Solar Radiation, Heat Balance and Temperature

- Solar Radiation – The earth receives almost all of its energy from the sun and it radiates the energy back to space. As a result, the earth neither warms up nor does it get cooled over a period of time. The energy received by the earth is termed as insolation- incoming solar radiation.
- Aphelion and Perihelion – During the revolution of earth around the sun, it is farthest from the sun on 4th July (152 million km) and this position is called aphelion. The earth is nearest to the sun on 3rd Jan (147 million km) and this position is called perihelion. Therefore, the solar energy received by the earth on 3rd Jan is slightly more than the amount received on 4th July. However, this variation in solar output does not greatly affect the daily weather changes on the surface of the earth, because this variation is masked by other factors like the distribution of land and sea, and the atmospheric circulation.

Variability of insolation at the surface of the earth

The amount and intensity of solar radiation received by the earth (insolation) varies during a day, in a season and in a year. The following are the factors which cause these variations-

1. The rotation of the earth on its axis.
2. The angle of inclination of the rays of the sun
3. The length of the day.
4. The transparency of the atmosphere, and
5. The configuration of the land in terms of its aspect.

(The insolation depends more on the first three factors)

The tilted position of the earth's axis is known as the inclination of the earth's axis. The earth's rotation axis makes an angle of about 66.5° with the plane of its orbit around the sun and this greatly influences the amount of insolation received at different places.

The amount of insolation also depends on the angle of inclination of the sun rays. The higher the latitude the less is the angle they make with the surface of the earth which results in slant sun rays.. The slant rays cover more area than the vertical rays. When more area is covered , the energy gets distributed and the net energy received per area decreases. Also, the slant rays have to pass through greater depth of the atmosphere which results in more absorption, diffusion and scattering.

Before striking the earth;s surface, the incoming solar radiation passes through the atmosphere. The atmosphere is largely transparent to shortwave solar radiations. Water vapours, ozone and other gases present in the atmosphere absorb most of the near infrared radiations. Small suspended particles in the troposphere scatter the visible spectrum both to space and towards the surface of the earth. The blue colour of the sky and the red colour of the rising and setting sun are the result of scattering of light within the atmosphere.

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 amount of solar radiation received at the surface of the earth is more in the tropics (about 320 watts/m^2) and least in the poles (70 watts/m^2). The subtropical deserts receive maximum insolation as the atmosphere

is more transparent (least cloudiness). At the same latitude, the insolation is more over the continents than over the oceans.

Terrestrial Radiation, Heating and Cooling of the Atmosphere

- Terrestrial Radiation – The solar radiation received by the earth is in short wave forms and it heats up its surface. The earth acts as a radiating body and radiates energy in the form of long waves to the atmosphere. This process is called terrestrial radiation and these long wave radiations heats up the atmosphere from below. The atmosphere inturn radiates and transmits heat to space. This maintains the constant temperature at the earth's surface, as the amount of heat received from the sun is transmitted to space.
- Heating and cooling of the atmosphere (conduction, convection and advection)-

The terrestrial radiation heats up the lower atmosphere which is directly in contact with the surface of the earth. This process is called conduction in which there is flow of energy from the warmer to cooler body and the transfer continues till both the bodies attain the same temperature.

As the lower layer of atmosphere heats up, it rises vertically in the form of currents and transmits the heat of the atmosphere. This vertical heating of the atmosphere is called convection and is restricted only to the troposphere.

