Insolation and Heat Balance of the Earth

Insolation

- The sun radiates its energy in all directions into space in short wavelengths, which is known as solar radiation
- The energy received by the earth's surface in the form of short waves is termed as Incoming Solar Radiation or Insolation.
- The amount of insolation received on the earth's surface is far less than that is radiated from the sun because of the small size of the earth and its distance from the sun.

- water vapour, dust particles, ozone and other gases present in the atmosphere absorb a small amount of solar radiation.
- The solar radiation 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.
- Due to this variation in the distance between the earth and the sun, the annual insolation received by the earth on 3rd January is slightly more than the amount received on 4th July

Factors influencing Insolation

- The amount of insolation received on the earth's surface is not uniform everywhere.
- It varies according to the place and time.
- When the tropical regions receive maximum annual insolation, it gradually decreases towards the poles.
- Insolation is more in summers and less in winters.

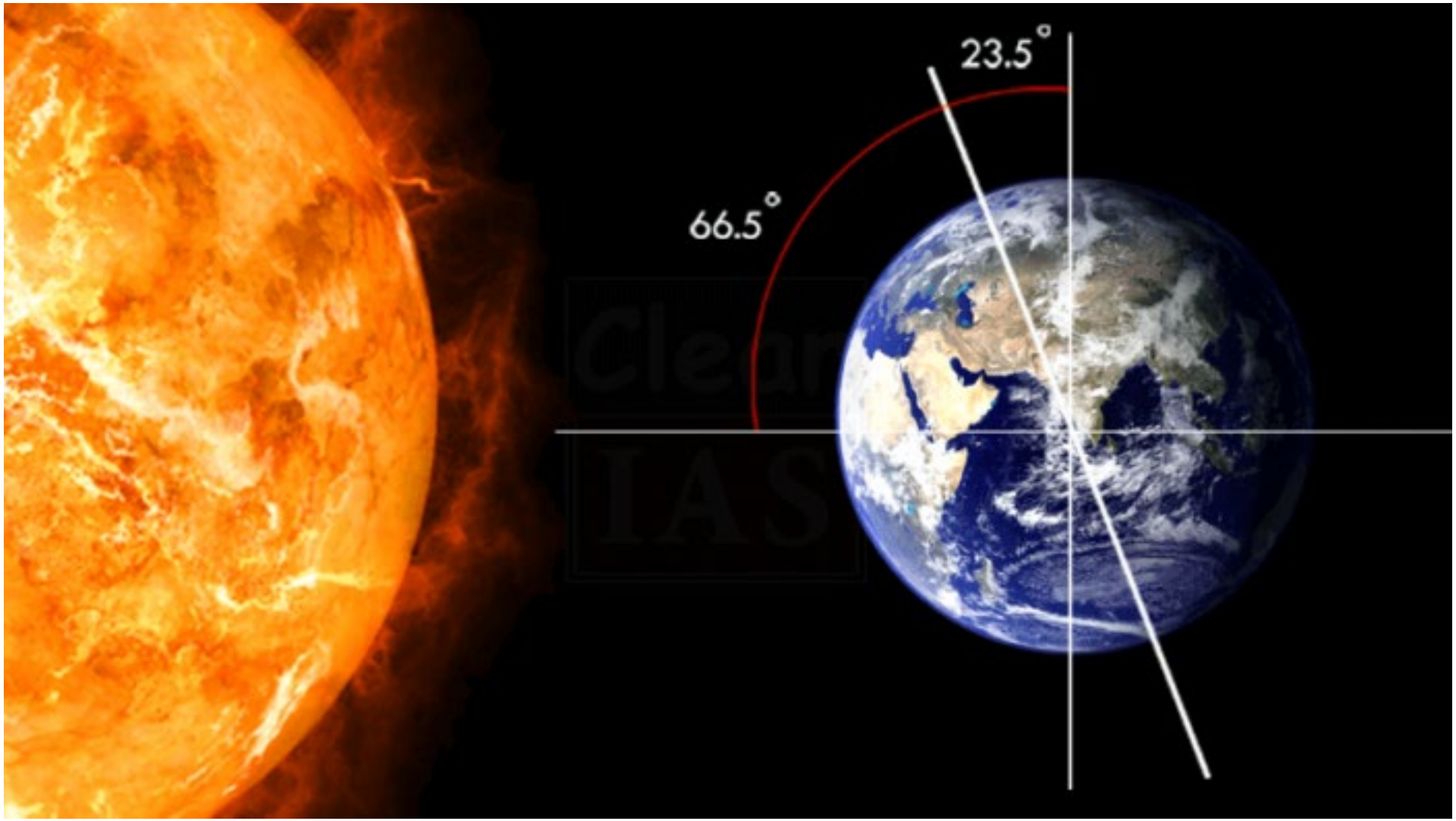
The major factors which influence the amount of insolation received are:

