CLIMATOLOGY

UNIT – II: Insolation - Heat balance of the earth, Temperature: Measurement, Horizontal and Vertical Distribution – Factors affecting the Distribution of Temperature.

Insolation, Heat Budget of the Earth, Temperature: Measurements, Horizontal and vertical distribution – Factors affecting the distribution of Temperature.

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.

Factors influencing Insolation

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

1. Rotation of the earth on its axis
2. The angle of incidence of the sun's rays
3. Duration of the day
4. Transparency of the atmosphere

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:

1. Terrestrial Radiation
2. Conduction
3. Convection
4. Advection

1. 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.

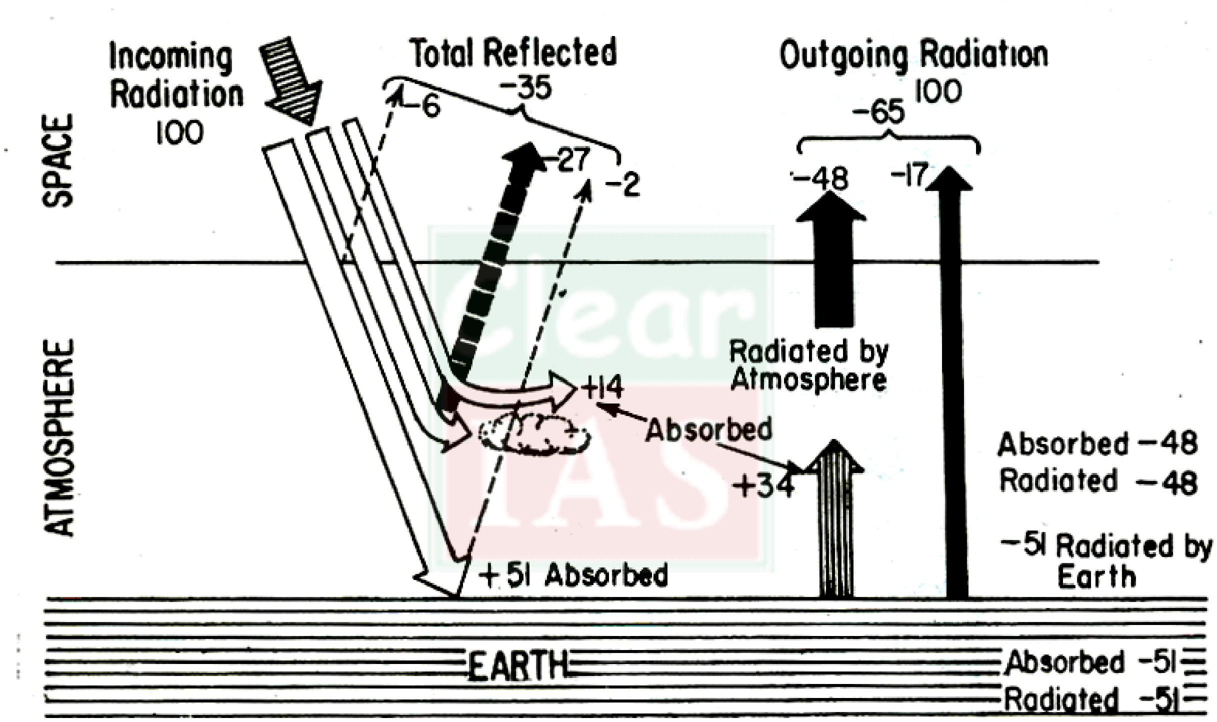
ii) Hotter objects emit more energy per unit area than colder objects.

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.

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.

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.

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

- 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.).

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.

Temperature Measurements:

Fahrenheit

Daniel Gabriel Fahrenheit (1686-1736) was a German physicist who is credited with the invention of the alcohol thermometer in 1709 and the mercury thermometer in 1714. The Fahrenheit temperature scale was developed in 1724. Fahrenheit originally established a scale in which the temperature of an ice-water-salt mixture was set at 0 degrees. The temperature of an ice-water (no salt) mixture was set at 30 degrees and the temperature of the human body was set at 96 degrees. Using this scale, Fahrenheit measured the temperature of boiling water as 212°F on his scale. He later adjusted the freezing point of water from 30°F to 32°F, thus making the interval between the freezing and boiling points of water an even 180 degrees (and making body temperature the familiar 98.6°F). The Fahrenheit scale is still commonly used in the United States.

