Temperature Distribution on Earth & Heat budget

The interaction of insolation with the atmosphere and the earth's surface creates heat, which is measured in terms of temperature. While heat represents the molecular movement of particles comprising a substance, temperature is the measurement in degrees of how hot (or cold) a thing (or a place) is. The distribution of temperature varies both **horizontally** and **vertically**.

Heat and Temperature

- Temperature indicates the relative degree of heat of a substance.
- Heat is the energy that makes things or objects hot, while temperature measures the intensity of heat.
- Heat (energy) is the total kinetic energy of all the atoms in a substance. The more atoms present, the greater the heat.
- Temperature represents the average kinetic energy of the atoms in a substance. A few atoms with rapid motion will have a higher temperature than many atoms with slow motion.
- Although quite distinct from each other, yet heat and temperature are closely related because gain or loss of heat is necessary to raise or lower the temperature.
- The movement of heat depends upon the temperature difference between two bodies.
- Heat always moves from a body of higher temperature to that of lower temperature.
- Primarily, it is measured in the kelvin (K) unit in the study of physical sciences.
- Therefore, the temperature is most commonly measured in Celsius (C) or Fahrenheit (F) or Kelvin (K) in day to day uses. They are denoted as °C, °F and °K.
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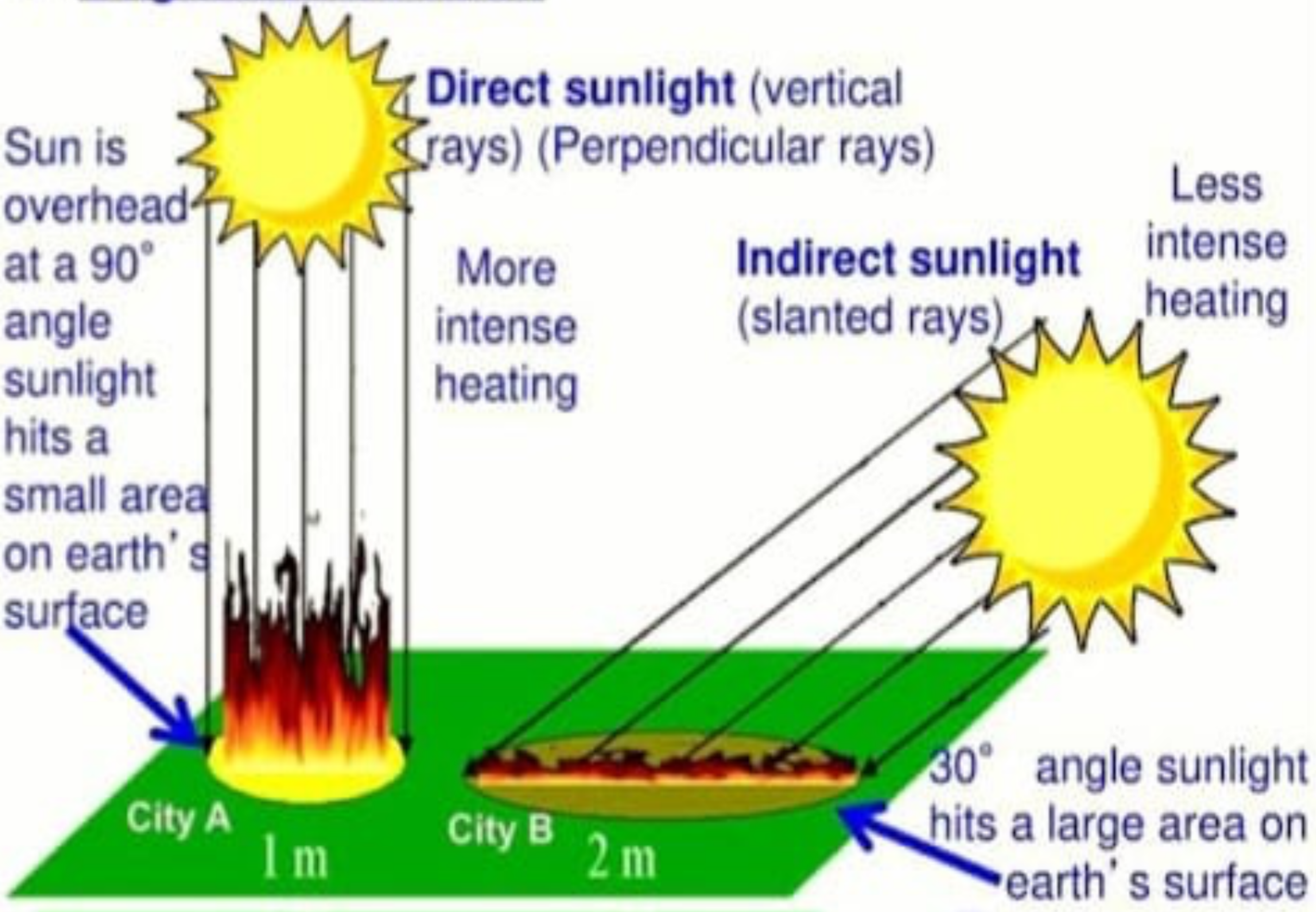
Factors Affecting the Temperature Distribution