- Rotation of the earth on its axis
- The angle of incidence of the sun's rays
- Duration of the day
- Transparency of the atmosphere

Rotation of the earth on its axis

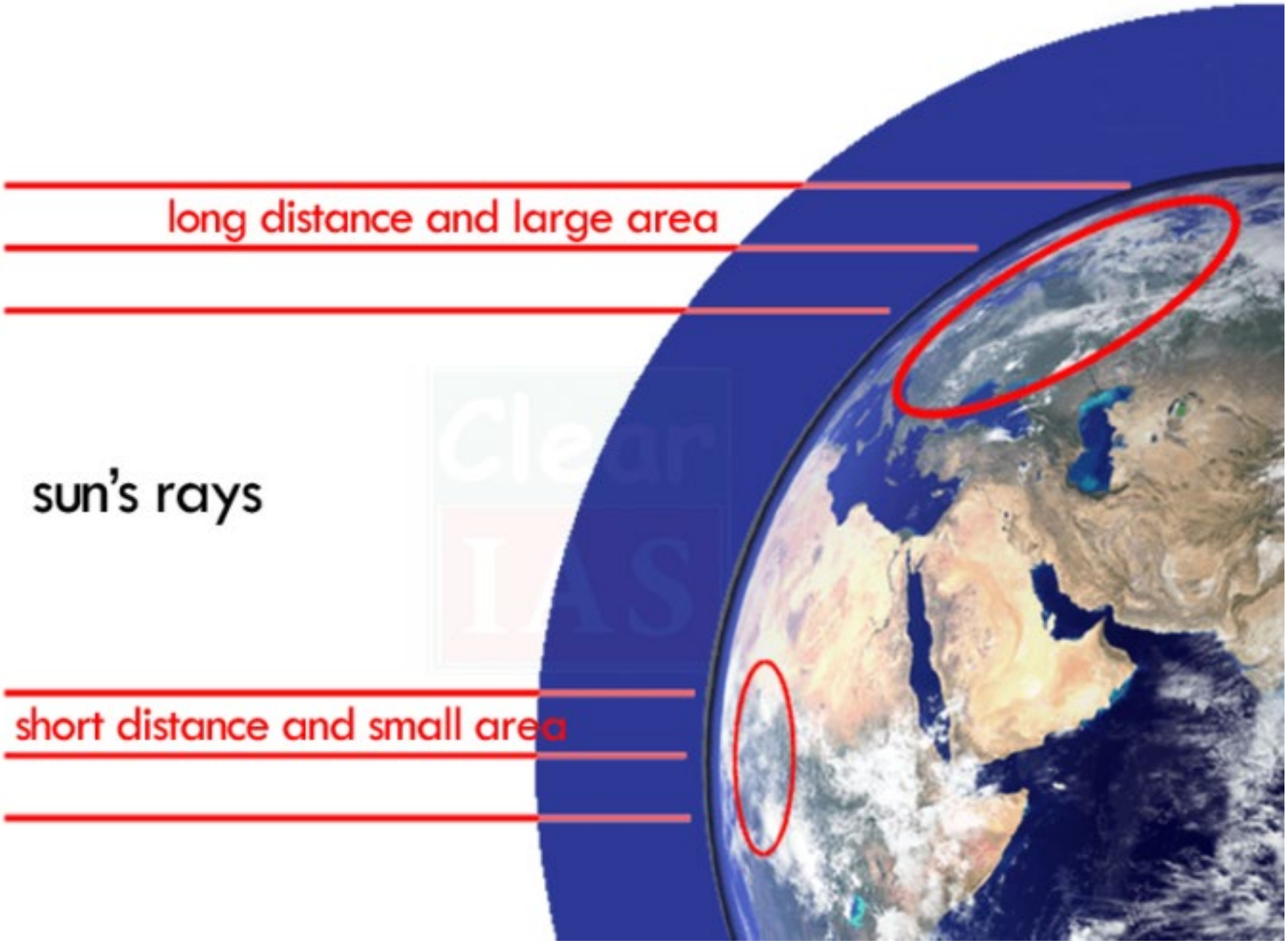
- The earth rotates on its own axis which makes an angle of 66.5 with the plane of its orbit around the sun.

- The rotation of the earth on this inclined axis has a greater influence on the amount of insolation received at different latitudes.