Celsius

Anders Celsius (1701-1744) was a Swedish astronomer credited with the invention of the centigrade scale in 1742. Celsius chose the melting point of ice and the boiling point of water as his two reference temperatures to provide for a simple and consistent method of thermometer calibration. Celsius divided the difference in temperature between the freezing and boiling points of water into 100 degrees (thus the name *centi*, meaning one hundred, and *grade*, meaning degrees). After Celsius's death, the centigrade scale was renamed the Celsius scale and the freezing point of water was set at 0°C and the boiling point of water at 100°C.

Kelvin

Lord William Kelvin (1824-1907) was a Scottish physicist who devised the Kelvin (K) Scale in 1854. The Kelvin scale is based on the idea of absolute zero, the theoretical temperature at which all molecular motion stops and no discernible energy can be detected. In theory, the zero point on the Kelvin scale is the lowest possible temperature that exists in the universe: -273.15ºC. The Kelvin scale uses the same unit of division as the Celsius scale; however, it resets the zero point to absolute zero: -273.15ºC. The freezing point of water is therefore 273.15 Kelvins, and 373.15

K is the boiling point of water. The Kelvin scale, like the Celsius scale, is a standard SI unit of measurement used commonly in scientific measurements. Since there are no negative numbers on the Kelvin scale (because theoretically nothing can be colder than absolute zero), it is very convenient to use Kelvins when measuring extremely low temperatures in scientific research.

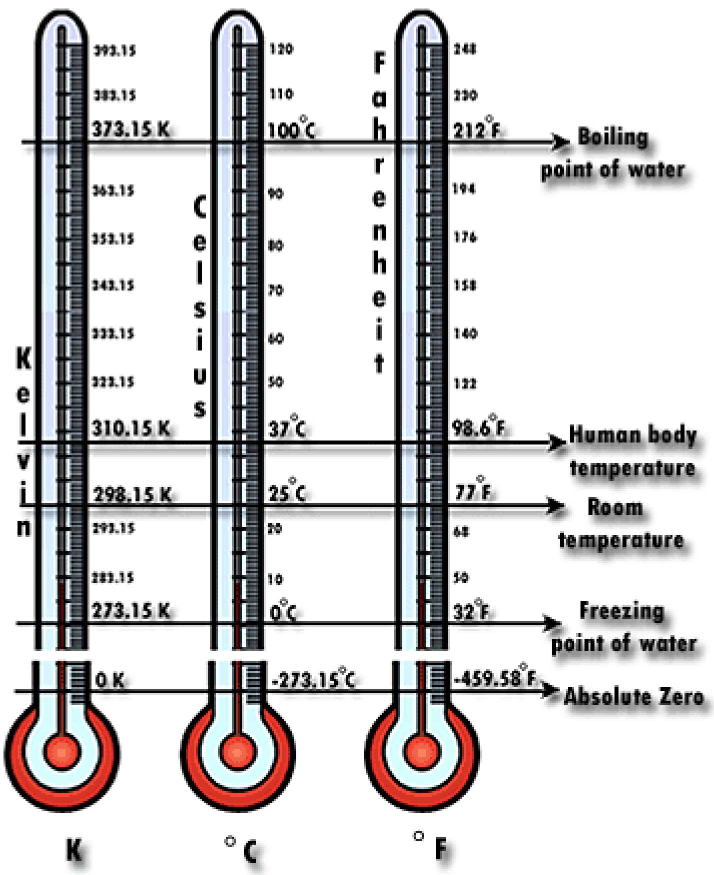


Figure 1: Comparison of three different temperature scales.