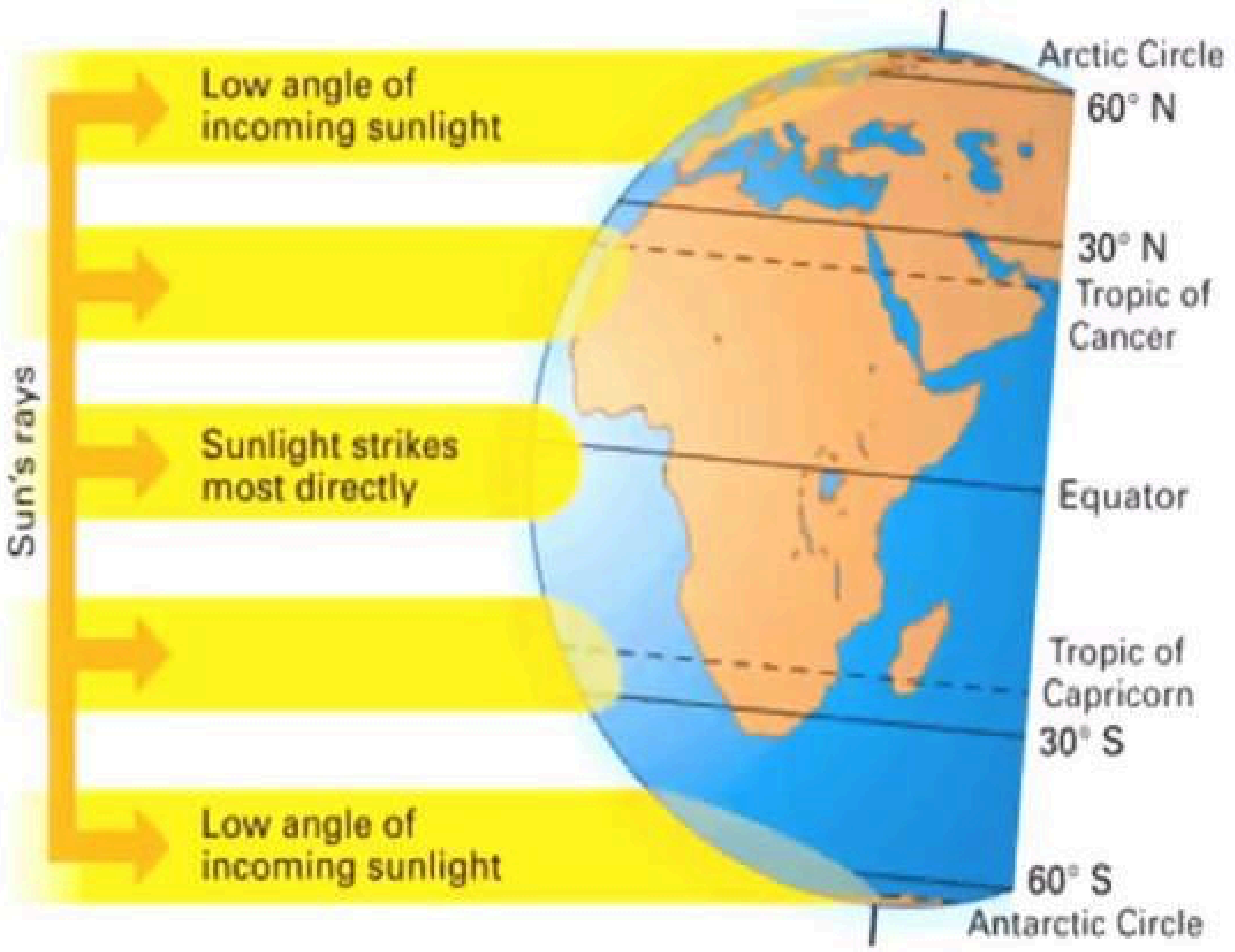
The temperature of the air at any place is influenced by the following factors:

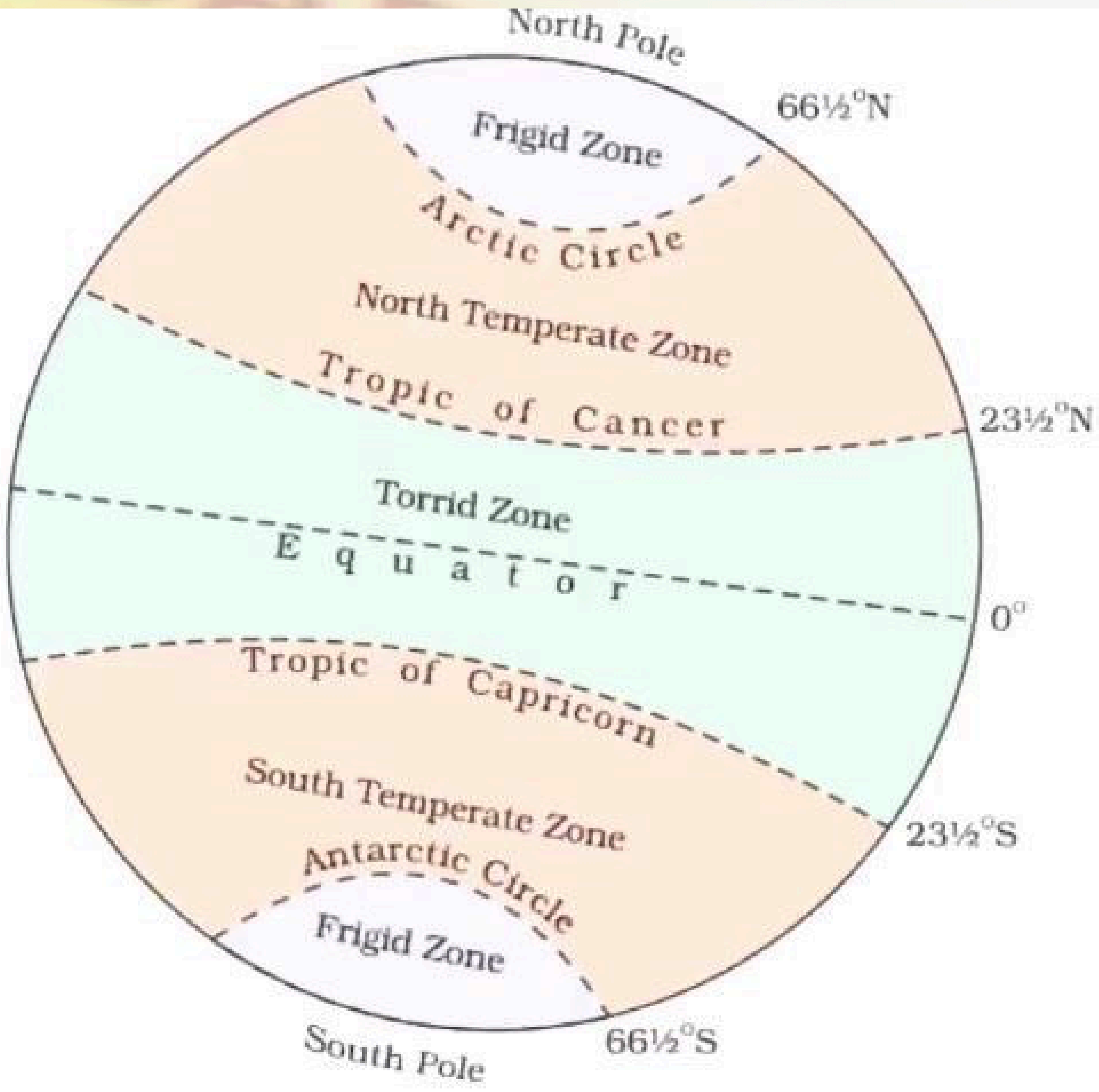
1. The latitude of the place;
2. The altitude of the place;
3. Distance from the sea, the air-mass circulation;
4. The presence of warm and cold ocean currents;
5. Local aspects.

2) How does the angle of the sun affect heating?

1. Angle of Insolation




Low angle of incoming sunlight
Sunlight strikes most directly
Low angle of incoming sunlight
Sun's rays
Arctic Circle
60° N
30° N
Tropic of Cancer
Equator
Tropic of Capricorn
30° S
60° S
Antarctic Circle


North Pole
66½°N
Frigid Zone
Arctic Circle
North Temperate Zone
Tropic of Cancer
23½°N
Torrid Zone
Equator
0°
Tropic of Capricorn
South Temperate Zone
23½°S
Antarctic Circle
Frigid Zone
South Pole
66½°S

Global Temperature Distribution

The temperature distribution globally can be explained in two ways:

1. Horizontal Temperature Distribution
2. Vertical Temperature Distribution

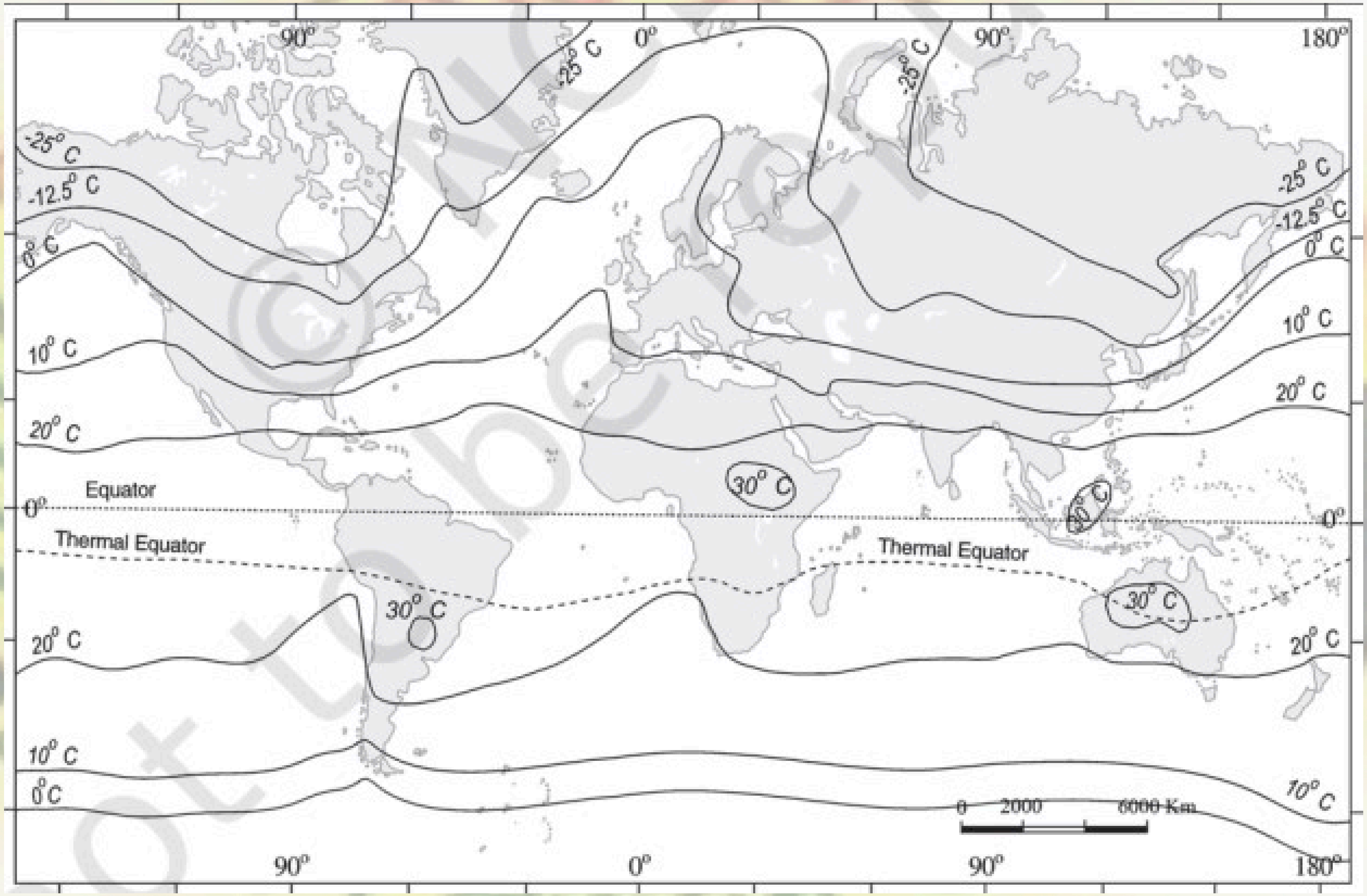
Horizontal Temperature Distribution

- The 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", lines connecting points that have equal temperatures.***

What is an Isotherm?

An isotherm is made of two words, 'iso' and 'therm'. 'Iso' means equal and 'therm' means" temperature.

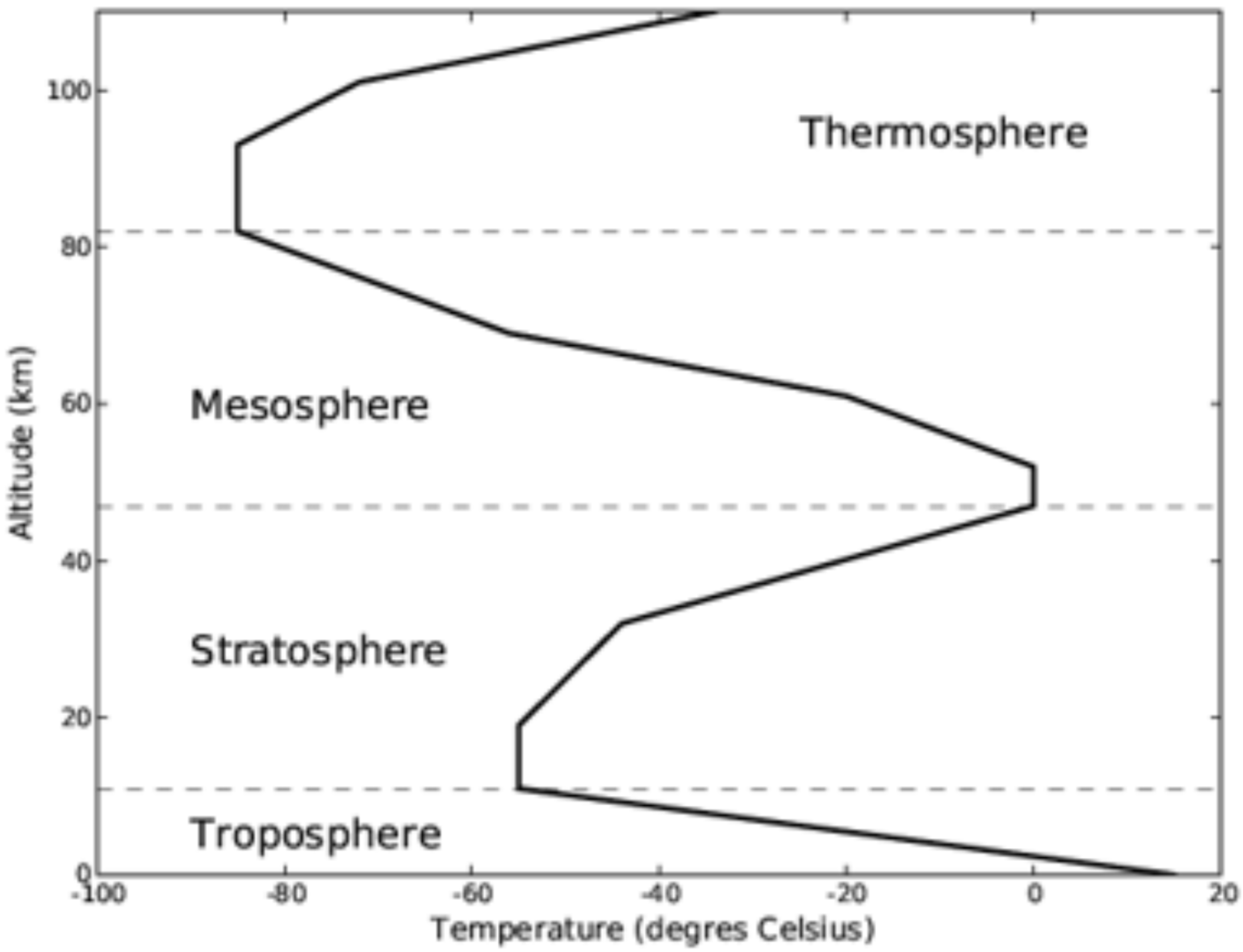
- In general, the equatorial region is hot, and its temperature is high throughout the year.
- Generally, from the equator to polewards, the temperature keeps on declining.
- The lowest temperature is at and near the poles.


