INSOLATION

FACTORS AFFECTING INSOLATION AND HEAT BUDGET OF THE EARTH

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Insolation

- Earth intercepts only **one in two billion parts** of solar radiation. This intercepted radiation is called Insolation.
- Insolation == Proportion of Solar energy received or intercepted by earth.
- Some heat within the core and mantle is transferred to the surface and ocean bottoms through volcanoes, springs and geysers. But this heat received at the surface form interiors of the earth is negligible compared to that received from sun.
- Earth receives Sun's radiation (heat) in the form of **short waves (visible light + wavelengths below visible light – most of it is ultraviolet radiation)** which are of electromagnetic nature. The earth absorbs short wave radiation during daytime and reflects back the heat received into space as **long-wave radiation (mostly infrared radiation)** during night.

Name	Wavelength	Frequency (Hz)	Photon Energy (eV)
Gamma ray	Less than 0.01 nm	more than 10 EHz	100 kev - 300+ GeV
X - ray	0.01 - 10 nm	30 EHz - 30 PHz	120 eV - 120 keV
Ultraviolet	10 nm - 400 nm	30 PHz - 790 THz	3 eV - 124 eV
Visible	390 nm - 750 nm	790 THz - 405 THz	1.7 eV - 3.3 eV
Infrared	750 nm - 1 mm	405 THz - 300 GHz	1.24 meV -1.7 eV
Microwave	1 mm - 1 meter	300 GHz - 300 MHz	1.24 μ eV - 1.24 meV
Radio	1 mm - km	300 GHz - 3 Hz	12.4 feV - 1.24 meV

Ways of Transfer of Heat Energy

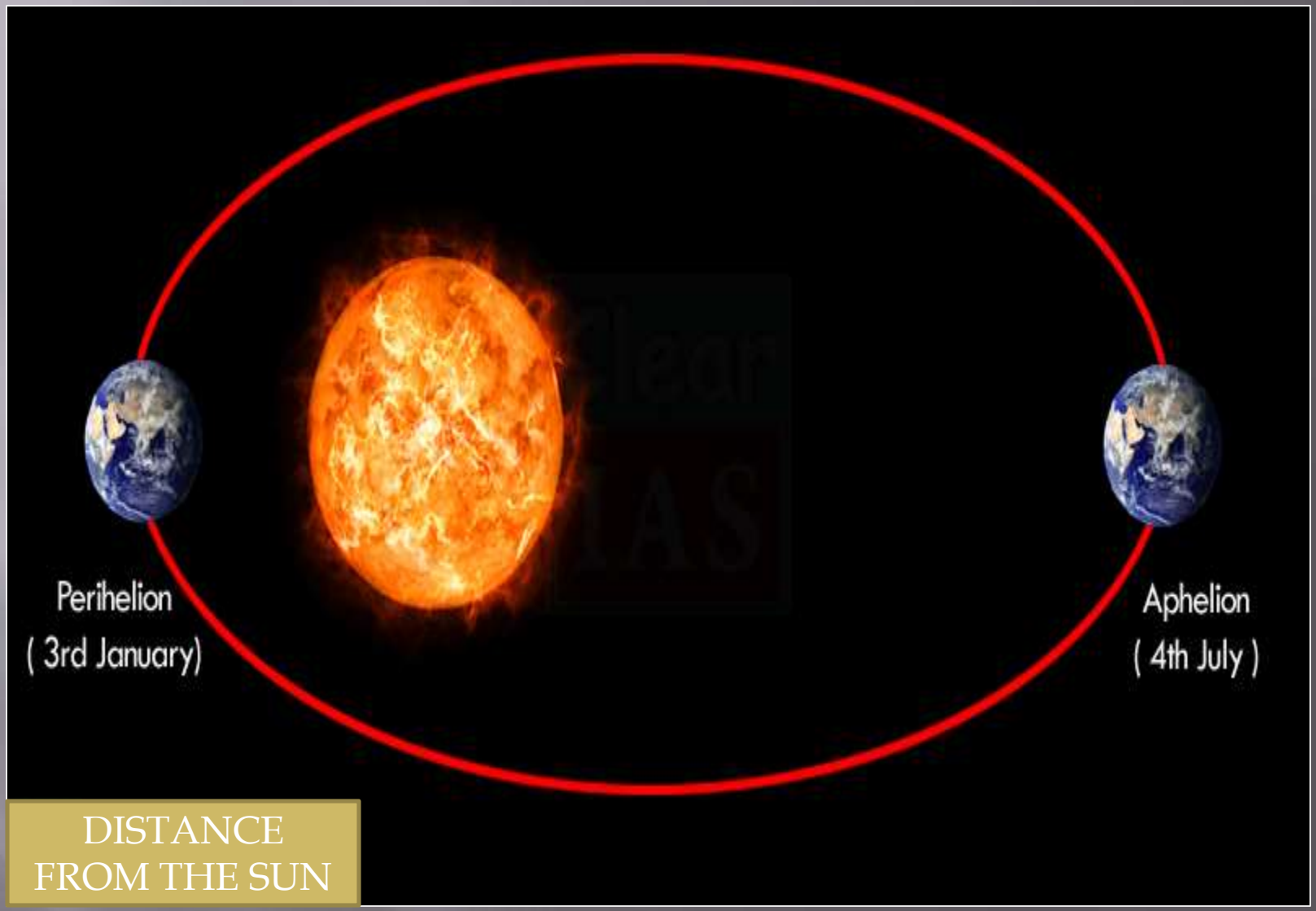
- The heat energy from the solar radiation is received by the earth through three mechanisms—
- Radiation == Heat transfer from one body to another **without actual contact or movement**. It is possible in relatively emptier space, for instance, from the sun to the earth through space.
- Conduction == Heat transfer through matter by **molecular activity**. Heat transfer in iron and other metals is by conduction. Generally, denser materials like water are good conductors and a lighter medium like air is a bad conductor of heat.
- Convection == Transfer of heat energy by **actual transfer of matter** or substance from one place to another. (heat transfer by convection cycles in atmosphere as well as oceans)

