6

STRUCTURE AND COMPOSITION; INSOLATION

In the earlier lesson, you got familiar with the significance of oceans and its variation in the temperature. As you know, life on earth originated in the oceans. In other words, Earth is the only known planet in the universe where life exists due to the presence of air and water. Both have noteworthy effects on our survival as they have different characteristics. For example, we can see and touch water but we can neither see nor touch air; we can only feel the movement of air. In this lesson, you will learn about the structure and composition of atmosphere, insolation, distribution of temperature and heat budget.

OUTCOMES

After studying this lesson, learner:

- identifies the layers of atmosphere;
- describes the composition of atmosphere;
- explains the factors influencing insolation and its horizontal distribution and
- describes the heat budget with the help of a diagram.

6.1 ATMOSPHERE

Before discussing composition and structure of the atmosphere, let us know more about the atmosphere in general. We know that life is only possible on the Earth's surface. The main reason for this is the presence of air. Without any horizontal movement we can't feel the presence of air. The earth is surrounded by a gaseous envelope which acts like an air blanket on the earth 's surface. It is attached due to the gravitational force of the earth. This is known as the atmosphere. Earth is a green planet only due to its atmosphere, without this existence of water bodies, clouds and sound are not possible.

Atmosphere protects the earth from harmful solar energy such as ultraviolet radiation. It is a very important part of our fragile earth system which controls our various human activities by different processes. Earth receives solar energy through the atmosphere. The climatic phenomena such as temperature, air pressure, winds, moisture, clouds, precipitation, fog, frost etc. are occurring in lower atmosphere. Atmosphere plays a fundamental role in the distribution or redistribution of energy over the planet earth through energy exchange to each other.

In recent years, the changing environment of the earth's surface has contributed to changes in atmospheric composition in the form of undesirable concentration of carbon dioxide, high pollution levels, ozone depletion and global warming. Among all, global warming is a major cause of concern. However, all these problems are also a matter of atmospheric dynamics.

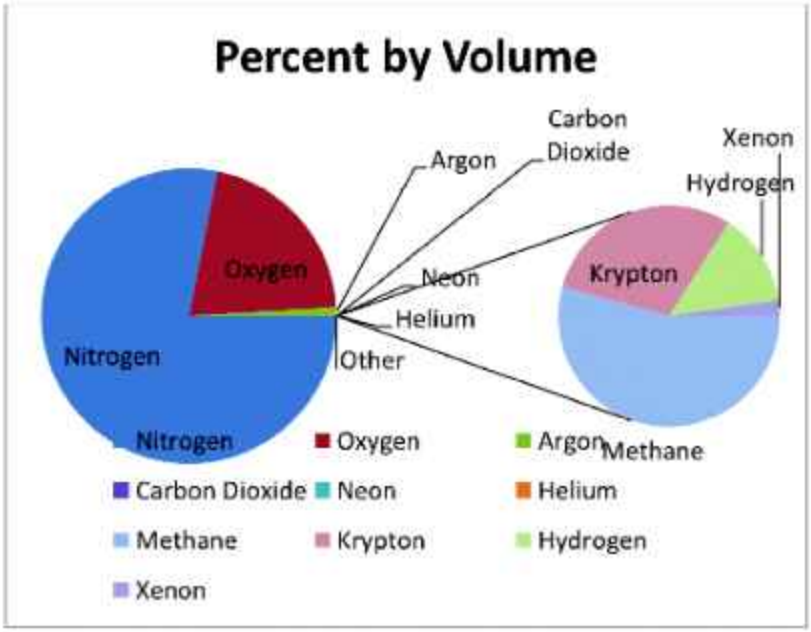
Among all of them global warming is major of concern in present scenario. Global warming is the result of greenhouse effect. It means the gradual increase in world-wide atmospheric warming due to accumulation of heat in lower atmosphere through the greenhouse gases like carbon dioxide (CO_2), Methene (CH_4), Chlorofluorocarbons (CFCs), Nitrous Oxide (N_2O), Ozone (O_3), water vapour. These phenomena are changing the composition of the atmosphere. We can better understand atmosphere, by knowing its composition.

6.2 COMPOSITION OF ATMOSPHERE

As we know, the atmosphere is made up of various gases, dust particles and water vapour. These are neither static nor spread uniformly in the atmosphere. We can find variation in their distribution according to altitude, latitude and seasons. The characteristics of three basic constituents' namely, gases, water vapour and dust particles are as follows:

a. Gases of atmosphere

Gases of atmosphere are, broadly, divided into two groups i.e. permanent and variable gases. Nitrogen, Oxygen, Argon, Neon, Helium, Hydrogen, and Xenon are permanent gases and Carbon dioxide, Methane, Nitrous oxide, Ozone and Chlorofluorocarbons (CFCs) are variable gases. We can see their amount of concentration by percentages in the given figure. It shows Nitrogen and Oxygen are found in large amounts.