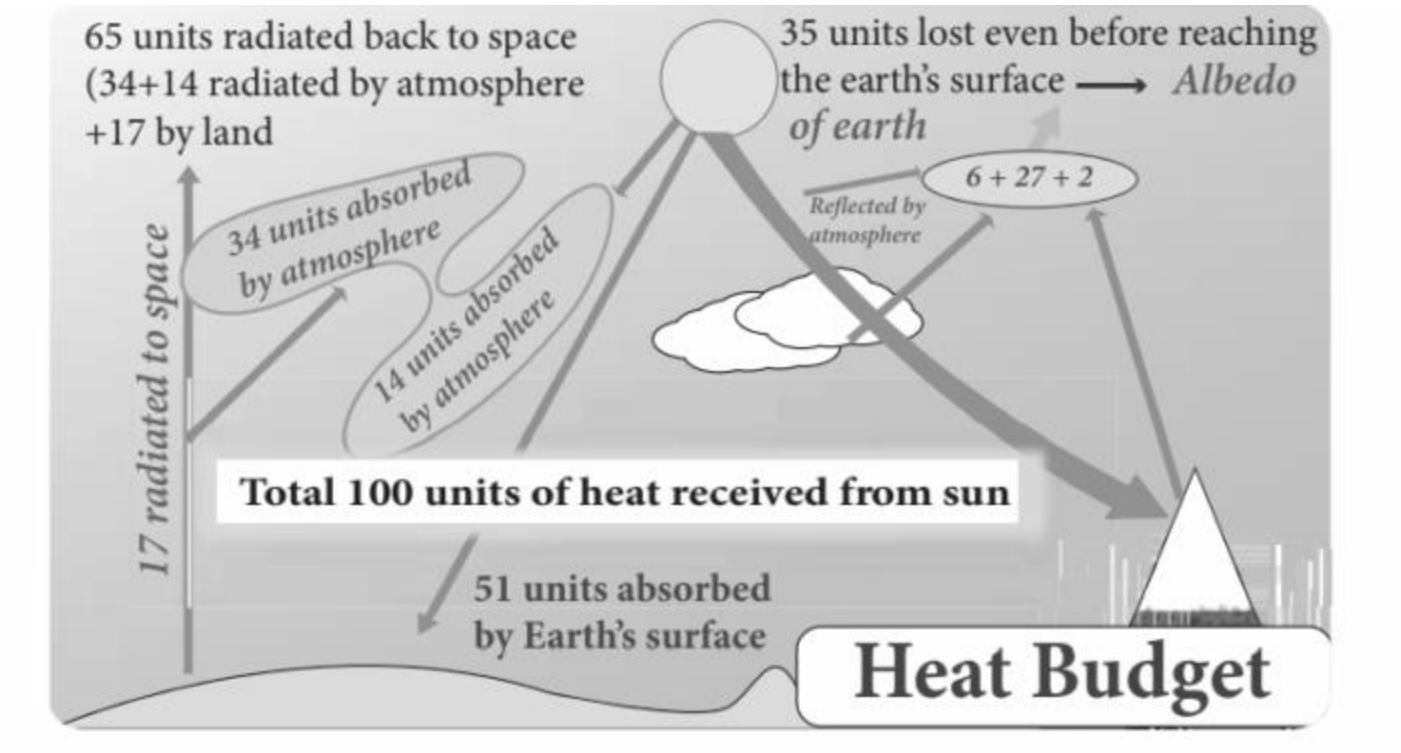
The transfer of heat through horizontal movement of air is called advection. During summer in India, the local winds called loo is the outcome of the advection process. Advection is relatively more important than convection. In middle latitude, most of the diurnal (day and night) changes are the result of advection alone.

Heat Budget of the Earth –

The surface of the earth maintains its temperature, this is because the amount of heat received by the earth in the form of insolation equals the amount of heat lost by the earth through terrestrial radiation.

When 100% of solar radiation reaches the earth's atmosphere, about 35% is reflected back to space even before reaching the surface of the earth. The reflected amount is called the albedo of the earth. This amount of energy does not heat either the earth or the atmosphere.

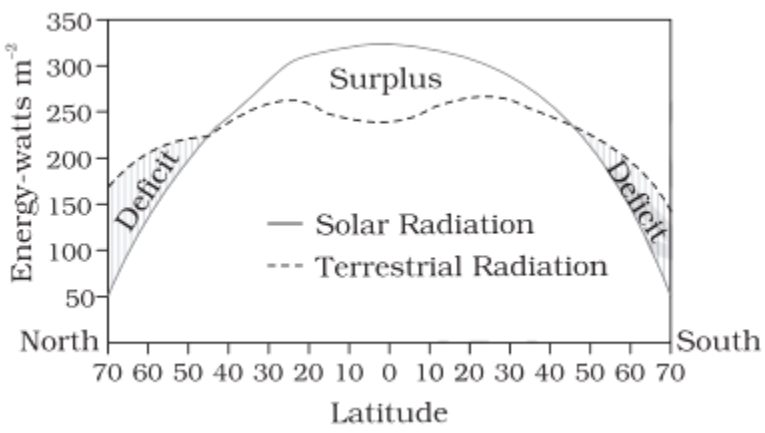
Out of the remaining 65% of the energy, 14% are absorbed by the atmosphere and the rest, 51% by the surface of the earth (34% through direct solar radiation and 17% from scattered radiation). 51% of energy received by the earth is radiated back as terrestrial radiation. 17% are radiated back to space directly and the remaining 34% are absorbed by the atmosphere (6% absorbed directly by the atmosphere, 9% through convection and 1(5 through latent heat of condensation). The total 48% absorbed by the atmosphere (14% from insolation and 34% from terrestrial radiation) are also radiated back to space. Thus, the total radiation returning back from the atmosphere and the earth is respectively 48+17=65% which balances the total of 65% received from the sun . This is termed the heat balance or heat budget of the earth, and explains how the earth maintains its temperature despite the huge transfer of heat.