INSOLATION

- **Insolation or Incoming Solar Radiation**
- As we all know, the sun is the primary source of energy for the earth. The sun radiates its energy in all directions into space in short wavelengths, which is known as **solar radiation**.
- The earth's surface receives only a part of this radiated energy (2 units out of 1,00,00,00,000 units of energy radiated by the sun).
- 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.
- Moreover, 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.
- During the earth's revolution around the sun, the earth is farthest from the sun on **4th July**. This position of the earth is called **aphelion**.
  On **3rd January**, the earth is nearest to the sun. This position is called **perihelion**.

- 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.
- However, the effect of this variation is masked by some other factors like the distribution of land and sea and the atmospheric circulation. Hence the variation does not have a greater effect on daily weather changes on the surface of the earth.



DISTANCE FROM THE SUN

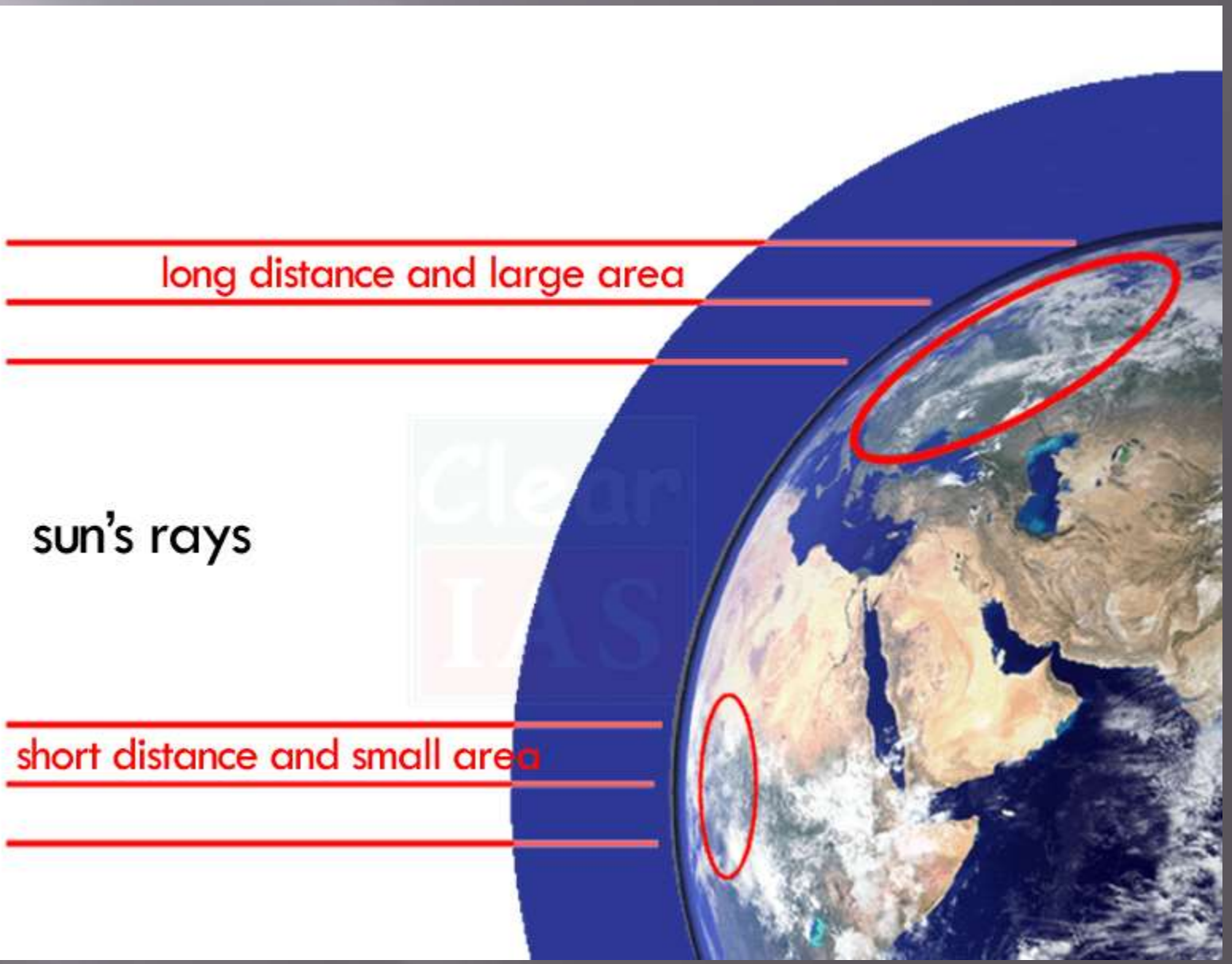
Factors influencing Insolation

- 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

- **1. 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.

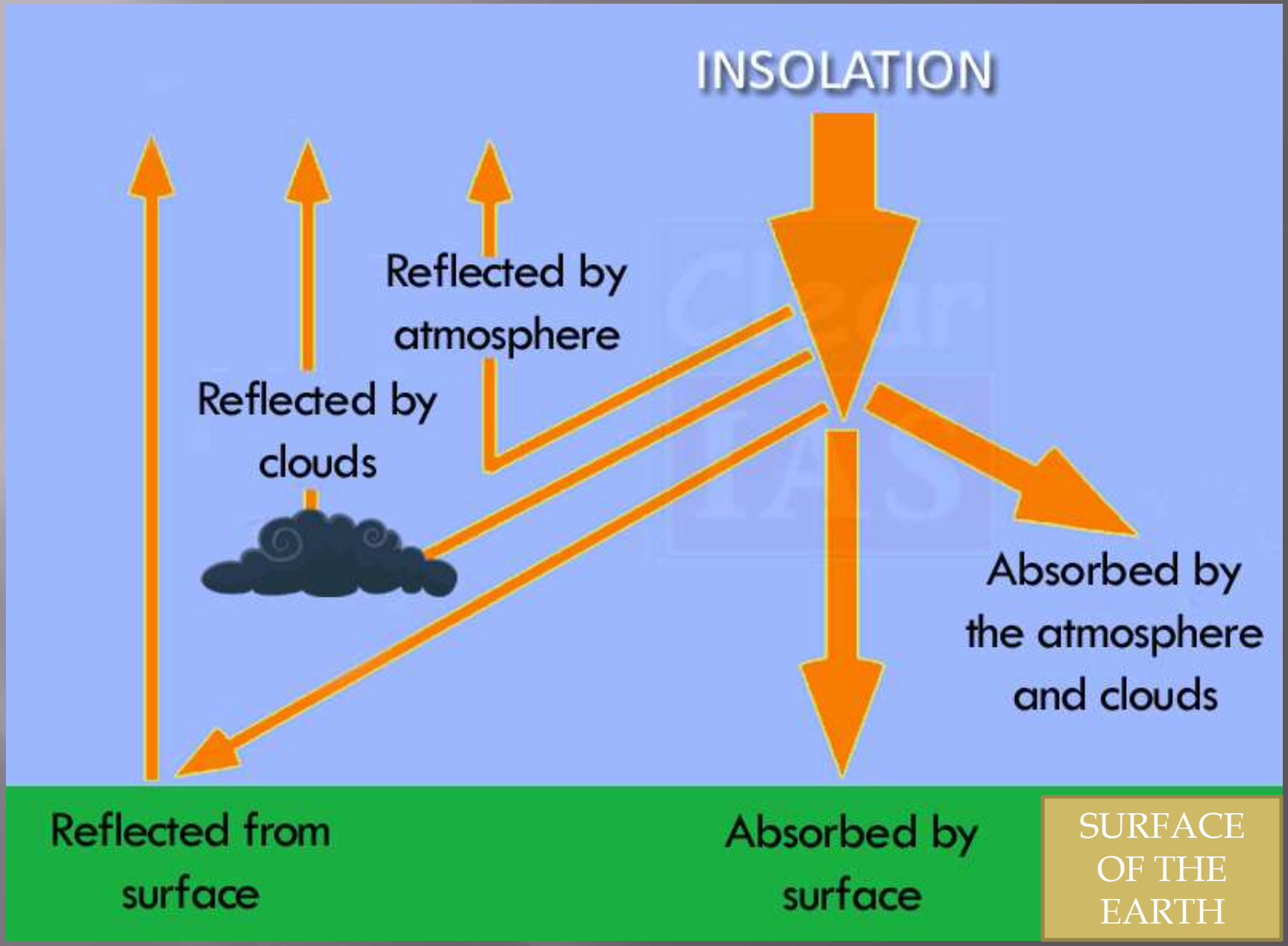
- **2. The angle of incidence of the sun's rays**