Gases	Percent by Volume
Nitrogen	78.08
Oxygen	20.95
Argon	0.93
Carbon Dioxide	0.0314
Neon	0.0018
Helium	0.0005
Methane	0.0002
Krypton	0.00011
Hydrogen	0.00006
Xenon	0.000009

Fig. 6.1 Composition of atmosphere

i. **Nitrogen:** Nitrogen is very important for all life forms in the biosphere because it is an essential part of amino acids which makes up proteins. It helps in controlling combustion by diluting oxygen and also indirectly helps in oxidation.

ii. **Oxygen:** Oxygen is a very active gas which combines with the majority of elements in the biosphere. Through the process of photosynthesis and respiration, it is exchanged between atmosphere and living organisms.

iii. **Carbon Dioxide:** The role of this gas is very important in atmospheric processes because of its ability to absorb radiant heat. It is a vital greenhouse gas that taps earth's outgoing radiation and is causing global warming. Its percentage is increasing in the atmosphere due to increasing burning of fossil fuels such as wood, coal, natural gas, gasoline and oil etc.

iv. **Ozone:** It is unevenly distributed and lies in between 20 km to 25 km of altitude. Ozone has a protective role in the atmosphere as it's essential for maintaining habitability of earth. It blocks the harmful ultraviolet radiation from the sun.

v. **Methane:** Methane is a second most abundant greenhouse gas which is emitted from both anthropogenic (landfills, agricultural activities, coal mining, stationary and mobile combustion) and natural sources. Methane absorbs earth radiation quite efficiently. Its presence in the atmosphere affects the temperature and climate system of earth.

b. Water Vapour

Water vapour is water in gaseous instead of liquid form. It is also the most important gas in the atmosphere. Some important facts about water vapour are as follows:

- Hydrosphere is the source of atmospheric water vapour.
- It changes their state from vapours (gas) into liquid (water) and liquid into solid (ice).
- Amount of water vapour varies in different regions. Maximum amount of water vapour present in the atmosphere is up to 4%.
- All forms of precipitation whether in liquid or solid are possible only by conversion of water vapour into the other forms.
- It also absorbs long-wave terrestrial radiation. Water vapour plays an important role in heat energy balance.

c. Dust Particles

Dust particles are made of fine particles of solid matter. It is found in the atmosphere. Its main significance is that they help in the formation of clouds, which in turn is important for precipitation and rainfall on earth.

INTEXT QUESTIONS 6.2

Write True against the correct statement and False against the incorrect statement:

i. Carbon dioxide is responsible for global warming.

ii. Nitrogen is very important for making proteins which is an essential part of amino acid.

iii. Atmospheric dust particles are mainly found in the upper part of the atmosphere.

iv. Methane is a permanent gas.

6.3 STRUCTURE OF THE ATMOSPHERE

Atmosphere is multi-layer gases and it is a component of the Earth-environment system. The atmosphere can be divided into various vertical layers. These layers are distinguished from one another by temperature, chemical composition and related phenomena.

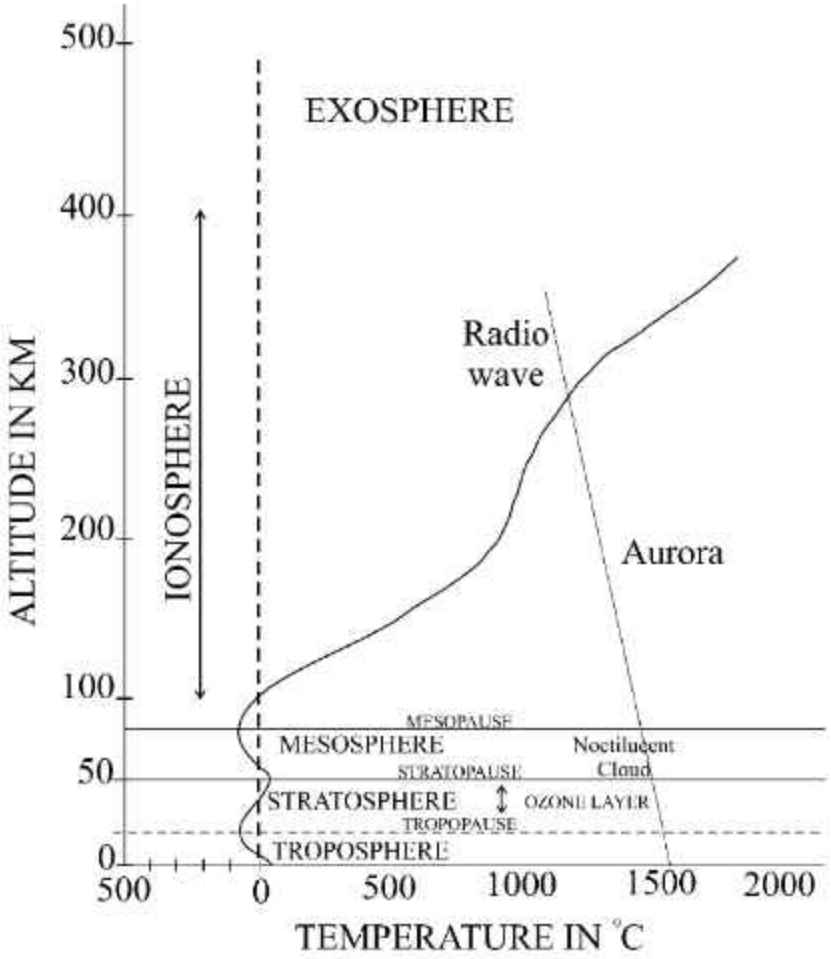


Fig. 6.2 Vertical Layer of Atmosphere

i. Troposphere

- The Troposphere is the first and lowermost layer of the atmosphere. This layer contains about 75% of gaseous mass along with the concentration of pollutants.
- The average height of this layer is around 12 kms., which varies with latitude. The height of the troposphere is not constant as it is 16 kms. on the equator, whereas 8 kms. on the poles.
- On the equator, height of this layer is determined by the presence of conventional hot currents.
- The lowest temperature is observed in this layer with increasing height. Moreover, all types of climatic and weather phenomena take place within the troposphere.
- A gradual decrease in the temperature with height is 6.5°C per thousand metres. This phenomenon is known as "Normal lapse rate". As the gradual decrease in temperature stops, tropopause starts.

ii. Stratosphere

- The stratosphere extends from tropopause to a height of 50 kms.
- Thermal conditions of the lower part of the stratosphere are stable due to non-existence of dust particles, water vapours and conventional current. It is known as an isothermal zone.
- This layer is considered ideal for flying aeroplanes because weather events do not take place. The Stratosphere covers about 24 % of the total air mass.
- As height increases, the temperature in the stratosphere increases due to the presence of ozone gas in the upper part of the layer.
- Without the Ozone layers, all living things could not exist on earth's surface. It protects us from the harmful effects of ultraviolet solar radiation.