90°
0°
90°
180°
-25° C
-12.5° C
0° C
10° C
20° C
30° C
Equator
Thermal Equator
0 2000 6000 Km

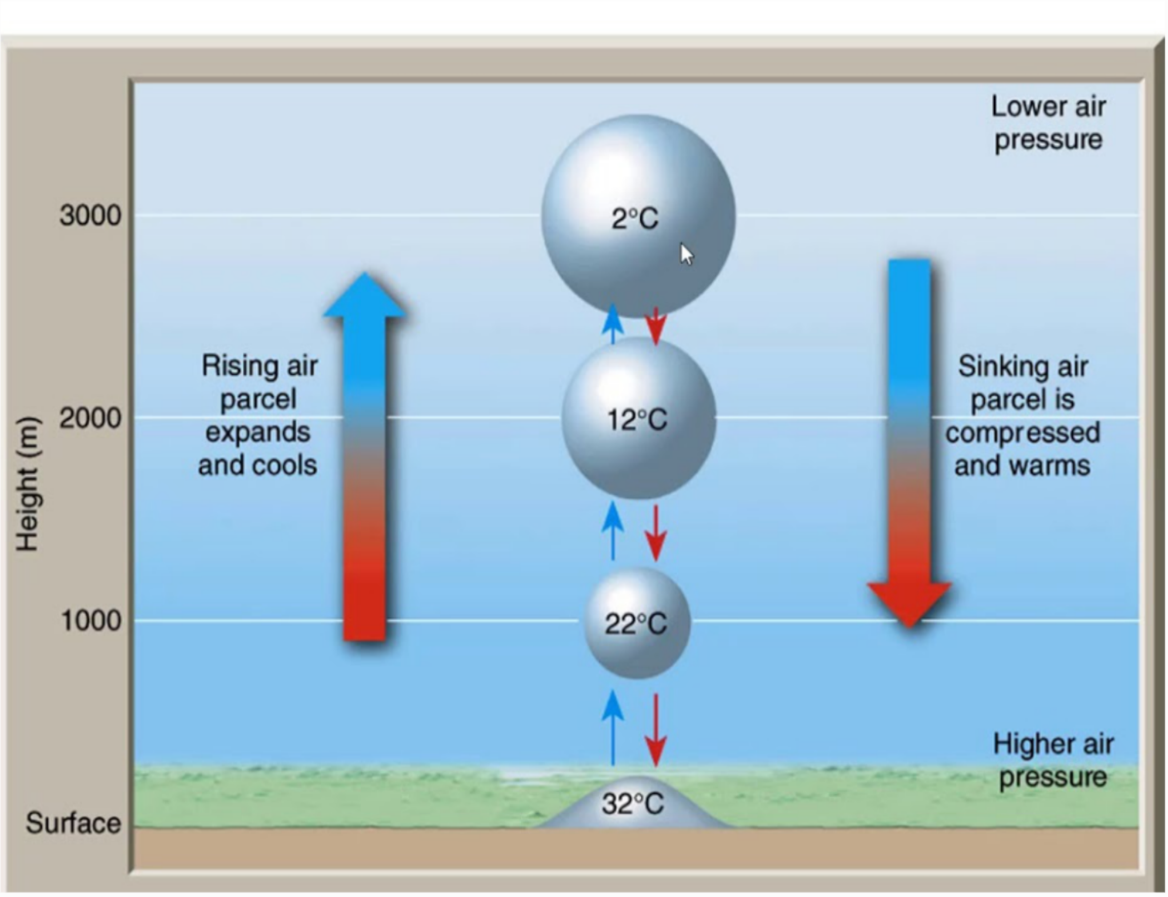
Vertical Temperature Distribution

- Normally, temperature decreases with an increase in elevation. It is called the normal lapse rate.
- The average rate of temperature decrease upward in the troposphere is about 6 °C per km, extending to the tropopause.
- This is also termed as vertical temperature gradient.
- The normal lapse rate is not always the same, but it differs depending upon height, season, latitude or other numerous local factors.

Parameter	Normal Lapse Rate	Adiabatic Lapse Rate