(Image Source- SCERT, Tamil Nadu)

Variation in the Net Heat Budget at the surface of the Earth

- The insolation received at the surface varies from place to place, some part of the earth has surplus radiation balance while the other part is deficit.
- There is a surplus of net radiation balance between 40°N and 40°S and the regions near the poles are in deficit. The extra heat energy from the tropics gets redistributed towards the poles, and as a result the tropics don't get progressively heated up due to accumulation of excess heat nor the high altitudes get permanently frozen due to excess deficit.



(Source-NCERT)

Factors controlling temperature distribution

The temperature at any place is influenced by the following factors-

1. Latitude of the place – The temperature of a place depends upon the solar radiation received . The insolation varies according to the latitude, so the temperature also varies accordingly. The solar radiations pass vertically along the equator. The angle of incidence decreases from equator towards the poles. The area heated by the solar radiation increases towards the poles, therefore temperature decreases from the equator to the poles.
2. Altitude of the place – The terrestrial radiation heats up the atmosphere from below. Hence, the places near the sea level have higher temperature than the places at higher altitudes. Generally, temperature decreases with the increase in height. The vertical decrease in temperature of the troposphere is called the “normal lapse rate” or “vertical temperature gradient”. The temperature reduces at the rate of 6.5°C per km of ascent.
3. Distance from the sea – The location of a place with respect to the sea also influences the temperature of a place. The variation of temperature over the sea is less compared to the land because the land heats up and cools down quickly, while the sea gets heated up slowly and also loses heat slowly. The places near the sea come under the moderating influence of the sea and land breezes which moderate the temperature. .
4. Air mass and ocean currents – 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.

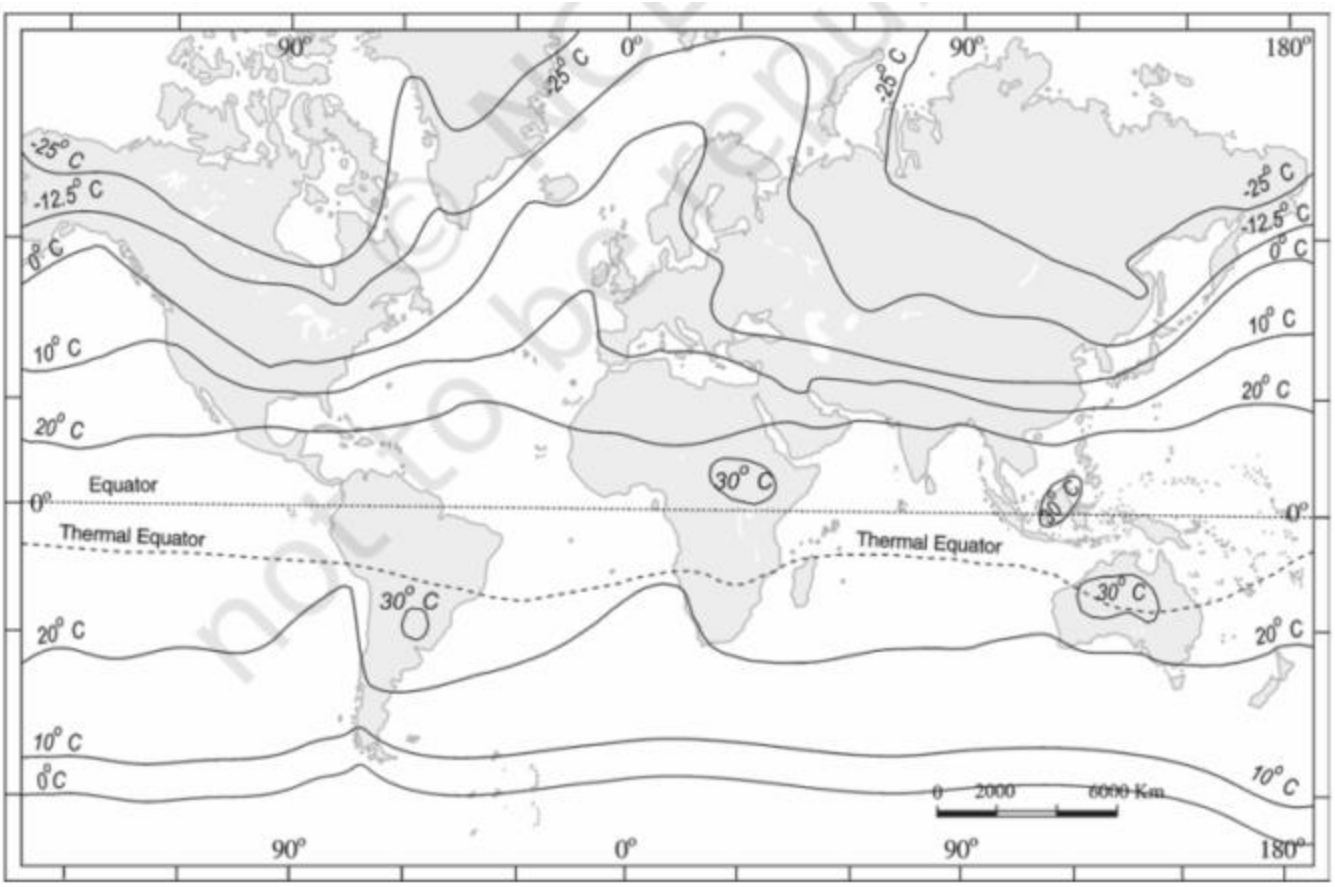
The places located on the coast where the warm ocean currents flow experience higher temperature than the places located on the coast where the cold currents flow.