DO YOU KNOW?

Vertical layer of lower stratosphere is known as **Isothermal zone** because the temperature remains constant with increasing altitude.

iii. Mesosphere

- Mesosphere is the third layer of the atmosphere which extends up to 80 kms.
- The temperature in the mesosphere continuously decreases with increasing height. The layer records the lowest temperature in the atmosphere i.e. -100° Celsius.
- Meteors occur in the mesosphere and "Noctilucent" clouds are formed by the process of condensation in association with meteoric dusts.

iv. Ionosphere

- The fourth layer, the ionosphere , is located above the mesosphere up to the height of 400 kms.
- Due to the high concentration of ions particles, this layer is known as the ionosphere. Temperature rises with increasing height in this layer.
- The Ionosphere plays a significant role in radio communications. From this layer, radio waves are reflected back on the earth and due to this radio broadcasting has become possible.
- The phenomenon known as "Aurora" has also been observed in this layer.

Notes

v. Exosphere

- This is the last and uppermost layer of the atmosphere.
- Exosphere is located above 400 kms of height after the ionosphere.
- Gases are very sparse in this layer because of the lack of gravitational forces.
- Hydrogen and Helium gases are predominant in this layer. They are very light in nature. Therefore, the density of this layer is very low.

INTEXT QUESTIONS 6.3

i. Name the layer which is related to "Normal lapse rate"

ii. Which gas protects us from ultraviolet solar radiation and where is it located?

iii. What is the importance of the ionosphere?

iv. Name the Layer where density is very low.

6.4 INSOLATION

The Sun is the primary source of energy, which has a surface temperature of more than 6000° Celsius. The radiant energy from the sun comes in the form of short-wave radiation. Incoming solar radiation (IN+SOL+ATION) is known as insolation. Therefore, Insolation has been defined as the energy received from the sun in the form of short-wave radiation.

A. Factors influencing Insolation

Amount of insolation is not uniform and varies with time and place. The tropical region receives more insolation than the polar region. Similarly, seasonal variation has also been observed, such as the amount of insolation is greater in summer than winter.

i. The Angle of Incidence

The amount of insolation on the earth surface depends on the angle of sun's rays which formed at the time of sun striking on earth surface. Every place on earth has a different angle of the sun's rays. As some places receive vertical angle and some receive oblique angle of the sun's rays. It is known as angle of incidence. This controls the amount of insolation in two ways: -

- When the sun rays are vertical, they are concentrated on a smaller area and give maximum insolation. On the contrary, the place where the angle of sun's rays is oblique, heats up a large area and receives less amount of insolation.

Notes

On the equator, the sun is always vertically overhead, as we move towards poles, the angle of incidence becomes oblique gradually. Therefore, the amount of insolation is greater on the equator and continues to decrease towards poles.

- Before reaching the earth surface, rays have to pass through the atmosphere. We know, rays with oblique angles have to travel a larger area. Therefore, much of their heat is reflected and absorbed by water vapours, clouds and dust particles. This is the reason why poles receive less amount of insolation. On the other hand, the Equator receives a high amount of insolation, because the distance between earth and atmosphere is less.

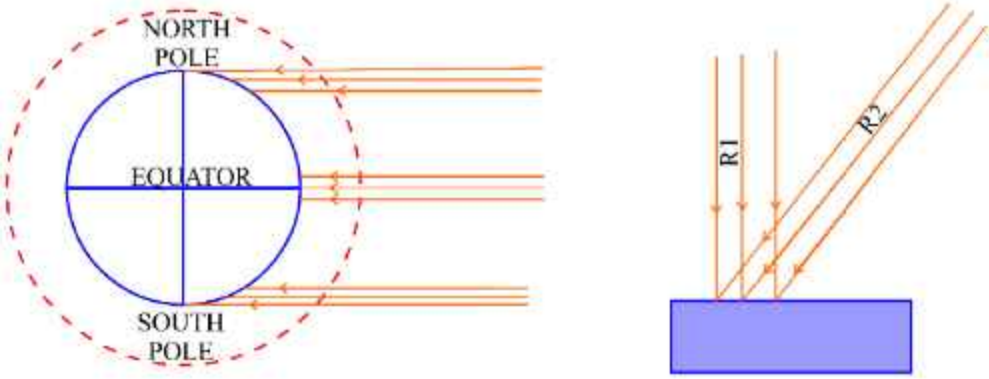


Fig. 6.3 (a) Angle of sunlight and altitude (b) Vertical (R1) and Oblique (R2) Sunrays

ii Duration / Length of day

The amount of insolation depends on the length of the day because it is received only in the daytime. Therefore, as the length of day is longer, the amount of insolation will be maximum. Length of day or duration of day time also varies from place to place and seasons to season. Only at equator, day and night is 12 hours, throughout the year. As we move towards poles from the equator, we can observe the variance between day and night as per the latitudes.

