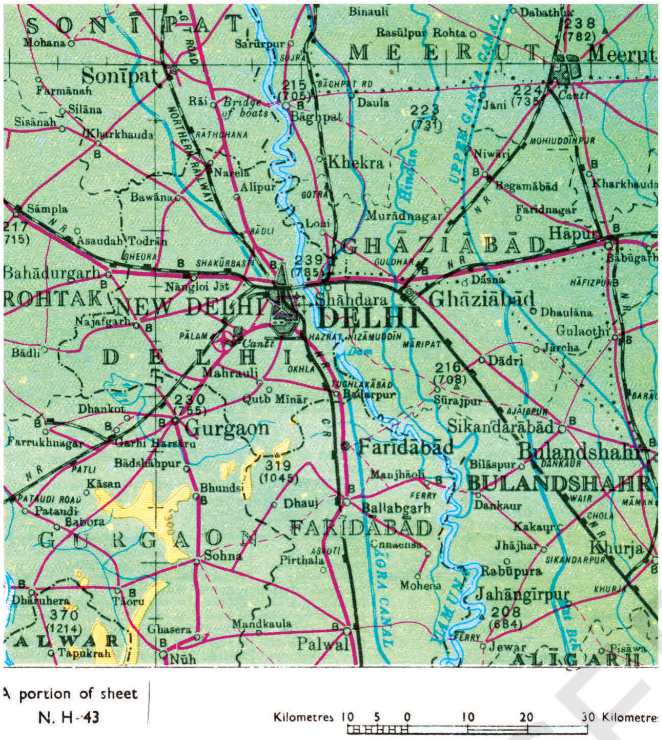
Essentials of Map Making

In view of the variety of maps, we may find it difficult to summarise what they all have in common. Cartography, being an art and science of map-making, does include a series of processes that are common to all the maps. These processes that may also be referred to as essentials of maps are :

- Scale
- Map Projection
- Map Generalisation
- Map Design
- Map Construction and Production

Scale: We know that all maps are reductions. The first decision that a map-maker has to take is about the scale of the map. The choice of scale is of utmost importance. The scale of a map sets limits of information contents and the degree of reality with which it can be delineated on the map. For example, figure 1.3 provides a comparison between maps having different scales and the improvements made thereupon with the change in scale.

Projection: We also know that maps are a simplified representation of the three-dimensional surface of the earth on a plane sheet of paper. The transformation of all-side-curved-geoidal surface into a plane surface is another important aspect of the cartographic process. We should know that such a radical transformation introduces some unavoidable changes in directions, distances, areas and shapes from the way they appear on a geoid. A system of transformation of the spherical surface to the plane surface is called a map projection. Hence, the choice, utilisation and construction of projections is of prime importance in map-making.



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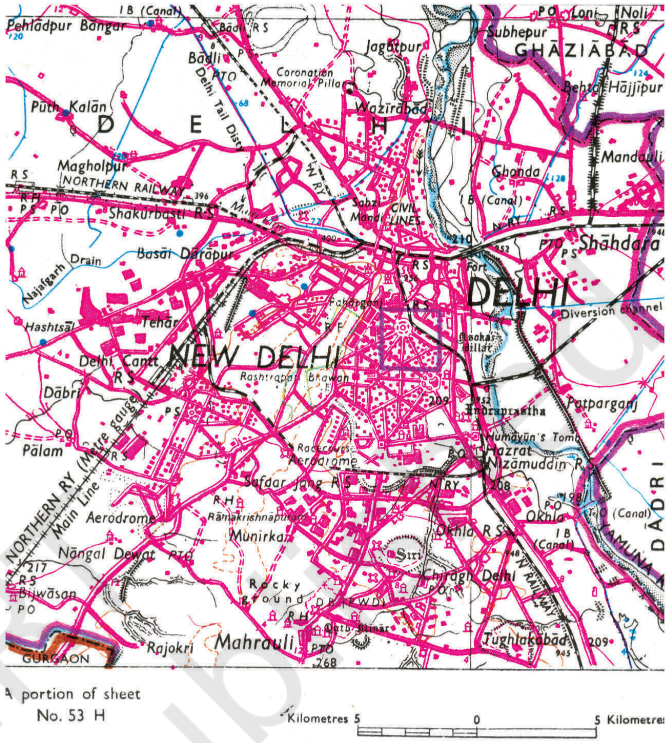