Global Distribution of Temperature–

The global distribution of temperature (horizontal) is generally shown on the map with the help of isotherms. The isotherms are imaginary lines joining places having equal temperature at mean sea level. The temperature distribution is understood by studying the temperature distribution in the months of January and July. The isotherms are generally parallel to the latitude, however there is deviation in this trend which is more pronounced in January, particularly in the northern hemisphere, than in July.

January Isotherms-

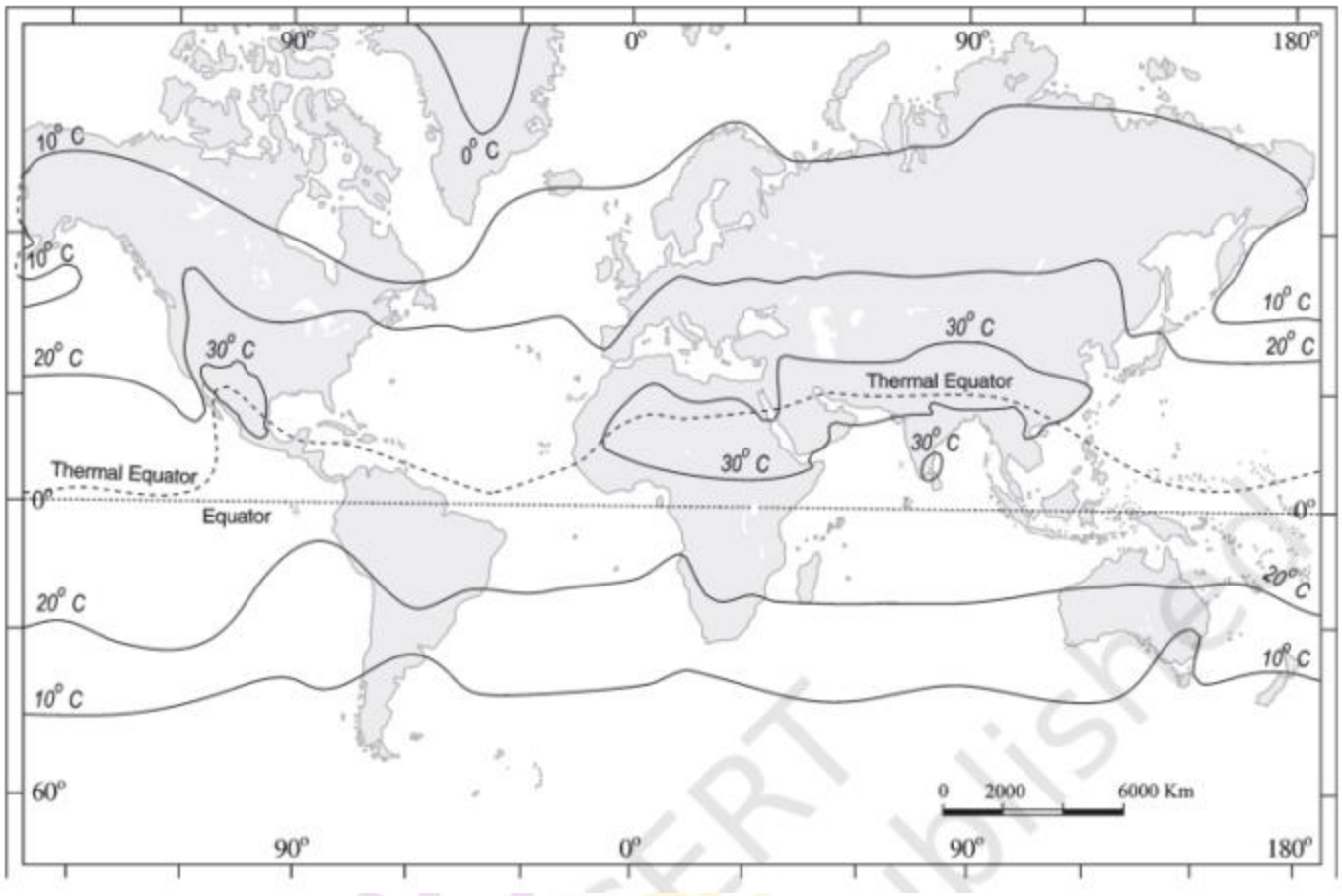
- In January, there is winter in the northern hemisphere and summer in the southern hemisphere.
- The isotherms deviate towards the north over the oceans and to the south over the continent. This deviation is observed more in the northern hemisphere because the land surface area is larger than in the southern hemisphere. 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 sharply.
- In the southern hemisphere, the isotherms are more or less parallel to the latitudes and the temperature varies gradually. The effect of the ocean is well pronounced in the southern hemisphere.
- The thermal equator lies to the south of the geographical equator because the ITCZ (InterTropical Convergence Zone) shifts southwards with the apparent movement of the sun.