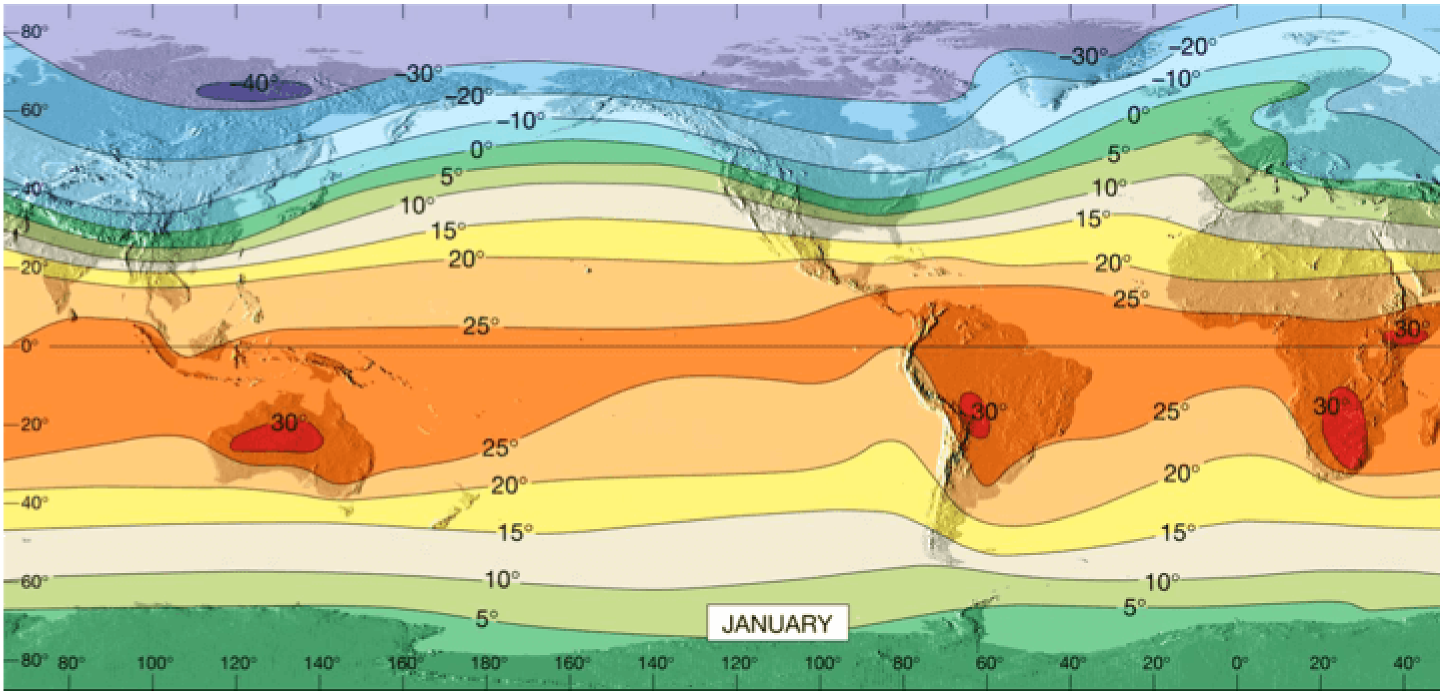
From	to Fahrenheit	to Celsius	to Kelvin
ºF	F	(ºF - 32)/1.8	(ºF-32)*5/9+273.15
ºC	(ºC * 1.8) + 32	C	ºC + 273.15
K	(K-273.15)*9/5+32	K - 273.15	K

Table 1: Temperature conversion

Horizontal and vertical distribution of Temperature:

Horizontal Distribution of Temperature

- Distribution of temperature across the latitudes over the surface of the earth is called its horizontal distribution.
- On maps, the horizontal distribution of temperature is commonly shown by isotherms.
- Isotherms are line connecting points that have an equal temperature.



- When we analyse an isotherm map, it can be seen that the horizontal distribution of temperature is uneven.

The factors responsible for the uneven horizontal distribution of temperature are:

1. Latitude

- In the previous article, we have studied that the angle of incidence of sun's rays goes on decreasing from the equator towards the poles.
- Higher the angle of incidence, higher is the temperature. Similarly, lower the angle of incidence, lower is the temperature.
- This is why the temperature is higher near the tropical regions and decreases towards the poles.