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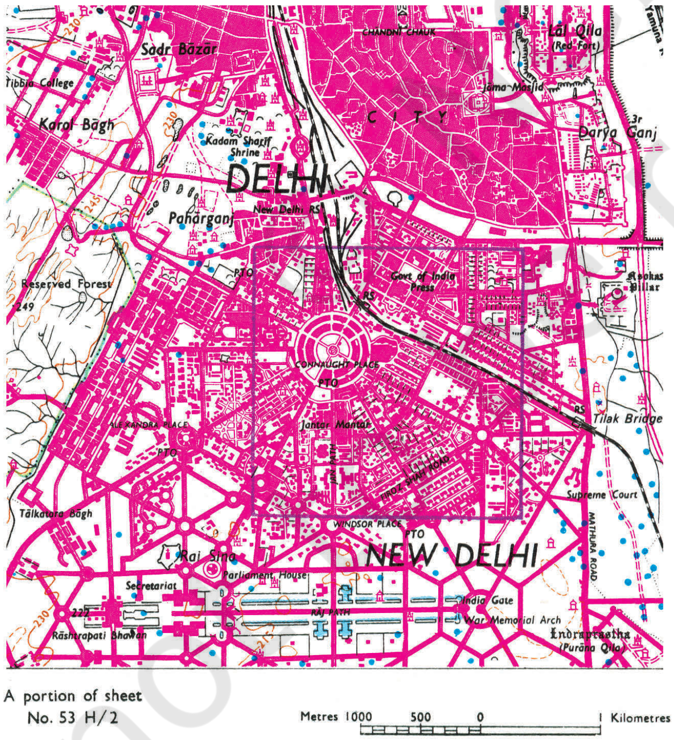

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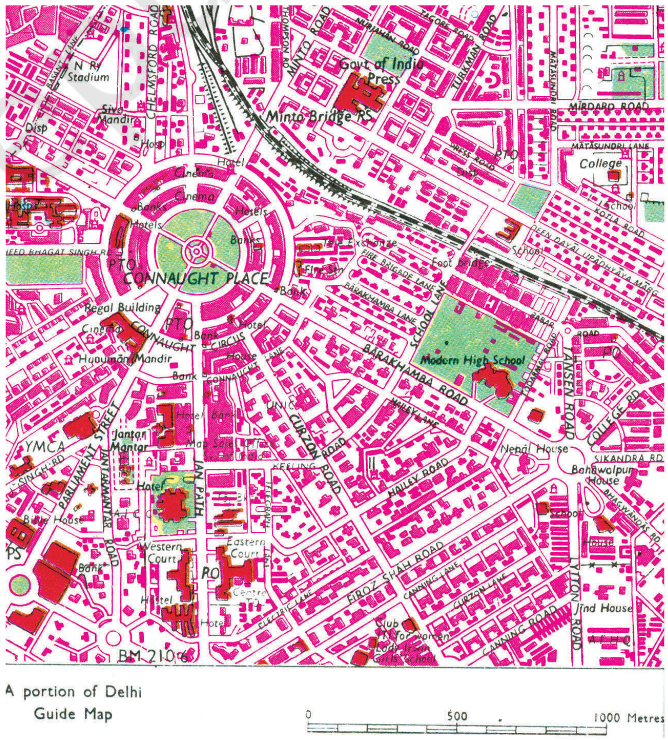

A Portion of Guide Map

Figure 1.3 Effect of Scale on Mapped Information

Generalisation: Every map is drawn with a definite objective. For example, a general purpose map is drawn to show information of a general nature such as relief, drainage, vegetation, settlements, means of transportation, etc. Similarly, a special purpose map exhibits information pertaining to one or more selected themes like population density, soil types or location of industries. It is, therefore, necessary to carefully plan the map contents while the purpose of the map must be kept in the forefront. As maps are drawn at a reduced scale to serve a definite purpose, the third task of a cartographer is to generalise the map contents. In doing so, a cartographer must select the information (data) relevant to the selected theme and simplify it as per the needs.

Map Design: The fourth important task of a cartographer is the map design. It involves the planning of graphic characteristics of maps including the selection of appropriate symbols, their size and form, style of lettering, specifying the width of lines, selection of colours and shades, arrangement of various elements of map design within a map and design for map legend. The map design is, therefore, a complex aspect of map-making and requires thorough understanding of the principles that govern the effectiveness of graphic communication.

Map Construction and Production: The drawing of maps and their reproduction is the fifth major task in the cartographic process. In earlier times, much of the map construction and reproduction work used to be carried out manually. Maps were drawn with pen and ink and printed mechanically. However, the map construction and reproduction has been revolutionalised with the addition of computer assisted mapping and photo-printing techniques in the recent past.