Definition	The rate at which atmospheric temperature decreases with an increase in altitude under normal, non-rising air conditions.	The rate at which temperature changes in a rising or descending air parcel without heat exchange with the surroundings.
Rate of Temperature Change	About 6.5°C per 1000 meters (average)	Dry Adiabatic Lapse Rate: 10°C per 1000 meters, Moist Adiabatic Lapse Rate: 5-9°C per 1000 meters
Atmospheric Conditions	Applies to static or stable air	Applies to moving air (ascending or descending air parcels)



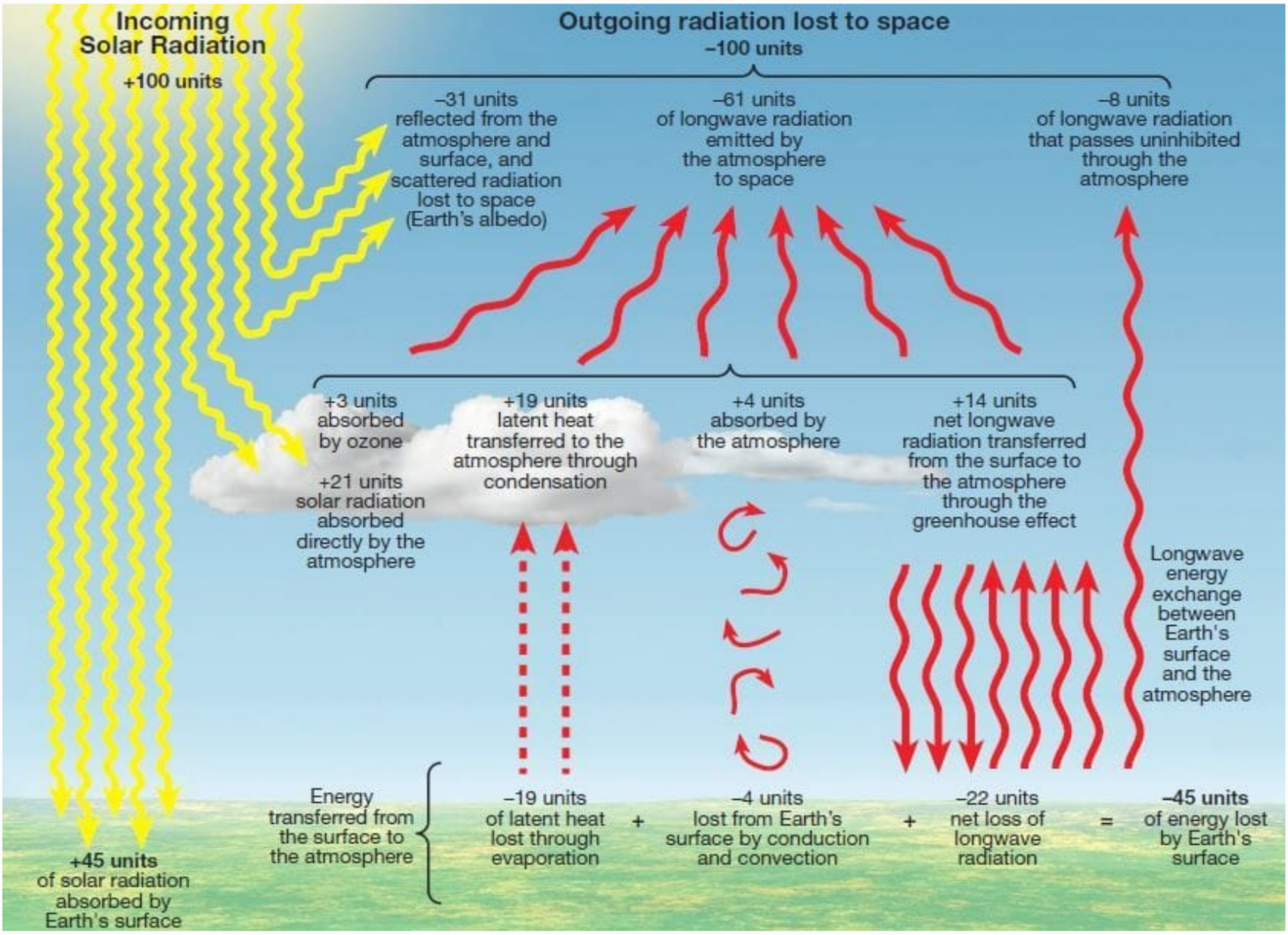
Thermosphere
Mesosphere
Stratosphere
Troposphere
Altitude (km)
Temperature (degres Celsius)
0
20
40
60
80
100
-100
-80
-60
-40
-20
0
20