2. Altitude

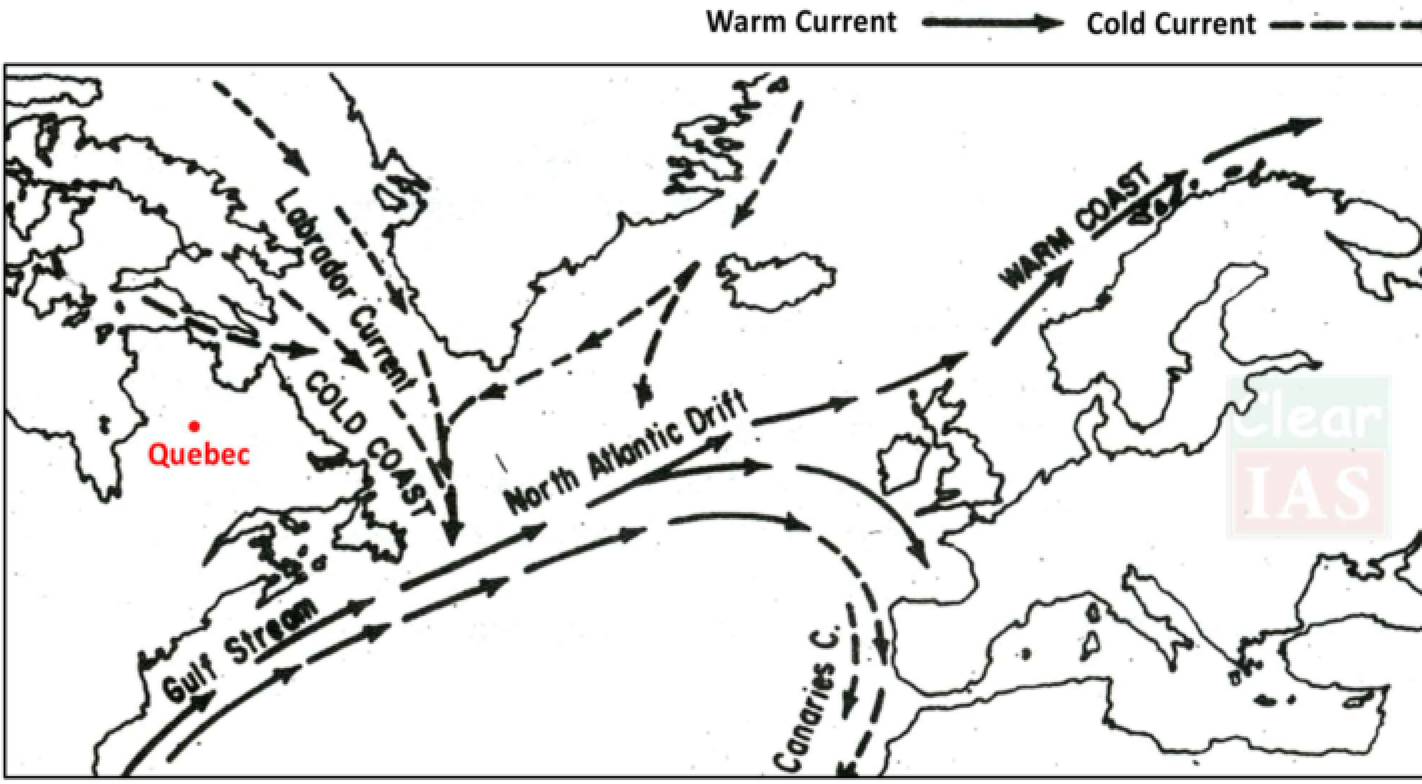
- As we all know, the temperature in the troposphere goes on decreasing with increase in height.
- Temperature decreases at an average rate of nearly 6 degree Celsius per 1000 m altitude, which is known as Normal Lapse Rate.

3. Land and Sea Contrast

- Compared to land, the sea gets heated slowly and loses heat slowly. Land heats up and cools down quickly.
- As a result, the temperature is relatively higher on land during day time and it is higher in water during the night.
- Also, the places situated near the sea come under the moderating influence of the sea and land breezes which moderates the temperature.
- There are also seasonal variations in the temperature of land and sea. During summer, the air above land has a higher temperature than the oceans. But the air above oceans gets higher temperature than landmass in winter.
- Notwithstanding the great contrast between land and water surfaces, there are differences in the rate of heating of different land surfaces. A snow-covered land as in polar areas warms very slowly because of a large amount of reflection of solar energy. A vegetation covered land does not get excessively heated because a great amount of insolation is used in evaporating water from the plants.