History of Map Making

The history of map making is as old as the history of mankind itself. The oldest map was found in Mesopotamia drawn on a clay tablet that belongs to 2,500 B.C. Figure 1.4 shows Ptolemy's Map of the World. Greek and the Arab geographers laid the foundation of modern cartography. The measurement of the circumference of the Earth and the use of the system of geographical coordinates in map-making are some of the significant contributions of the Greeks and the Arabs. The art and science of map

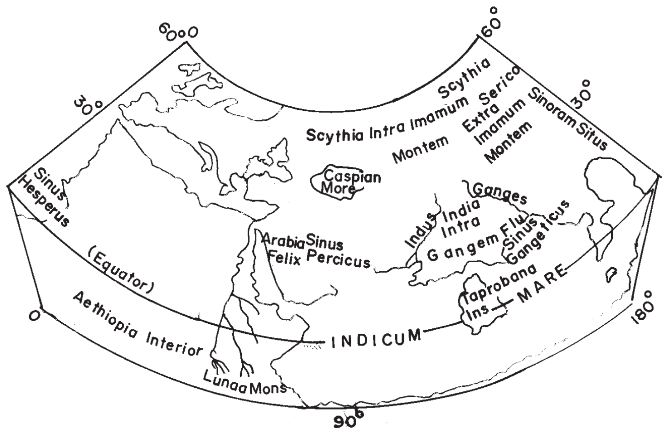

Figure 1.4 Ptolemy's Map of the World

making was revitalised in early modern period, with extensive efforts made to minimise the effects of the transformation of the geoid onto a plane surface. The maps were drawn on different projections to obtain true directions, correct distances and to measure area accurately. The aerial photography supplemented the ground method of survey and the uses of aerial photographs stimulated map-making in the nineteenth and twentieth centuries.

The foundation of map-making in India was laid during the Vedic period when the expressions of astronomical truths and cosmological revelations were made. The expressions were crystallised into 'sidhantas' or laws in classical treaties of Arya Bhatta, Varahamihira and Bhaskara, and others. Ancient Indian scholars divided the known world into seven 'dwipas' (Fig. 1.5). Mahabharata conceived a round world surrounded by water (Fig. 1.6).

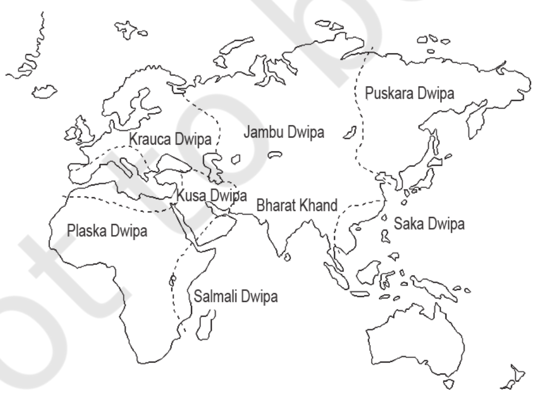

Figure 1.5 Seven Dwipas of the World as conceived in Ancient India

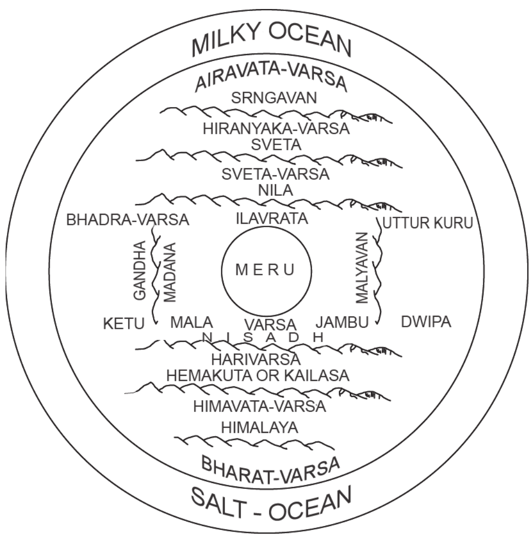

Figure 1.6 Round World surrounded by water as conceived in Mahabharata

Todarmal pioneered land surveying and map-making as an integral part of the revenue collection procedure. Besides, Sher Shah Suri's revenue maps further enriched the mapping techniques during the medieval period. The intensive topographical surveys for the preparation of up–to–date maps of the entire country, were taken up with the setting up of the Survey of India in 1767, which culminated with the map of Hindustan in 1785. Today, the Survey of India produces maps at different scales for the entire country.

Types of Maps Based on Scale: On the basis of scale, maps may be classified into large-scale and small-scale. Large scale maps are drawn to show small areas at a relatively large-scale. For example, the topographical maps drawn at a scale of 1: 250,000, 1:50,000 or 1:25,000 and the village maps, the zonal plans of the cities and house plans prepared on a scale of 1:4,000, 1:2,000 and 1:500 are large scale maps. On the other hand, small-scale maps are drawn to show large areas. For example, atlas maps, wall maps, etc.