Lower air pressure
3000
2°C
Rising air parcel expands and cools
Sinking air parcel is compressed and warms
2000
12°C
Height (m)
1000
22°C
Higher air pressure
Surface
32°C

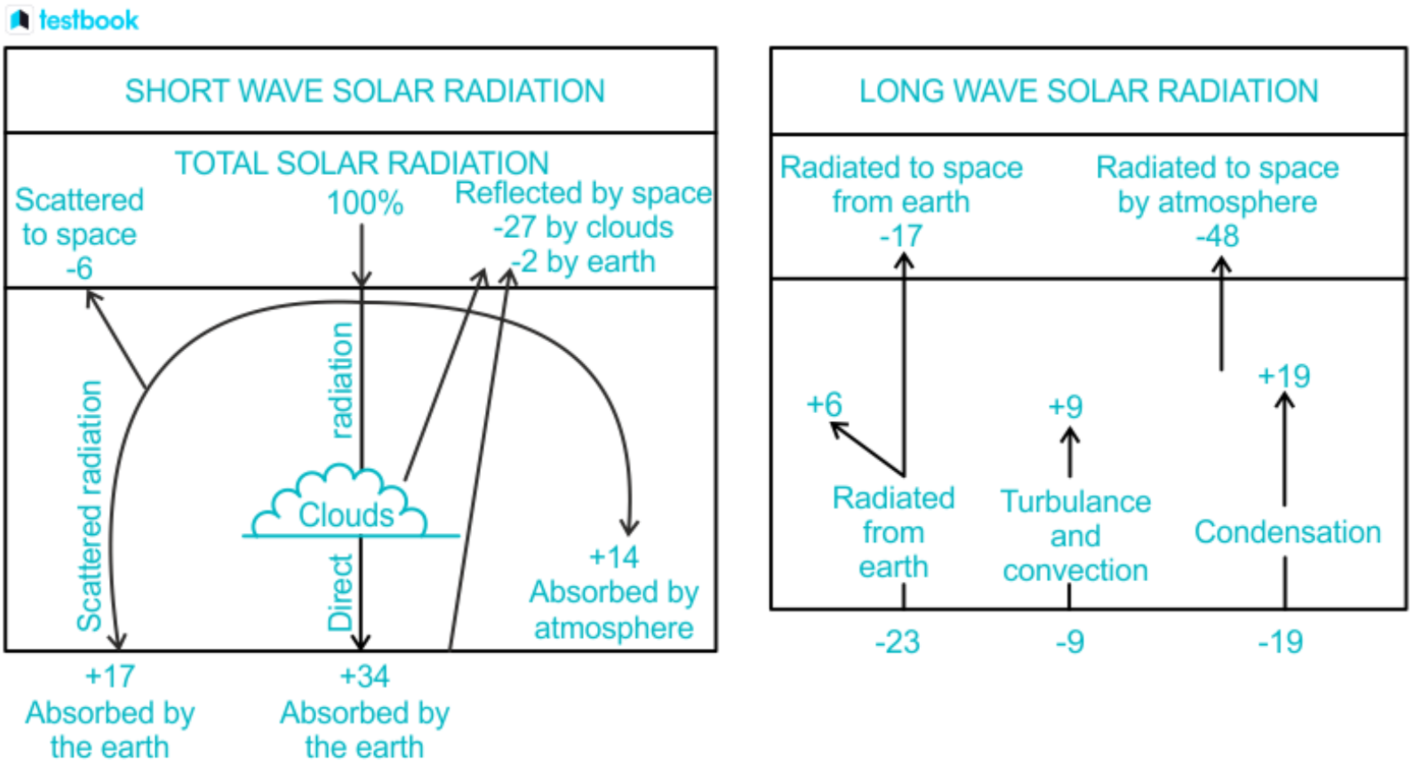
Parameter	Dry Adiabatic Lapse Rate (DALR)	Moist Adiabatic Lapse Rate (MALR)	Normal Lapse Rate (NLR)
Definition	The rate at which the temperature of unsaturated (dry) air decreases as it rises without any heat exchange.	The rate at which the temperature of saturated (moist) air decreases as it rises due to condensation of water vapor.	The average rate at which temperature decreases with altitude under normal atmospheric conditions.
Rate of Temperature Change	10°C per 1000 meters	5-9°C per 1000 meters (varies due to latent heat release)	6.5°C per 1000 meters (average)
Atmospheric Conditions	Applies to rising or descending dry air parcels	Applies to rising or descending moist air parcels	Applies to static air in the atmosphere under normal conditions

- **Heat budget of earth**

- A heat budget is a perfect balance between incoming heat (insolation) absorbed by the earth and outgoing heat (terrestrial radiation) escaping it in the form of radiation.
- If the incoming heat and the outgoing heat are not balanced, then Earth would be getting either too warmer or cooler. Since these are perfectly balanced the earth is neither too warm nor too cold.
- The equilibrium that exists between the insolation (short waves) and the terrestrial radiation (long waves) is called the **heat budget of the earth**.