4. Ocean Currents

- Ocean Currents are of two types – warm and cold.
- Warm currents make the coasts along which they flow warmer, while cold currents reduce the temperature of the coasts along which they flow.
- The North-Western European Coasts do not freeze in winter due to the effect of North Atlantic Drift (a warm current), while the Quebec on the coast of Canada is frozen due to the Cold Labrador Current flowing along it, though the Quebec is situated in lower latitudes than the North-West European Coast.



5. Air Masses

- 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.

6. Vegetation Cover

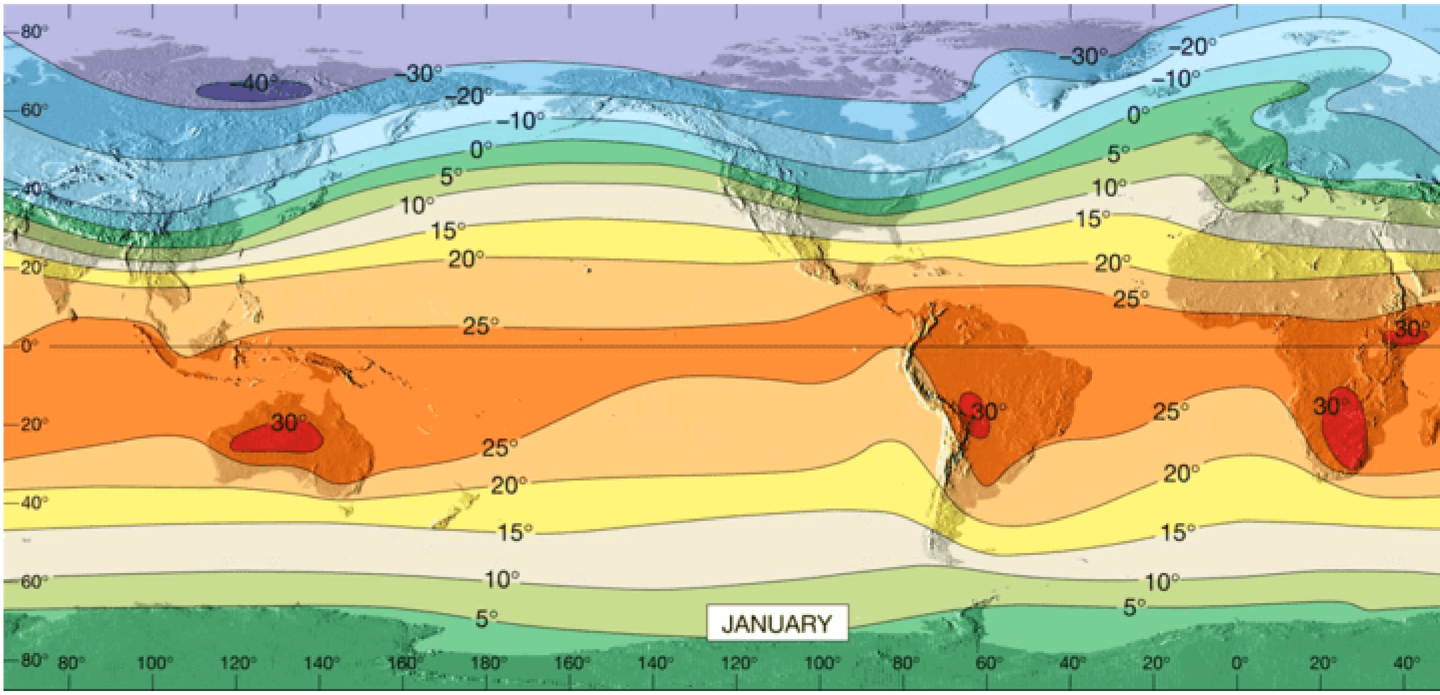
- Soil devoid of vegetation cover receives heat more rapidly than the soil under vegetation cover. Because vegetation cover absorbs much of sun's heat and then prevents quick radiation from the earth whereas the former radiates it more rapidly.
- Hence the temperature variations in densely forested areas are lower than those in desert areas.

Note: Along with these, the other factors which are responsible for the uneven horizontal distribution of temperature are winds, nature of the soil, slope and aspect of the surface, relief features, etc.