(i) Large-scale Maps: Large-scale maps are further divided into the following types :

(a) Cadastral maps

(b) Topographical maps

(a) Cadastral Maps : The term 'cadastral' is derived from the French word 'cadastre' meaning 'register of territorial property'. These maps are drawn to show the ownership of landed property by demarcating field boundaries of agricultural land and the plan of individual houses in urban areas. The cadastral maps are prepared by the government agencies to realise revenue and taxes, along with keeping a record of ownership. These maps are drawn on a very large scale, such as the cadastral maps of villages at 1 : 4,000 scale and the city plans at a scale of 1 : 2,000 and larger.

(b) Topographical Maps : These maps are also prepared on a fairly large scale. The topographical maps are based on precise surveys and are prepared in the form of series of maps made by the national mapping agencies of almost all countries of the world (Chapter 5). For example, the Survey of India undertakes the topographical mapping of the entire country at 1 : 250,000, 1 : 50,000 and 1 : 25,000 scale (Fig. 1.3). These maps follow uniform colours and symbols to show topographic details such as relief, drainage, agricultural land, forest, settlements, means of

communication, location of schools, post offices and other services and facilities.

(ii) Small-scale Maps: Small-scale maps are further divided into the following types :

(a) Wall Maps

(b) Atlas Maps

(a) Wall Maps : These maps are generally drawn on large size paper or on plastic base for use in classrooms or lecture halls. The scale of wall maps is generally smaller than the scale of topographical maps but larger than atlas maps.

(b) Atlas Maps : Atlas maps are very small-scale maps. These maps represent fairly large areas and present highly generalised picture of the physical or cultural features. Even so, an atlas map serves as a graphic encyclopaedia of the geographical information about the world, continents, countries or regions. When consulted properly, these maps provide a wealth of generalised information regarding location, relief, drainage, climate, vegetation, distribution of cities and towns, population, location of industries, transport-network system, tourism and heritage sites, etc.

Types of Maps Based on Function: The maps may also be classified on the basis of their functions. For example, a political map serves the function of providing administrative divisions of a continent or a country and a soil map shows the distribution of different types of soils. Broadly, maps based on their functions may be classified into physical maps and cultural maps.

(i) Physical Maps: Physical maps show natural features such as relief, geology, soils, drainage, elements of weather, climate and vegetation, etc.

(a) Relief Maps: Relief maps show general topography of an area like mountains and valleys, plains, plateaus and drainage. Figure 1.7 shows the relief and slope map of Nagpur district.

(b) Geological Maps: These maps are drawn to show geological structures, rock types, etc. Figure 1.8 shows the distribution of rocks and minerals in Nagpur district.

(c) Climatic Maps : These maps depict climatic regions of an area. Besides, maps are also drawn to show the distribution of temperature,