Table 6.1 Maximum length of day at different latitudes

Latitude	0°	17°	41°	49°	63°	66.5°	67°21'	90°
Length of the day (hours)	12	13	15	16	20	24	1 month	6 months

iii. Transparency of atmosphere

The amount of insolation also depends on the transparency of the atmosphere. The transparency of the atmosphere may also control the amount of insolation. It is

determined by cloud cover, water vapours and dust particles. As an increase in the quantity, especially clouds and dust particles, they reflect the insolation. Besides this, insolation is also absorbed by water vapour in the atmosphere. For example, thick clouds hinder the insolation to reach while clear sky condition helps in reaching insolation on earth surface.

B. Way of Energy Transfer

We already know, sun is the only source of energy and we get it directly as insolation. Besides that, there are some ways by which energy can be transferred from one place to another place as follows:

i. **Radiation:** Radiation is a very important process in the atmosphere. In radiation, heat transfers through space by waves, it is called electromagnetic waves. The Process of radiation does not require any medium to transfer the heat. It can pass through the atmosphere without the aid of the air molecules and also move even in a vacuum. In other words, radiation is the way by which solar energy reaches the earth in short waves and heat is radiated from the earth in long waves. Temperature and wavelength are inversely related. Hotter the object shorter is the length of the wave and vice versa.

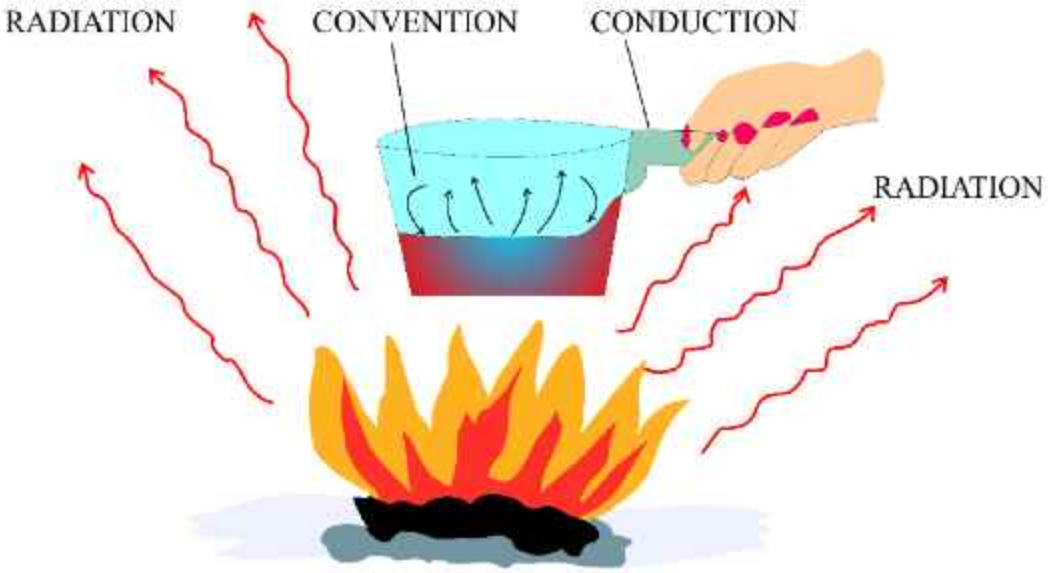


Fig: 6.4 Ways of energy transfer within the Earth atmosphere

ii. **Conduction:** In the process of conduction, heat transfers from one molecule to another molecule within a substance. In this process, heat energy flows from the warmer object to the cooler object. This process continues till the temperature of both objects become equal, or the contact is broken. When material and objects can easily pass energy from one place to another, it may be called the lower good

Notes

conductor of conduction. Air is a bad conductor of conduction. By this process, the atmosphere is heated in contact with the surface heat.

iii. **Convection:** In this process, heat has been transferred by the mass movement of fluids like water and air. It is a very important process of heating the atmosphere. The conventional process in the atmosphere is associated with the cyclic movement of heat transfer from the lower layer to the upper layer. In cyclic movement, atmosphere heats a higher part of the atmosphere

When incoming solar radiation strikes with atmospheric gases, dust particles and air molecules, some amount of energy is lost through various processes, which are as follows:

- **Scattering:** During the process of incoming solar radiation, sun rays strike at air molecules and dust particles. The sunlight deflected in different directions (up, down, and sides); this is called scattering. It depends on the size of particles and wavelength of light. For example, blue light with shorter wavelength scatters more easily than red light. This is the reason behind the blue colour of our sky.
- **Reflection:** When some sunlight is striking by air molecules and clouds that insolation is reflected to space. For example, clouds are the most important reflector which reflectivity depending upon the thickness of clouds. The amount of reflected sunlight is known as albedo.
- **Absorption:** In this process, radiation is retained by a substance and converted to heat energy. Mainly heat has been absorbed by gases, water vapour and dust particles in the atmosphere. Oxygen, ozone, carbon dioxide and water vapour are known to be good absorbers. For example, ultraviolet radiation is absorbed by oxygen and ozone at the stratosphere.

INTEXT QUESTIONS 6.4

i. Define insolation.

ii. What are the factors influencing the amount of insolation?

iii. By which process energy transfers from sun to earth?

iv. In which place, hours of the day and night are equal throughout the year.

Notes

6.5 HEAT BUDGET

Earth not only received solar energy but also reradiated the energy. Energy released from the earth surface is in the form of longwave radiation. This is known as terrestrial radiation. Earth receives continued energy from the sun but earth maintains average temperature. Incoming energy from sun to earth and outgoing energy from earth to sun is going on simultaneously. This flow of energy is a complex system; this involves radiation, storage and transport of heat.