- The horizontal distribution of temperature over the globe can be studied easily from the isotherm maps of January and July months since the seasonal extremes of high and low temperature are most obvious in both northern and southern hemispheres during these months.

Horizontal Distribution of Temperature in January

- In January, the sun shines vertically overhead near the tropic of Capricorn. Hence, it is summer in southern hemisphere and winter in the northern hemisphere.
- A high temperature is found over the landmasses mainly in three regions of the southern hemisphere. These regions are North-West Argentina, East and Central Africa, and Central Australia.
- Isotherm of 30°C closes them.

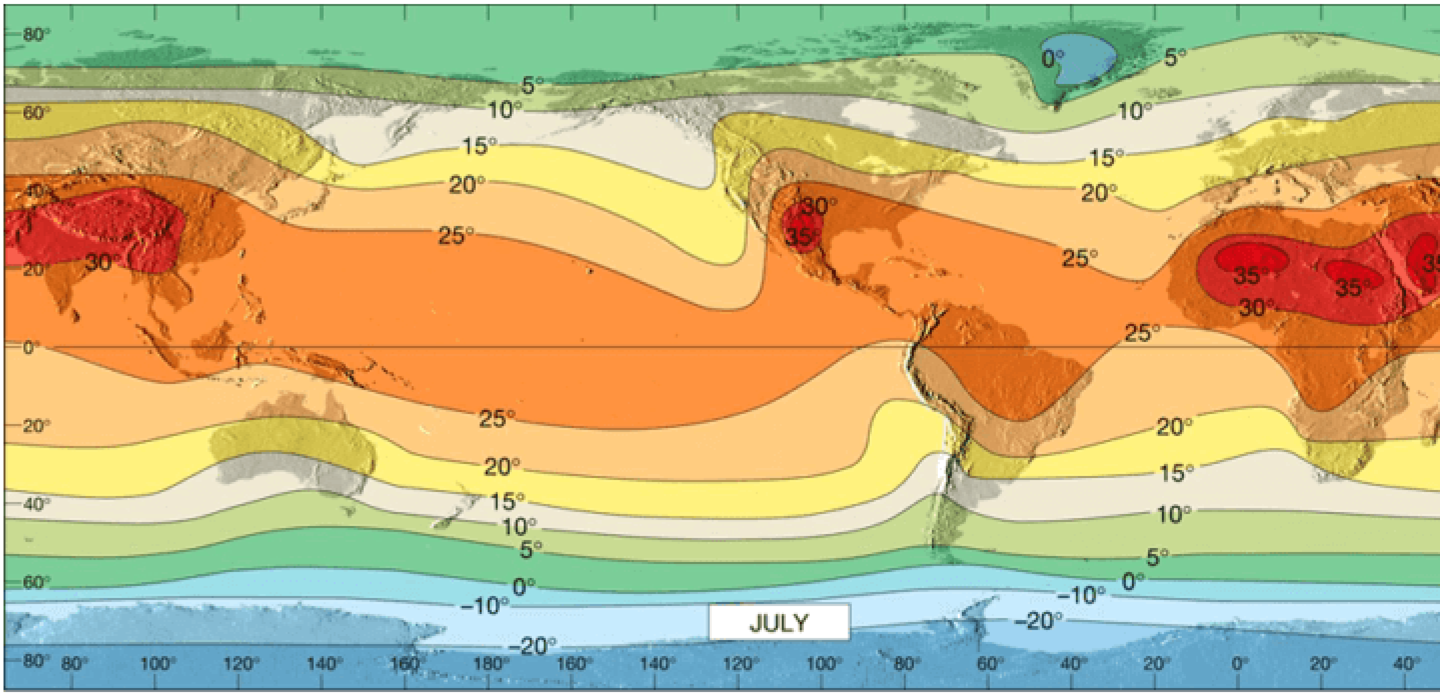


- In the northern hemisphere, landmasses are cooler than the oceans. As the air is warmer over the oceans than over landmasses in the northern hemisphere, the isotherms bend towards the north (poles) when they cross the oceans and to the south (equator) over the continents.
- This can be clearly visible over the North Atlantic Oceans. The presence of warms ocean currents (Gulf Stream and North Atlantic Drift) make the Northern Atlantic Ocean warmer and the isotherms bend towards the poles. Over the land, the temperature decreases sharply and the isotherms bend towards the equator in Europe.
- In the southern hemisphere, the effect of the oceans is well pronounced (due to few landmasses).
- Here, the isotherms are more or less parallel to the latitudes and the variation in temperature is more gradual than in the northern hemisphere.