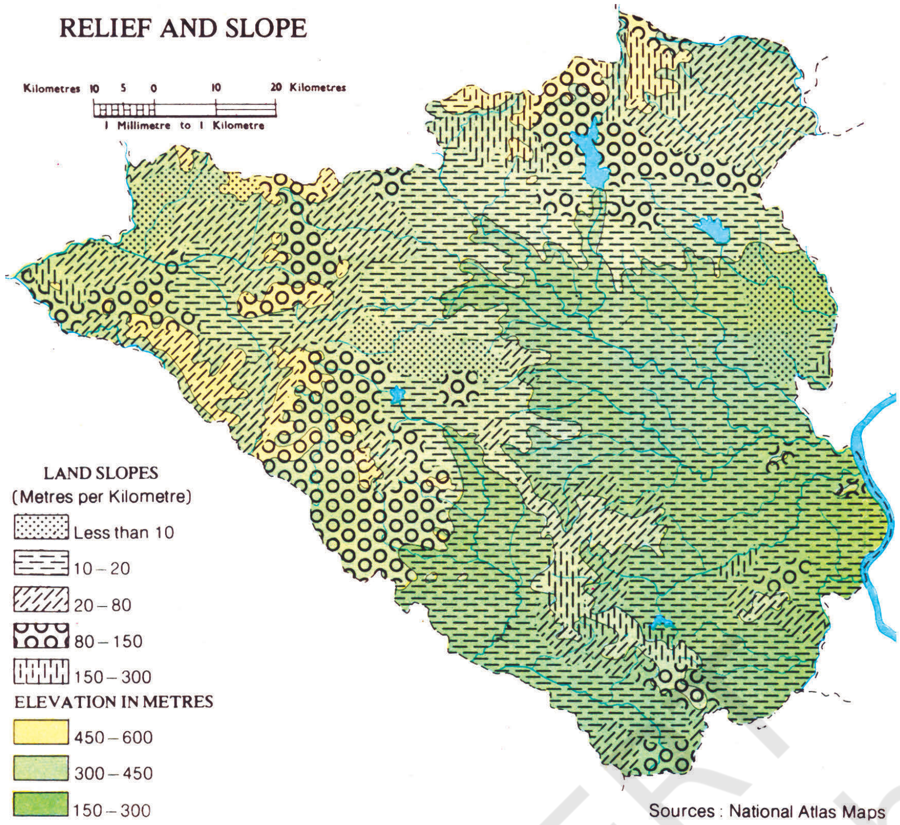

Figure 1.7 Relief and Slope Map of Nagpur District

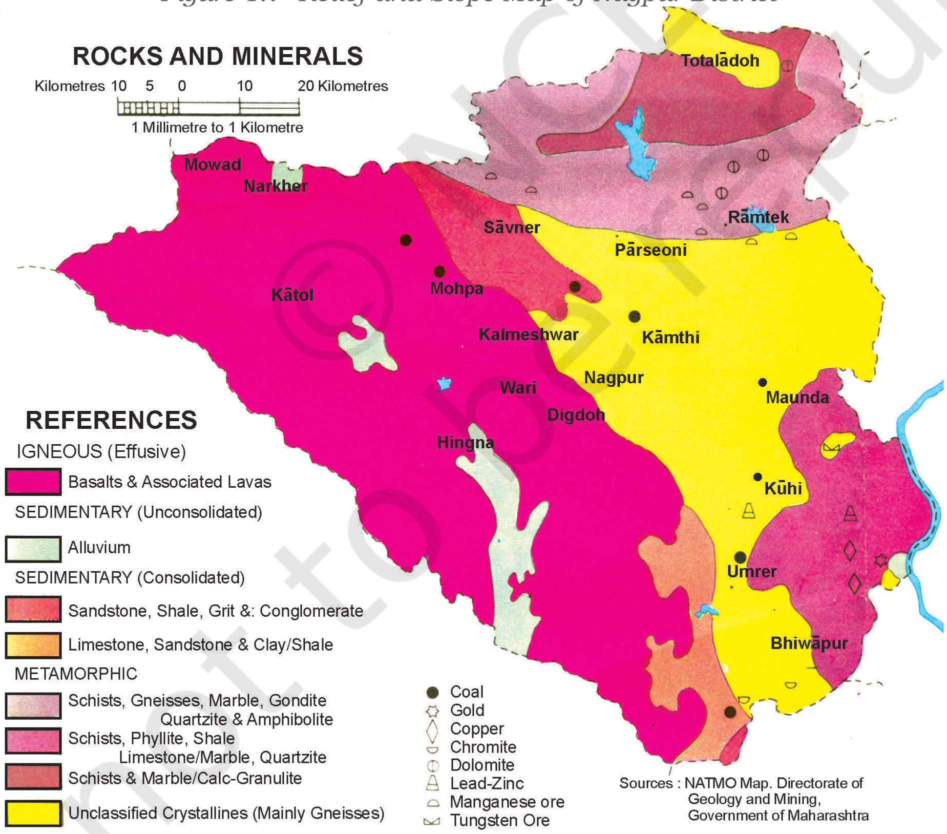

Figure 1.8 Distribution of Rocks and Minerals in Nagpur District

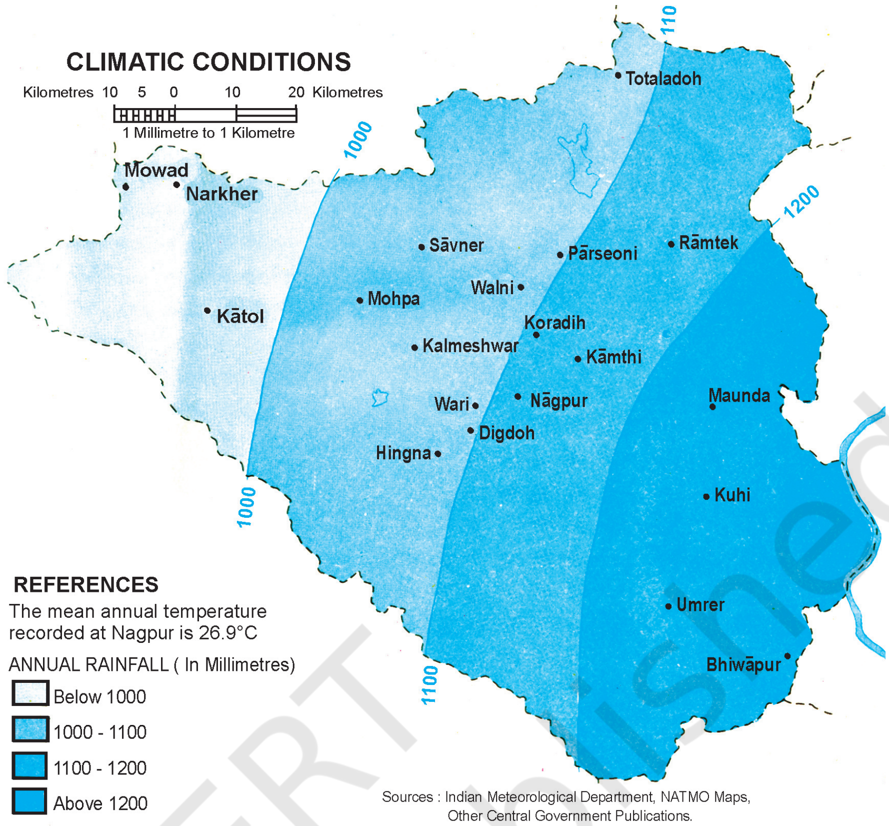

Figure 1.9 Map showing Climatic Conditions of Nagpur District

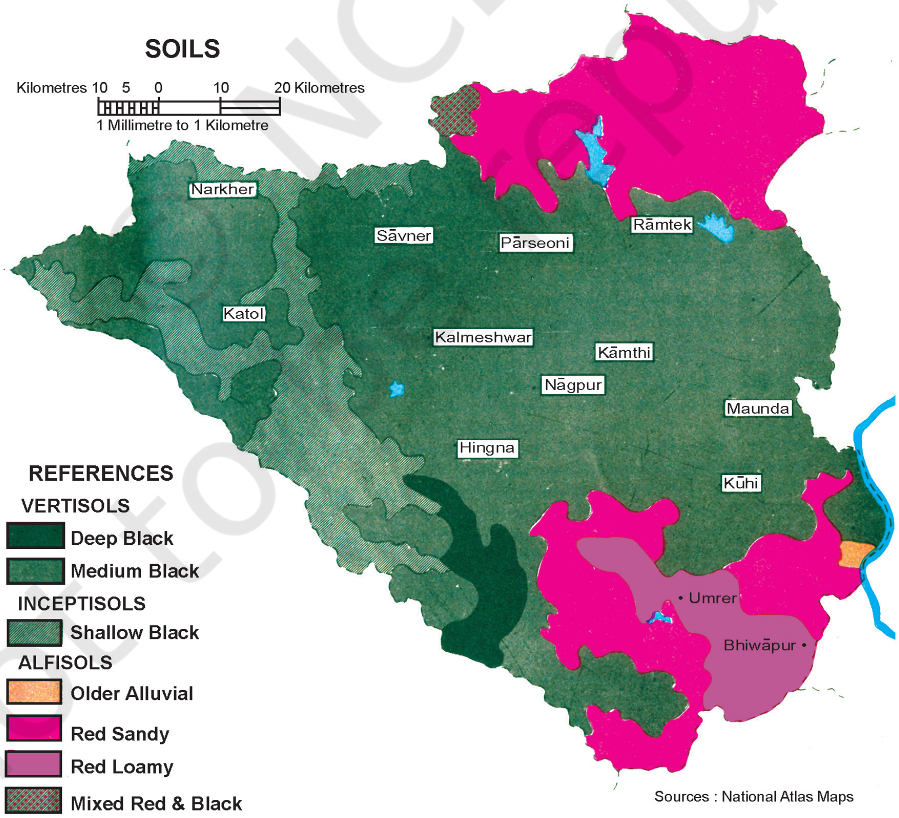

Figure 1.10 Soils of Nagpur District

rainfall, cloudiness, relative humidity, direction and velocity of winds and other elements of weather (Fig 1.9).

(d) Soil Maps : Maps are also drawn to show the distribution of different types of soil(s) and their properties (Fig. 1.10).

(ii) Cultural Maps: Cultural maps show man-made features. These include a variety of maps showing population distribution and growth, sex and age, social and religious composition, literacy, levels of educational attainment, occupational structure, location of settlements, facilities and services, transportation lines and production, distribution and flow of different commodities.

(a) Political Maps : These maps show the administrative divisions of an area such as country, state or district. These maps facilitate the administrative machinery in planning and management of the concerned administrative unit.