As we already know, water plays a powerful controller in global heat supply and energy exchange. Water has the capacity to absorb or release heat between the atmosphere - ocean - continent systems.

At global level, heat received and energy absorbed by our planet is matched by planetary output of terrestrial energy transferred into outer space. The energy exchange between earth and atmosphere absorbs energy from the sun as well as from each other a delicate balance is maintained. These gains and losses of heat through incoming and outgoing radiation are known as **'Heat Budget'**

The 100 units of energy from the sun reaches the top of earth's atmosphere. Out of the total 35% of insolation are reflected through clouds (27%) and scattered (6%) out to space. It has no role in heating the earth. This amount of reflected energy is known as **'Albedo'**. From the remaining 65%, 14% of energy is absorbed by gases and water vapour in the atmosphere. The Rest 51% (65-14=51) of energy is received as through the direct radiation (34%) and by diffuse daylight (17%) on earth's surface.

On the other hand, earth warms the layers of air above by direct contact or conductions and transmission of heat by upward movement of air through convection currents. Out of 51% of total energy received by the earth's surface is sent back to the atmosphere (34%) and in space (17%) through terrestrial radiation.

Total budget of the atmosphere is 48% of which 14% is received through absorption of solar radiation. Others (48-14=34) received by various ways like evaporation (19%) convection (9%) or turbulence and absorption 6% by atmosphere (19+9+6=34) of terrestrial radiation.

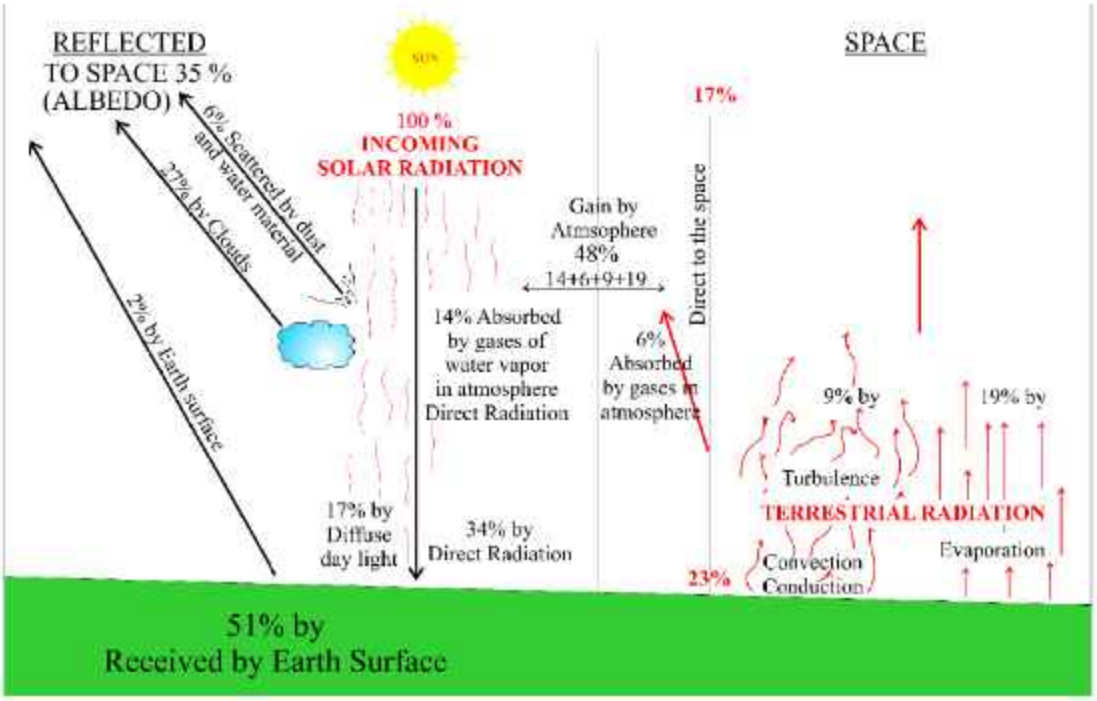


Fig 6.5 The earth's heat budget

i. Heat Transfer

On the basis of the above discussion, net annual radiation for the globe is zero. In some places energy is coming faster than it is going out. This is known as gain or energy surplus and loss or energy deficit. High intensity of insolation at low latitude, it gradually decreases towards the poles. At the global level, the area between 40 north latitude to 40-degree south latitude is an energy surplus region. Poleward from the 40 north and south latitude is a two deficit set of energy regions. Therefore, the latitudinal balance of energy is not maintained by each latitude. To compensate for the deficit and surplus of energy, wind in the atmosphere and currents in the oceans exchange warm air and water towards poles and cold air and water towards the equator. By this process net latitudinal radiation for the entire globe is zero.