Horizontal Distribution of Temperature in July

- In July, the sun shines vertically overhead near the Tropic of cancer. Hence, high temperatures are found in the entire northern hemisphere.

- The regions having high temperature include South Western USA, the Sahara, the Arabia, Iraq, Iran, Afghanistan, desert region of India and China.
- However, the lowest temperature of 0°C is also noticed in the Northern Hemisphere during summer in the central part of Greenland.



- During summer in the northern hemisphere, isotherms bend towards the equator while crossing oceans and towards the poles while crossing landmasses.
- Isotherms are wide spaced over oceans while they are closely spaced over landmasses.
- In July, the deviation of isotherms is not that much pronounced as in January.

B) Vertical Distribution of Temperature

- We have already studied that the temperature in the troposphere decreases with an increase in the altitude.
- This vertical gradient of temperature is commonly referred to as the standard atmosphere or Normal Lapse Rate.
- However, this normal lapse rate varies with height, season, latitude and other factors.
- Indeed the actual lapse rate of temperature does not always show a decrease with altitude.

Inversion of Temperature

- The phenomenon in which temperature increases with increasing altitude temporarily and locally under certain conditions is known as inversion of temperature.
- Inversion is usually of short duration but quite common nonetheless.
- Long winter night, clear sky, dry air and absence of winds leads to quick radiation of heat from the earth's surface, as well as from the lower layers of the atmosphere.

- This results in the cooling of the air near the earth's surface. The upper layers which lose their heat not so quickly are comparatively warm.
- Hence the normal condition, in which temperature decreases with increasing height, is reversed. The cooler air is nearer the earth and the warmer air is aloft.
- In other words, temperature increases with increasing height temporarily or locally.
- The phenomenon of inversion of temperature is mostly observed in intermontane valleys due to air drainage.
- During winters the mountain slopes cool very rapidly due to the quick radiation of heat.
- The air resting above them also becomes cold and its density increases. Hence, it moves down the slopes and settles down in the valleys.
- This air pushes the comparatively warmer air of valleys upwards and leads to the phenomenon of inversion of temperature.
- Sometimes the temperature falls below freezing point in the valleys leading even to the occurrence of frost. In contrast, the higher slopes remain comparatively warmer.
- This movement of heavy and dense cold air towards the valley slopes almost like water is termed as air drainage.

Factors affecting the distribution of Temperature:

1. Latitude: Since the earth's crust is curved, the sun 's vertical ray strike different parts of the earth surface at different angles. At the equator, the vertical rays hit the earth's surface at an angle of 90◦(angle of incidence) towards the poles.

2. Altitude: At the higher altitudes , the amount of atmosphere decreases and as the result there is less water vapour in the air. The atmosphere absorbs less heat and therefore the temperature at higher altitude drops.

3. Distance from the sea: The difference in heating of land and water affects the temperature of places located near the coast differently from those located inland.

4. Ocean currents: Ocean currents are large streams of water flowing in the oceans. These generated when winds blow over the water surface.

5. Humidity: Humidity is the amount of water vapour in the atmosphere and its influences the cloud cover in the sky. The higher the humidity the greater amount of cloud cover. The lower the humidity the less amount of cloud cover.

6. Cloud cover: Place near the equator has greater amount of cloud cover. Areas in the desert where humidity is low will have lower amount of cloud cover.

7. Aspect: Aspect is the direction in which a slope faces in relation to the sun. In the tropical areas the aspect is not much importance because the sun is high in the sky during mid day. In the temperate areas, the sun is low angle in winter, this will affect the temperature of slopes that face north to south. In north hemisphere, the south facing slope receive greater concentration of solar radiation and usually warmer than the north facing slope.

8. Types of land surface: Dense forest– the vegetation prevents solar radiation from reaching the ground directly. The ground remain cool. In the city– the presence of concrete surface tends to keep the air temperature high. The concrete surface absorb heat during the day and retain the heat at night.