23.5°
66.5°

The angle of incidence of the sun's rays

- Since the earth is a geoid resembling a sphere, the sun's rays strike the surface at different angles at different places. This depends on the latitude of the place.
- The higher the latitude, the less is the angle they make with the surface of the earth.
- The area covered by the 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.


long distance and large area
sun's rays
short distance and small area

Duration of the day

- Duration of the day varies from place to place and season to season.
- It decides the amount of insolation received on the earth's surface.
- The longer the duration of the day, the greater is the amount of insolation received.
- Conversely shorter the duration of the day leads to receipt of less insolation

Transparency of the atmosphere

- The transparency of the atmosphere depends upon the cloud cover and its thickness, dust particles, water vapour, etc.
- They reflect, absorb or transmit insolation.
- Thick cloud hinders the solar radiation to reach the earth's surface.
- Similarly, water vapour absorbs solar radiation resulting in less amount of insolation reaching the surface.

- Maximum insolation is received over the subtropical desert, where the cloudiness is the least.
- The 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 the Atmosphere

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

- Terrestrial Radiation
- Conduction
- Convection
- Advection

Terrestrial Radiation

- The temperature of an object determines the wavelength of radiation.
- Temperature and wavelength are inversely proportional. Hotter the object, shorter is the length of the wave.
- So, when the earth's surface after being heated up by the insolation (in the form of short waves), it becomes a radiating body.
- The earth's surface starts to radiate energy to the atmosphere in the form of long waves.

- This is terrestrial radiation.
- This energy heats up the atmosphere from bottom to top.
- It should be noted that the atmosphere is transparent to short waves and opaque to long waves.
- The long-wave radiation is absorbed by the atmospheric gases particularly by carbon dioxide and other greenhouse gases.
- Thus, the atmosphere is indirectly heated by the terrestrial radiation.

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

Conduction (transfer of heat by contact)

- Conduction is the process of heat transfer from a warmer object to a cooler object when they come in contact with each other.
- The flow of heat energy continues till the temperature of both the objects become equal or the contact is broken.
- The conduction in the atmosphere occurs at the zone of contact between the atmosphere and the earth's surface.
- Conduction is important in heating the lower layers of the atmosphere

Convection (vertical transfer of heat)

- Transfer of heat by the movement of a mass or substance from one place to another, generally vertical, is called convection.
- The air of the lower layers of the atmosphere gets heated either by the earth's radiation or by conduction.
- The heating of the air leads to its expansion. Its density decreases and it moves upwards.
- The continuous ascent of heated air creates a vacuum in the lower layers of the atmosphere.
- As a consequence, cooler air comes down to fill the vacuum, leading to convection.

- The cyclic movement associated with the convectional process in the atmosphere transfer heat from the lower layer to the upper layer and heats up the atmosphere.
- The convection transfer of energy is confined only to the troposphere

Advection (horizontal transfer of heat)

- The transfer of heat through horizontal movement of air (wind) is called advection.
- Winds carry the temperature of one place to another.
- The temperature of a place will rise if it lies in the path of winds coming from warmer regions.
- The temperature will fall if the place lies in the path of the winds blowing from cold regions

Heat Budget of the Earth

- The earth as a whole does not accumulate or lose 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.
- This balance between the insolation and the terrestrial radiation is termed as the
- heat budget or heat balance of the earth

- Let us assume that the total heat received at the top of the atmosphere is 100 units.
- Roughly, 35 units are reflected into space even before reaching the earth's surface
- 27 units are reflected from the top of the clouds
- 2 units from the snow and ice-covered areas of the earth
- 6 units are reflected by the atmospheric layer itself.
- The reflected amount of radiation is called the albedo of the earth.

- The remaining 65 units are absorbed,
- 14 units within the atmosphere
- 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 the space directly
- 34 units are absorbed by the atmosphere.

- Forty-eight 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 balances the total of 65 units received from the sun.
- This is termed as heat budget or heat balance of the earth.