- 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.
- Moreover, the sun's rays with small angle traverse more of the atmosphere than rays striking at a large angle.
- Longer the path of the sun's rays, greater is the amount of reflection and absorption of heat by the atmosphere. As a result, the intensity of insolation is less.


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

- **3. 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.

- **4. 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.
- When the solar radiation passes through the atmosphere, water vapour, ozone and other gases absorb much of the near infrared radiation (mainly in the troposphere).
- Very small suspended particles in the troposphere scatter visible spectrum both to space and towards the earth's 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 results of scattering of the light within the atmosphere.


INSOLATION
Reflected by atmosphere
Reflected by clouds
Absorbed by the atmosphere and clouds
Reflected from surface
Absorbed by surface
SURFACE OF THE EARTH

- 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

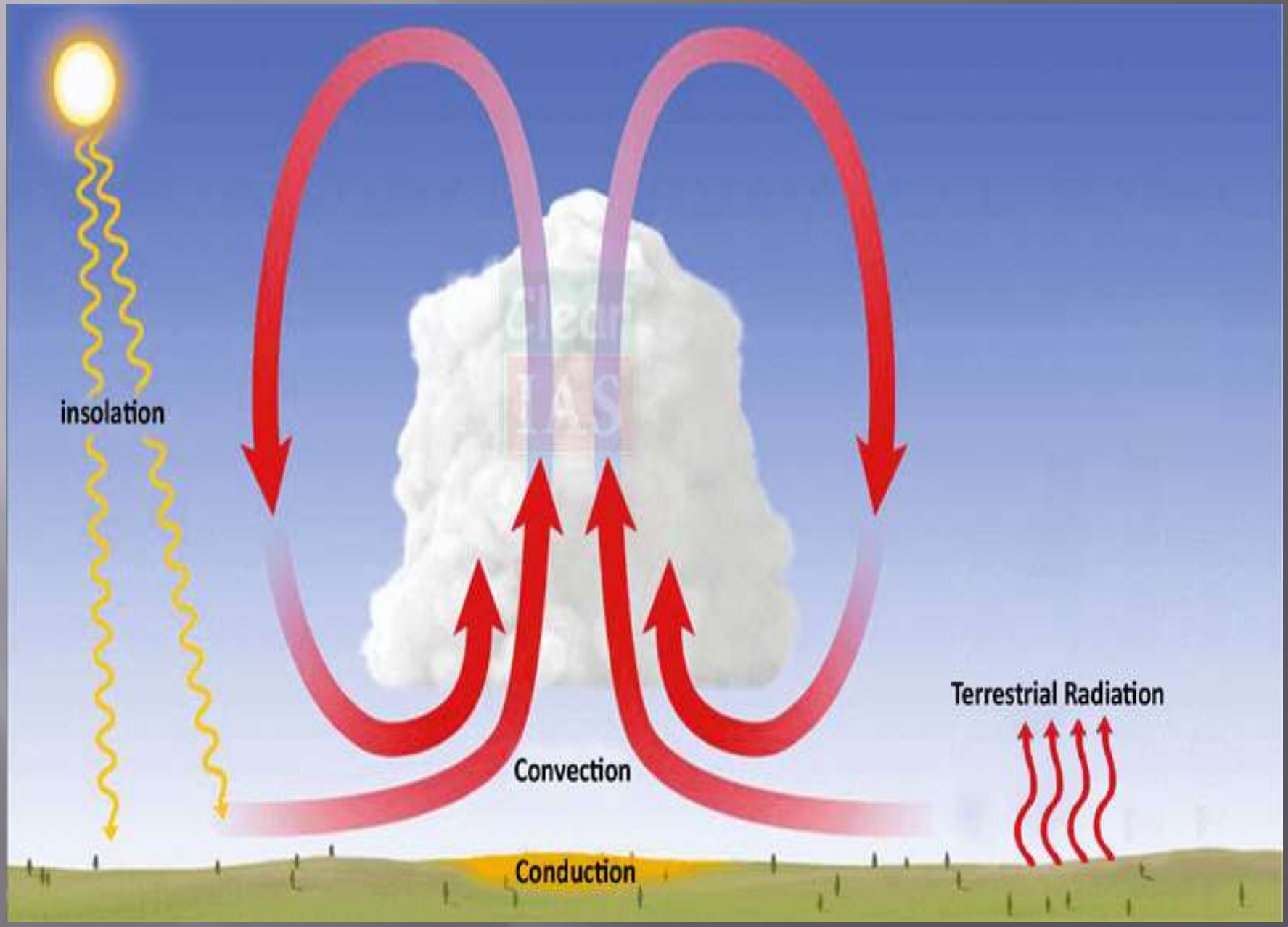
- The sun is the ultimate source of atmospheric heat and energy. There are different ways of heating and cooling of the atmosphere. They are:
- Terrestrial Radiation
- Conduction
- Convection
- Advection

- **. Terrestrial Radiation**
- Before discussing terrestrial radiation, the following facts about radiation are worth noting.
- i) All objects whether hot or cold emit radiant energy continuously.
- ii) Hotter objects emit more energy per unit area than colder objects.
- iii) 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 what we call as **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.

- **2. 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.