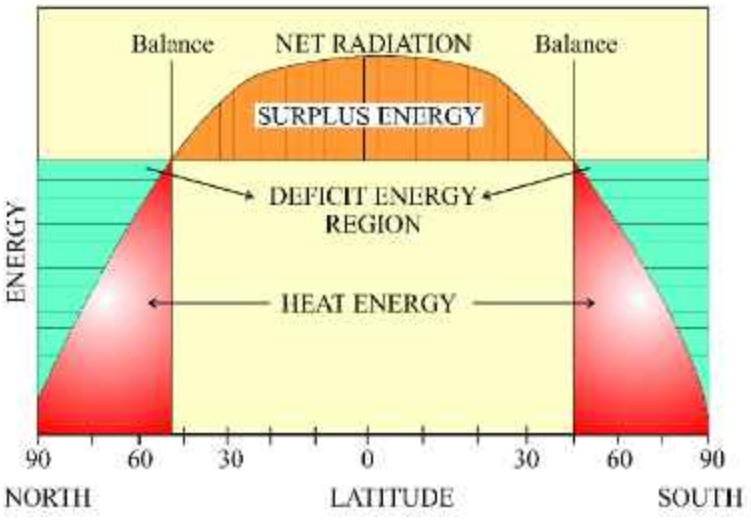


Fig 6.6 Average latitudinal distribution of radiation

Notes

INTEXT QUESTIONS 6.5

i. What do you mean by the term 'Albedo'?

ii. What is the Heat budget?

iii. Which amount of energy received by earth?

iv. What is the net annual radiation for the globe?

6.6 TEMPERATURE

Do you know, intensity of heat is known as temperature? It is measured by the degree of hotness of the heat energy available in the air and soil. Temperature only indicates how "hot" or "cold" an object or particle is. The temperature of air near the surface of the earth is warmer than the air above it. We know that the temperature decreases with height in the troposphere. But sometimes the temperature increase with height under special circumstances is called inversion of temperature. It may occur at close to land surface or it may also at upper atmosphere. Temperature inversion near the surface may occur under such conditions like long and clear winter nights, clear skies, calm air and snow-covered surface etc.

Temperature of any particular place is a result of several complex combinations of elements, which are directly and indirectly controlled by various factors. It, directly depends on the amount of insolation of a given place and distribution of temperature which indirectly determined by the several others elements of earth's surface such as winds, currents, water and land distribution etc.

a. Factors of temperature distribution

Among various factors regarding the amount of insolation received, Latitude is an important factor that controls spatial variations of temperature distribution on the earth's surface. Some others factors which determine temperature of place are as follows:

i. **Latitude:** The total amount of solar energy received varies as per different latitudes. It is intense in amount at the lower latitudes and gradually decreases towards higher latitudes. In the last section we have already understood that the vertical position of the sun's rays at the equator almost throughout the year, favours the high amount of isolations. Inclination of the sun's rays increases from equator (low latitude) to poles (high latitudes). Therefore, the angle of the sun rays is the prime reason for the variation in the amount of solar energy.

Notes

ii. **Altitude:** Height above the sea level (altitude) of any place also controls the temperature of a given place. Temperature decreases with height at the rate of 1 degree for 165 metres. It is known as normal lapse rate.

iii. **Cloudiness:** As we know, the amount of insolation is also determined by the sky conditions, especially cloudiness. Clouds reflect insolation to space and do not express high temperature. High temperature found in clear and cloudless sky.

iv. **Winds:** Winds are the most important changer of the place. Warm winds raise the temperature while cold winds cause a fall in temperature. Winds wherever they are blowing from their original place changes the temperature of that place as per their nature (hot or cold). For example, the hot wind of the Sahara Desert "Sirocco" blows towards Italy and raises the temperature.

v. **Nature of the Land Surface:** Land surface affects inversely towards amount of insolation as per their nature. For example , snow cover areas (bright and smooth) reflect the maximum amount of solar radiation and temperature remains low while dark colour surfaces (black soil region) absorb maximum solar radiation which helps in raising the temperature.

vi. **Distribution of Sea and Land:** Due to variations in the rate of heating and cooling of land and water experiences great variations in temperature of the same place. On the land temperature is higher during summer and day time. On the other hand, oceans have high temperatures in winter and during nights. The seasonal variations in temperature are the results of spatial variations.

vii. **Oceanic Currents:** Like wind, oceanic currents also influence the temperature of adjacent areas. An oceanic current moves from warm temperature areas to colder temperature areas and vice versa. Moving currents influence the temperature of their path by its original nature of current like warm or cold. The warm currents raise the temperature whereas cold currents lower the temperature of areas.

b. Horizontal Distribution of Temperature:

When we study temperature across latitudes is known as horizontal distribution. It is shown by the "isotherm" lines on the map. Isotherm (ISOS means equal and THERMS means temperature) line is an imaginary line which joins places having equal temperature. After a detailed study of isotherms, we can understand the temperature of a particular place. If we look at the global level, January is considered the coldest month while July is the hottest month of the year. Both the months represent seasonal extremes of temperature. Therefore, we should study these months separately.

Notes

(i) **Horizontal Distribution of Temperature in January:** In the month of January, Winter season in the northern hemisphere and summer season in the southern hemisphere. Its main reason is the position of the sun which is vertically overhead near the tropic of Capricorn. High temperature regions are in the southern hemisphere i.e. north-west Argentina, east-central Africa, Borneo and central Australia. We can see Isotherms of 30° Celsius passing through these regions.

In January, the landmass of the northern hemisphere is colder in comparison to ocean areas. In the northern hemisphere, the Northeastern part of Asia experiences low temperatures. Especially, the middle part of the continent shows a lower temperature than the oceans areas of the same latitude.

Due to large expanse of water exist in the southern hemisphere; isotherms lines are regular and widely spaced. On the other hand, in the northern hemisphere isotherms lines are irregular and closely spaced due to large expanse of land masses.