(b) Population Maps: The population maps are drawn to show the distribution, density and growth of population, age and sex composition,

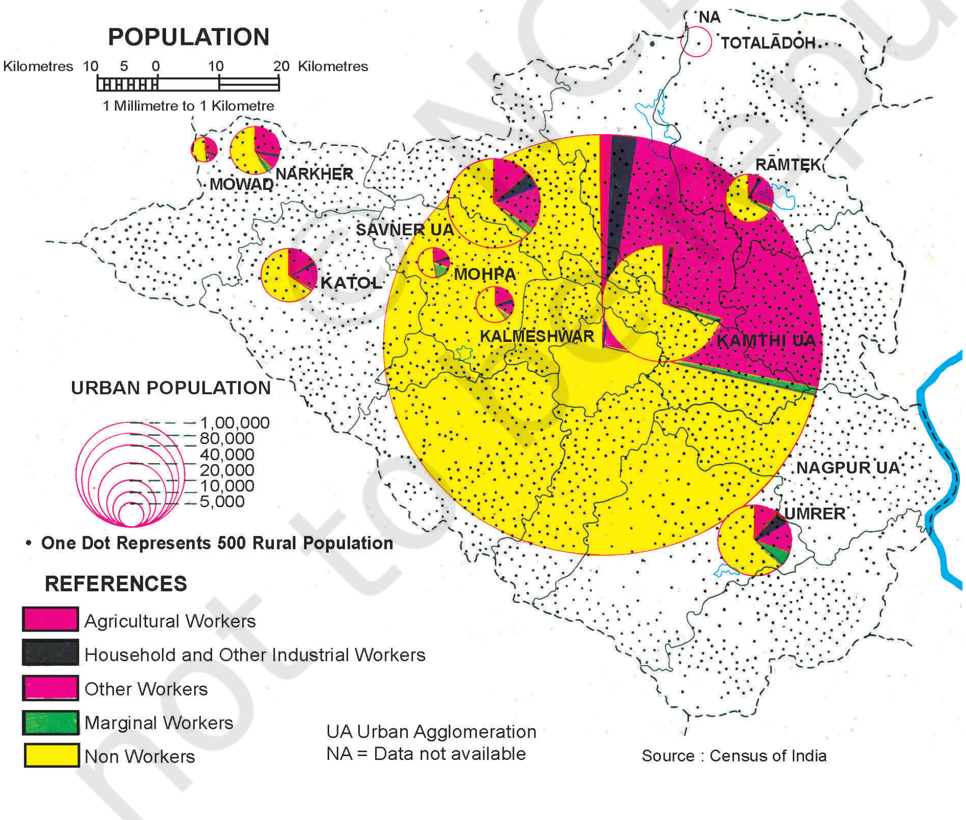

Figure 1.11 Nagpur District : Distribution of Population

distribution of religious, linguistic and social groups, occupational structure of the population, etc. (Fig 1.11 on previous page). Population maps serve the most significant role in the planning and development of an area.

(c) Economic Maps: Economic maps depict production and distribution of different types of crops and minerals, location of industries and markets, routes for trade and flow of commodities. Figures 1.12 and 1.13 show the land use and cropping patterns and the location of industries in Nagpur district respectively.