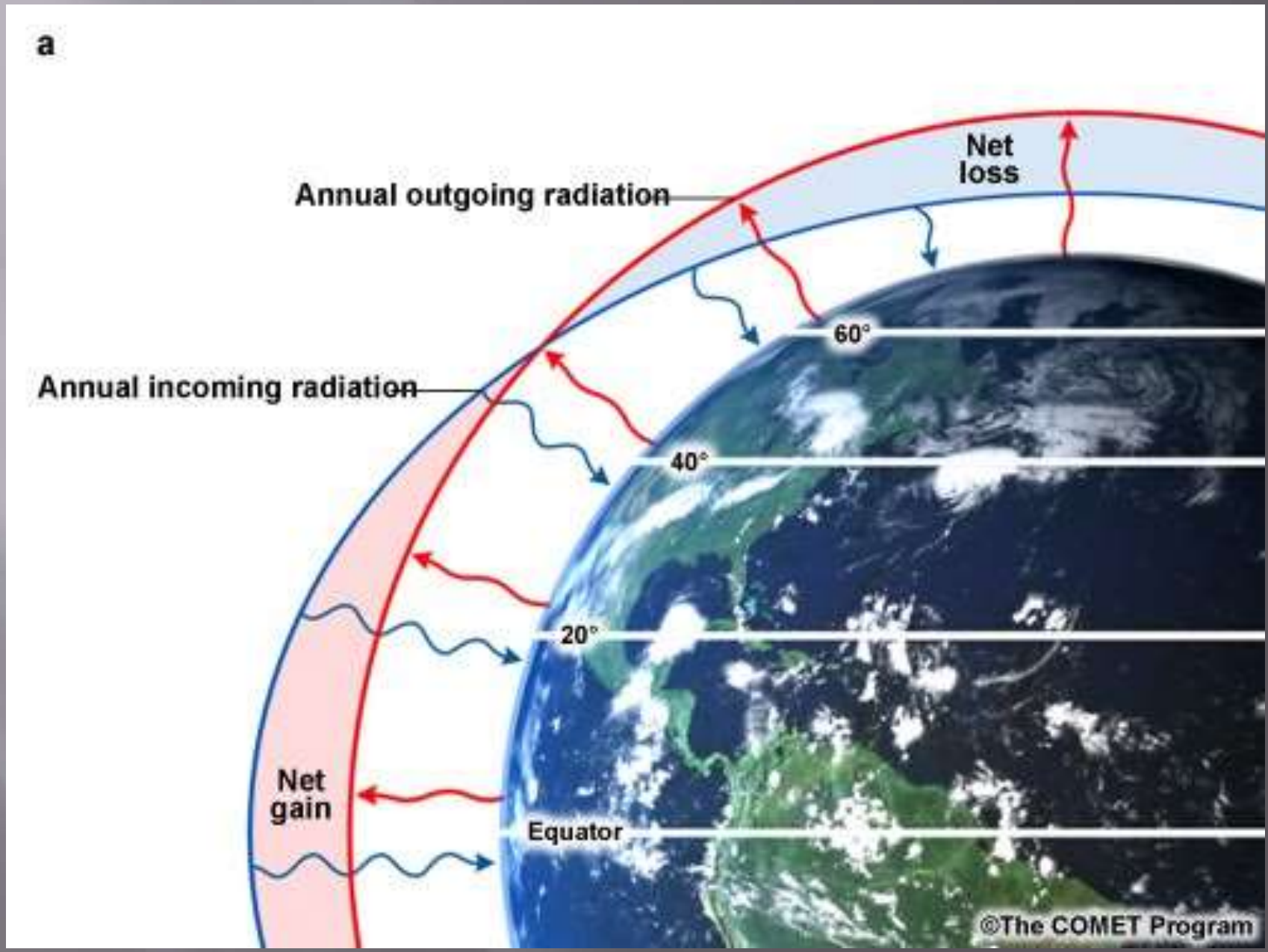
- **3. Convection (vertical transfer of heat)**
- Transfer of heat by the movement of a mass or substance from one place to another, generally vertical, is called convection.
- The air of the lower layers of the atmosphere gets heated either by the earth's radiation or by conduction. The heating of the 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.


insolation
Convection
Conduction
Terrestrial Radiation

- **4. 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.
- Horizontal movement of the air is relatively more important than the vertical movement. In the middle latitudes, most of diurnal (day and night) variations in daily weather are caused by advection alone.
- In tropical regions particularly in northern India during the summer season, local winds called **'Loo'** is the outcome of advection process.

Latitudinal Heat Balance

- The amount of insolation received varies from latitude to latitude.
- Regions within the equator and 40° N and S latitudes receive abundant sunlight and hence more heat will be gained than lost. Hence they are **energy surplus regions.**
- Regions beyond 40° N and S latitudes lose more heat than that gained from sunlight. Hence they are **energy deficit regions** (This is because of **slant sunlight and high albedo of polar regions**).
- Going by this logic, the tropics should have been getting progressively hotter and the poles getting progressively cooler. And the planet would have been inhospitable except for few regions near mid-latitudes. But, in reality, this does not happen.
- The atmosphere **(planetary winds)** and the oceans **(ocean currents)** transfer excess heat from the tropics (energy surplus region) towards the poles (energy deficit regions) making up for heat loss at higher latitudes.
- ***And most of the heat transfer takes place across the mid-latitudes (30° to 50°)[more while studding jet streams and cyclones], and hence much of the stormy weather is associated with this region.***
- Thus, the transfer of surplus energy from the lower latitudes to the deficit energy zone of the higher latitudes, maintains an overall balance over the earth's surface.