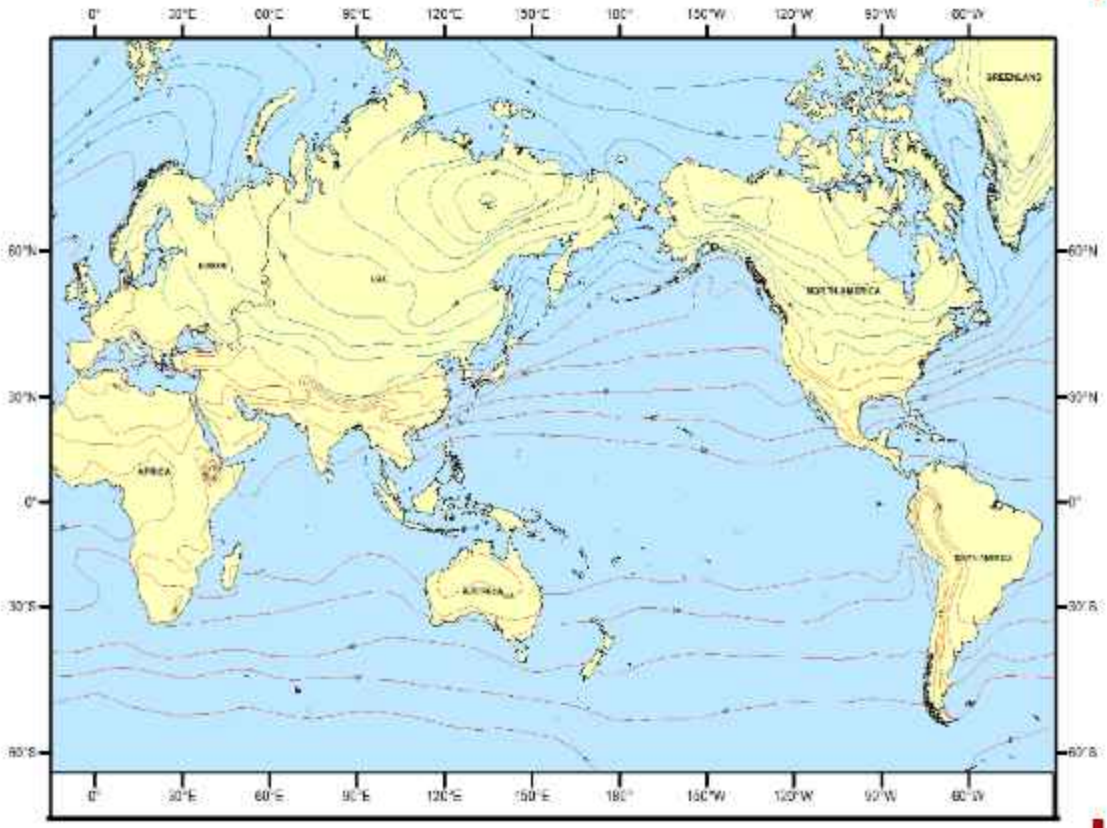


Fig. 6.7 Horizontal distribution of temperature in January

(ii) **Horizontal Distribution of Temperature in July:** As the sun position is vertically overhead near the tropic of cancer in the month of July. Therefore, the northern hemisphere experiences summer seasons. High temperature is experienced in the entire northern hemisphere and isotherms line of 30° Celsius located between 10°

north and 40° north latitudes places like south-eastern U.S.A, the Sahara, and Arabia, Iraq, Iran, Afghanistan, the Gobi Desert, Chani and Thar Desert of India have high temperatures. At the same time, the lowest temperature of 0° Celsius is also located in the northern hemisphere, especially in the central part of Greenland. The temperature of middle areas of the continents in the northern hemisphere is higher than oceans of the same latitude. Oceans areas have shown wider spacing isotherms lines than continents.