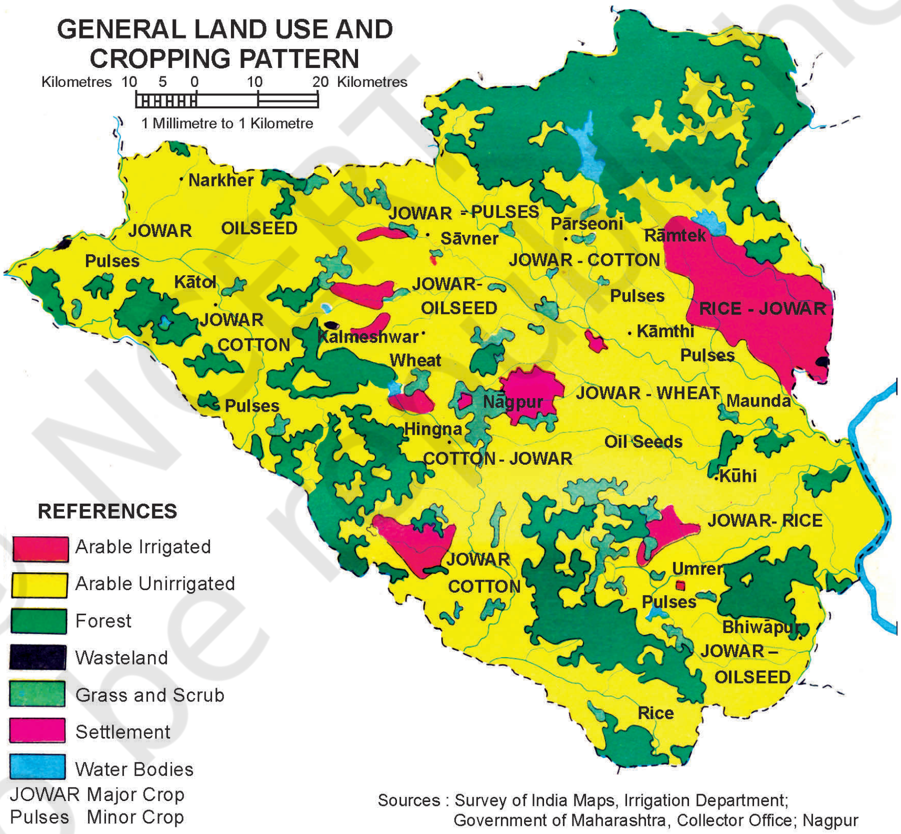

Figure 1.12 Land use and Cropping Patterns in Nagpur District

(d) Transportation Maps: These maps show roads, railway lines and the location of railway stations and airports.

Figure 1.13 Location of Industries in Nagpur District

Uses of Maps

Geographers, planners and other resource scientists use maps. In doing so, they make various types of measurements to determine distances, directions and area.

Measurement of Distance: The linear features shown on the maps fall into two broad categories, i.e. straight lines and erratic or zigzag lines. The measurement of straight line features like roads, railway lines and canals is simple. It can be taken directly with a pair of dividers or a scale placed on the map surface. However, distances are required, more often, along erratic paths, i.e. the coastlines, rivers and streams. The distances along all such features can be measured by placing a thread at the starting point and carrying it along the line up to the end point. The thread is then stretched and measured to determine the distance. It can also be measured by using a simple instrument called *Rotameter*.

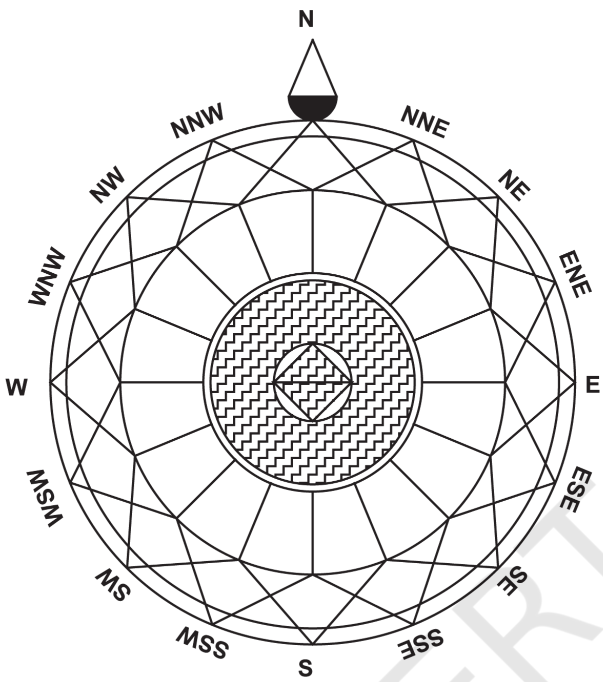

Figure 1.14 Cardinal and Intermediate Directions

The wheel of the 'rotameter' is moved along the route to measure the distance.

Measurement of Direction: Direction is defined as an imaginary straight line on the map showing the angular position to a common base direction. The line pointing to the north is zero direction or the base direction line. A map always shows the north direction. All other directions are determined in to this relation. The north direction enables the map-user to locate different features with respect to each other. The four commonly known directions are North, South, East and West. These are also called the cardinal points. In between the cardinal points, one may have several intermediate directions (Fig. 1.14).

Measurement of Area: The measurement of area of features like that of administrative and geographic units is also carried out over the surface of the map by map-users. There are different methods in which areas can be determined. One of the simplest but not very accurate method to determine the area is by means of regular pattern of squares. In this method, the area to be measured is covered by squares by placing a sheet of graph paper beneath the map on an illuminated tracing table or by tracing the area onto the square sheet. The total number of 'whole squares' are summed up, together with 'partial squares'. The area is then determined by a simple equation :

$$\text{Area} = \text{Sum of whole squares} + \left(\frac{\text{Sum of partial squares}}{2}\right) \times \text{Map Scale}$$

The area can also be calculated by using a fixed area *polar planimeter* (Box 1.1).