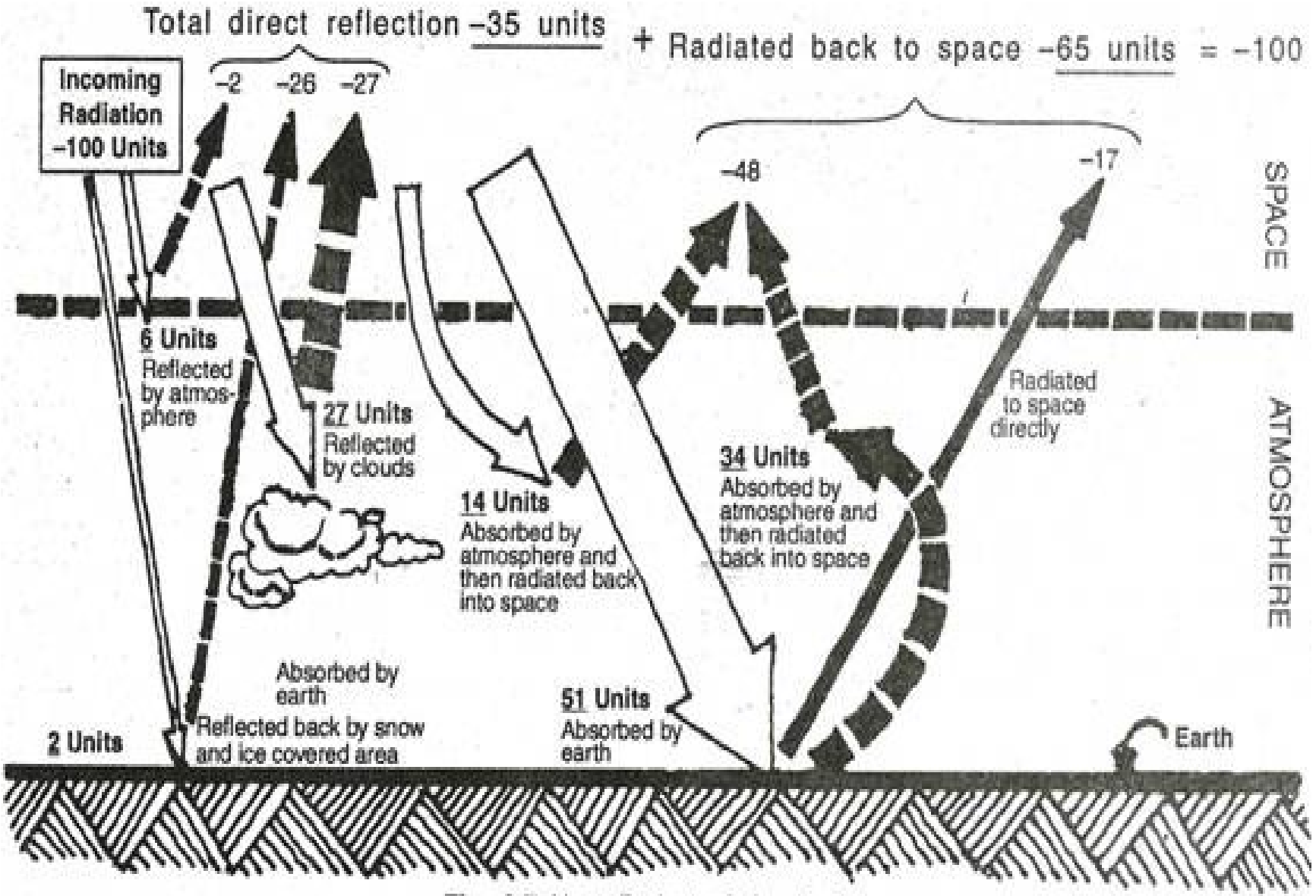


Fig. 2.7 Heat Budget of the Earth.

Albedo

- Albedo can be simply defined as a measure of how much light that hits a surface is reflected back without being absorbed.
- It is a reflection coefficient and has a value less than one.
- When the solar radiation passes through the atmosphere, some amount of it is reflected, scattered and absorbed.
- The reflected amount of radiation is called as the albedo of the earth.
- The value of albedo will be different for different surfac

- Because of the effect of albedo, highly developed areas such as urban cities can experience higher average temperatures than the surrounding suburban or rural areas, a phenomenon known as the “Urban Heat Island Effect ”.
- The higher average temperature can be attributed to less vegetation, higher population densities, and more infrastructures with dark surfaces (asphalt roads, brick buildings, etc.).

Table showing albedos of different materials from "Fundamentals of Remote Sensing and Airphoto Interpretation" by Avery and Berlin 1992

Material	Percent Reflected
Fresh Snow	80-95
Thick Cloud	70-80
Water (sun near horizon)	50-80
Old Snow	50-60
Light soil	25-45
Thin Cloud	20-30
Dry soil	20-25
Wet soil	15-25
Deciduous forest	15-20
Dark soil	5-15
Asphalt	5-10
Crops	10-25
Coniferous forest	10-15
Water (sun near zenith)	3-5

Planet	Albedo
Mercury	0.12
Venus	0.75
Earth	0.30
Moon	0.12
Mars	0.16
Jupiter	0.34
Saturn	0.34
Uranus	0.30
Neptune	0.29
Pluto	0.4

Variation in the net budget at the earth's surface

- Although the earth as a whole maintains a balance between the insolation and the terrestrial radiation
- this is not true what we observe at different latitudes.
- there are variations in the amount of insolation received at different latitudes.

- In the tropical region, the amount of insolation is higher than the amount of terrestrial radiation.
- Hence it is a region of surplus heat.
- In the polar region, the heat gain is less than the heat loss.
- Hence it is a region of deficit heat.
- Thus the insolation creates an imbalance of heat at different latitudes.

- This imbalance is nullified to some extent by winds and ocean currents, which transfer heat from surplus heat regions to deficit heat regions.
- This process of redistribution and balancing of latitudinal heat is commonly known as Latitudinal Heat Balance .