(Image Source -NCERT)

July Isotherms-

- In July, there is summer in the northern hemisphere and winter in the southern hemisphere.
- The isothermal behaviour in July is opposite to the behaviour observed in January. The isotherms run generally parallel to the latitudes.
- Land masses get overheated and the hot tropical winds move into the interiors of the northern hemisphere. The oceans are comparatively cooler and carry a moderating effect into tropical interiors.
- The thermal equator lies to the north of the geographical equator, with the apparent movement of the sun.



(Image Source – NCERT)

Inversion of Temperature

The condition at which the temperature increases with the altitude is called “inversion of temperature”. In this condition warm air lies over the cold air. Normally temperature decreases with the increase in elevation, which is called normal lapse rate (temperature decreases at the rate of 6.5°C per km). At times, the normal lapse rate is inverted which is called inversion of temperature. It can occur near the earth’s surface or upper troposphere.

The conditions for inversion of temperature are –

1. Long winter nights – The heat of the day is radiated off during the night, and by early morning hours, the earth is cooler than the air above. Temperature inversion is a common phenomenon in the polar regions.
2. Clear sky – Clouded sky acts as a shield and prevents temperature from escaping the ground. The clear sky allows higher amounts of terrestrial radiation to escape which leads to lower temperature at low level.
3. Dry air near the ground – The dry air absorbs less terrestrial radiation and allows the radiation to escape.
4. Calm and stable air – Calm and stable air enables warm air to rise smoothly and turbulence prevents inversion of temperature as it leads to mixing of warm and cool air.

Effects of Temperature Inversion-

1. An inversion acts as a cap on the upward movement of air from the layers below. Therefore, it hinders the diffusion of smoke, dust and other pollutants. These get collected beneath the inversion layer and spread horizontally to fill the lower strata of the atmosphere.
2. Inversion layer prevents clouds from growing high enough to produce showers.
3. Visibility is greatly reduced due to the accumulation of smoke and dust particles below the inversion.
4. Dense fogs in mornings are common occurrences especially during winter.

Valley Inversion – It takes place in hills and mountains due to air drainage. During winter nights, the upper surface radiates heat and gets cooled. Cold air being heavy and dense moves under the influence of gravity. It moves down the slope to pile up deeply in pockets and valley bottoms with warm air above it. This is also called air drainage type of inversion.