a
Net loss
Annual outgoing radiation
60°
Annual incoming radiation
40°
20°
Net gain
Equator
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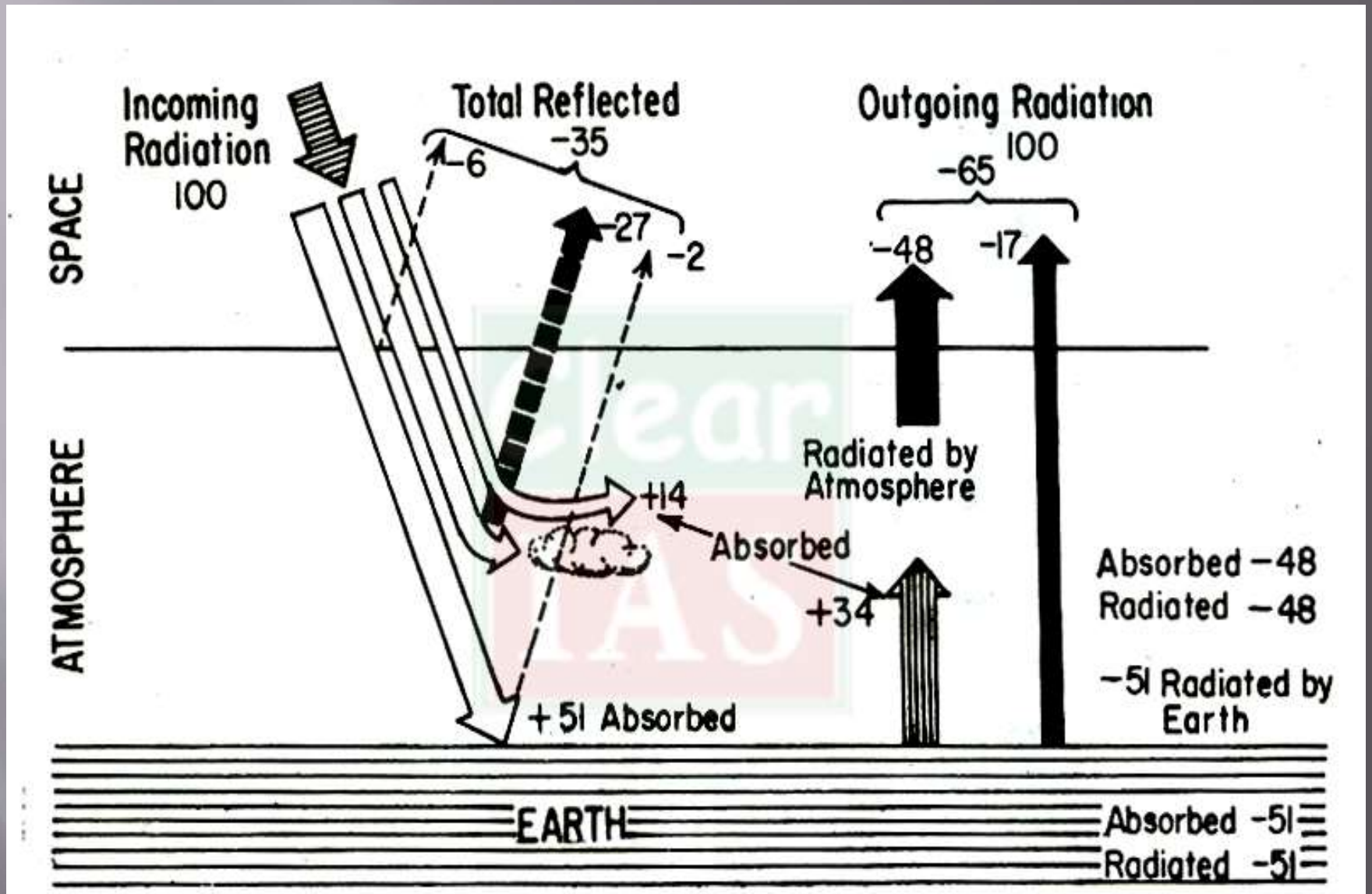
Heat Budget of the Earth

- 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**.
- This is why the earth neither warms up nor cools down despite the huge transfer of heat that takes place.



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 surfaces.
- 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.).

Surface	Details	Albedo
Soil	Dark and Wet	0.05 – 0.40
	Light and Dry	
Sand		0.15 - 0.45
Grass	Long	0.16 – 0.26
	Short	
Agricultural Crops		0.18 – 0.25
Tundra		0.18 – 0.25
Forest	Deciduous	0.15 – 0.20
	Coniferous	0.05 – 0.15
Water	Small Zenith Angle	0.03 – 0.10
	Large Zenith Angle	0.10 – 1.00
Snow	Old	0.40 – 0.95
	Fresh	
Ice	Sea	0.30 – 0.45
	Glacier	0.20 – 0.40
Clouds	Thick	0.60 – 0.90
	Thin	0.30 – 0.50

Fresh snow > Old Snow > Thick cloud > Thin cloud > Sea ice > Glacier > Dry sand > Dry soil > Grass > Crops > >

Albedo of different surfaces

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.
- As we have discussed earlier, 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**.