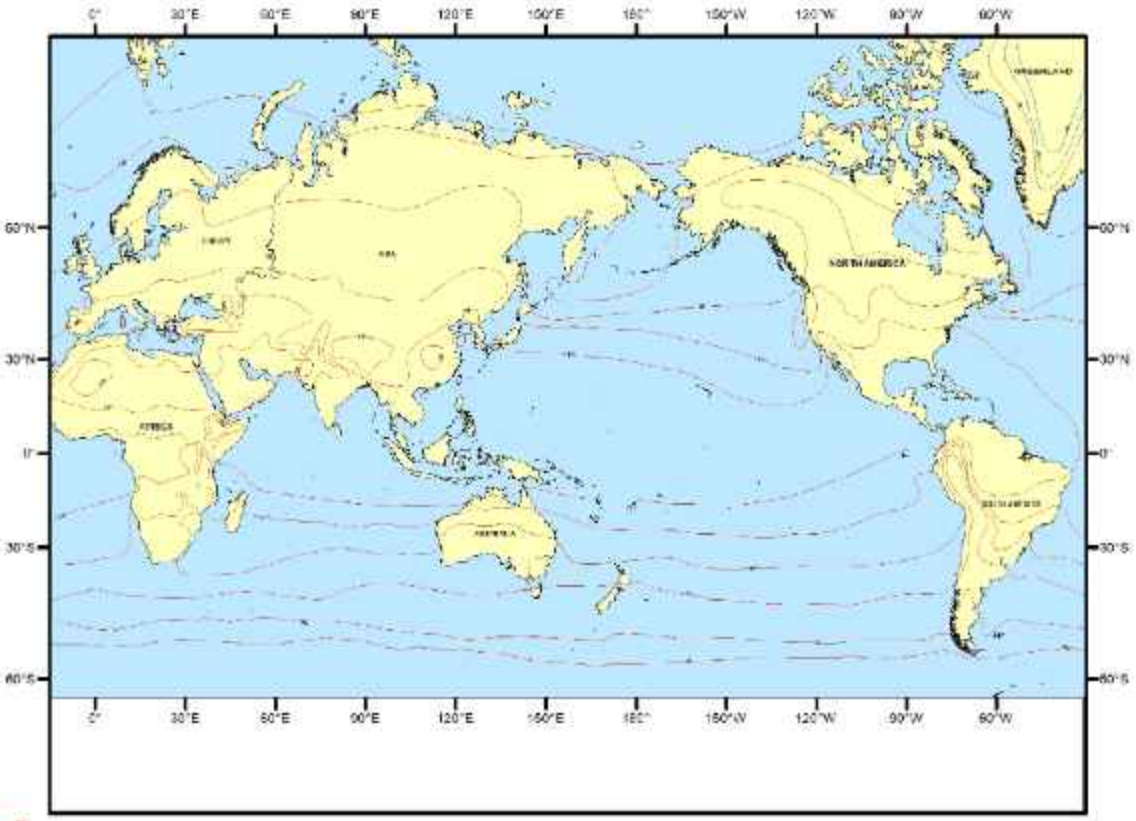


Fig. 6.8 Horizontal distribution of temperature in July

After the study of the isotherms line of January and July, we found lines change very little in position over the equator. This shows the feature of consistency of insolation throughout the year near the equator.

Apart from the horizontal distribution of temperature, vertical distribution of temperature is also important. Generally, temperature decreases with increasing height in the troposphere. It varies with height, latitude and seasons. Sometimes temperature increases with increasing altitude but the phenomenon has been characterised temporarily and locally.

INTEXT QUESTIONS 6.5

i. Which latitude receives the maximum amount of insolation?

ii. What is the nature of "Sirocco" wind and where is it blown?

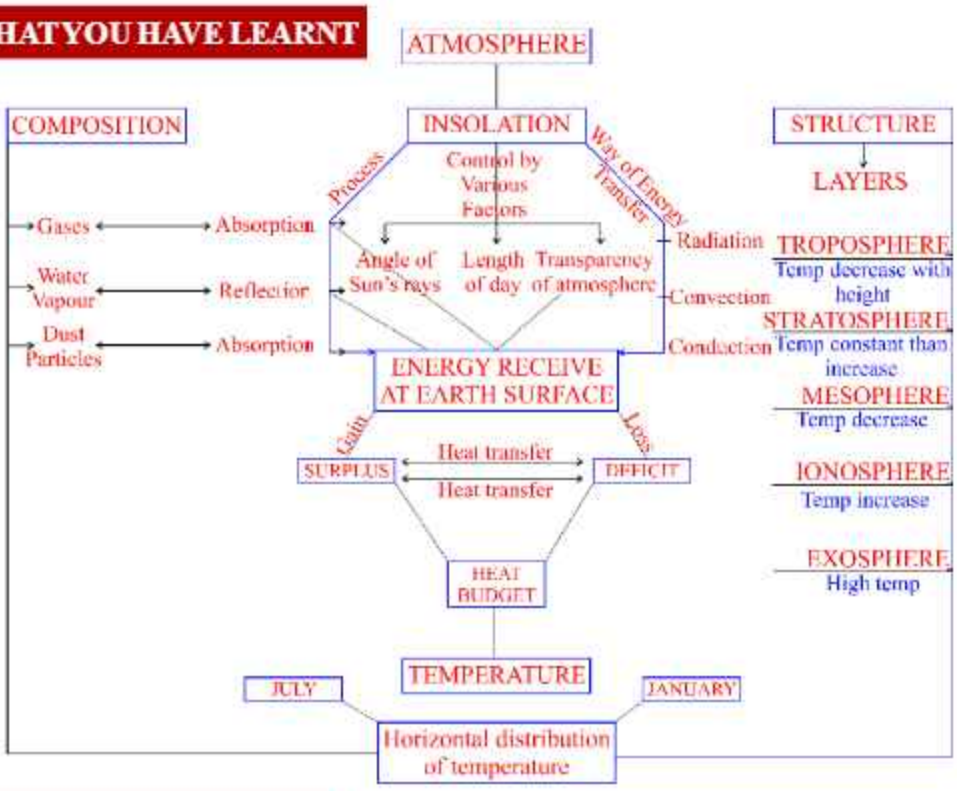
iii. Which months represent seasonal extremes of temperature on the globe?

iv. In the southern hemisphere, which season is found in the month of January?

ACTIVITY

Make lists of various examples which represent processes of energy transfer.

WHAT YOU HAVE LEARNT



TERMINAL QUESTIONS

1. What are the three mechanisms by which heat energy is transferred?

2. Write a note on the important gases of the atmosphere.

3. Explain different layers of the atmosphere with the help of a diagram.

4. Distinguish between convection and radiation ways of heat transfer.

Notes

5. Why do Poles receive less amount of insolation?

6. Describe important factors of horizontal distribution of temperature.

7. Identify surplus and deficit zones of energy on earth.

8. Describe heat budget with the help of diagrams.

ANSWERS TO INTEXT QUESTIONS

6.2

(i) T (ii) T

(iii) F (iv) F

6.2

(i) Troposphere (ii) Ozone gas and Stratosphere

(iii Ionosphere plays an important role in radio communication.

(iv) Exosphere

6.3

(i) Incoming solar radiation is known as insolation.

(ii) Angle of incidence, length of day, transparency of atmosphere.

(iii) Radiation (iv) Equator

6.4

(i) Amount of reflected solar energy is known as 'Albedo'.

(ii) Heat budget is the balance between incoming and outgoing radiation.

(iii) 51% (iv) Zero

6.5

(i) Low latitudes

(ii) Hot wind and blowing towards Italy.

(iii) January and July

(iv) Summer season