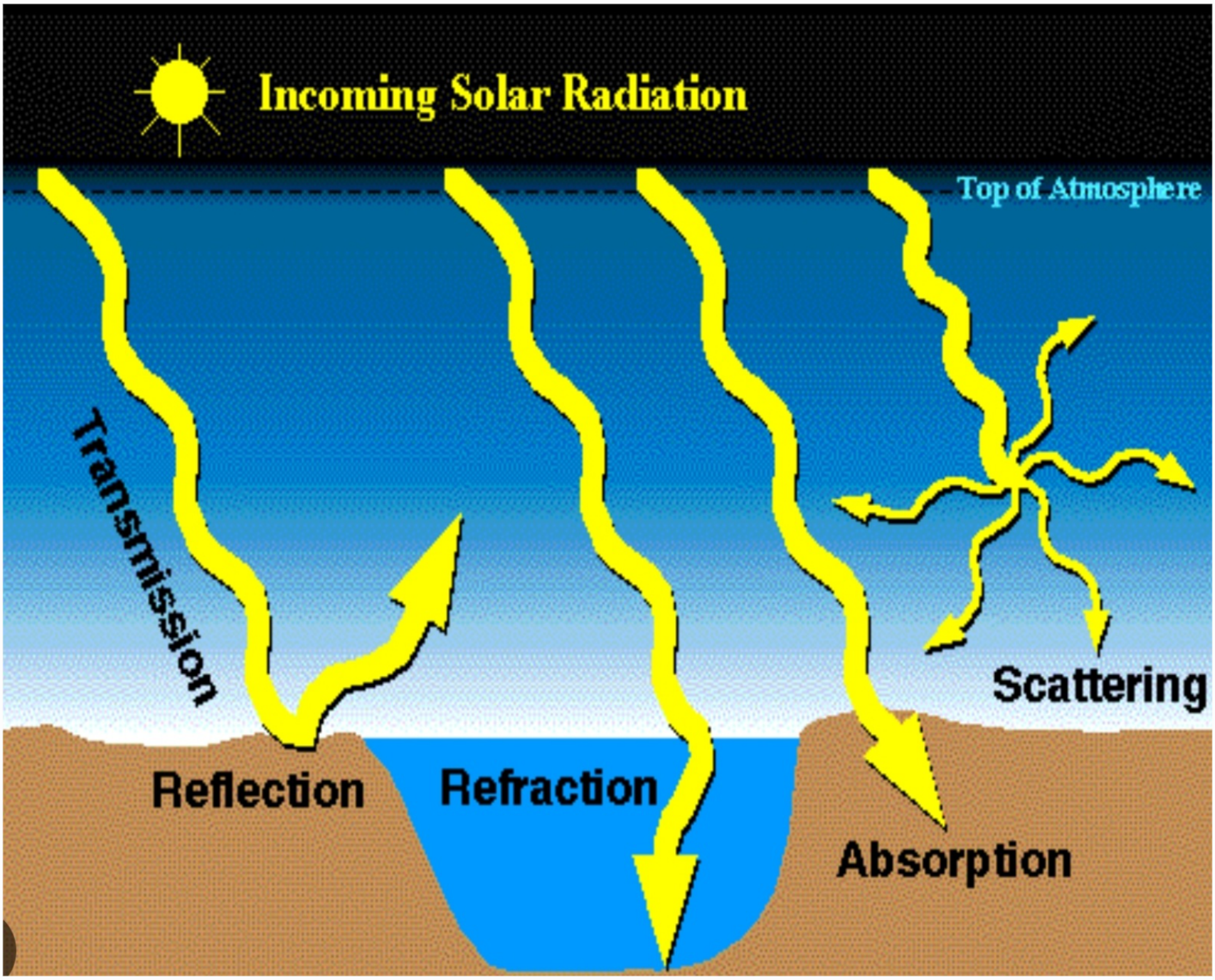


Incoming Solar Radiation
+100 units
Outgoing radiation lost to space
–100 units
–31 units reflected from the atmosphere and surface, and scattered radiation lost to space (Earth's albedo)
–61 units of longwave radiation emitted by the atmosphere to space
–8 units of longwave radiation that passes uninhibited through the atmosphere
+3 units absorbed by ozone
+21 units solar radiation absorbed directly by the atmosphere
+19 units latent heat transferred to the atmosphere through condensation
+4 units absorbed by the atmosphere
+14 units net longwave radiation transferred from the surface to the atmosphere through the greenhouse effect
Longwave energy exchange between Earth's surface and the atmosphere
Energy transferred from the surface to the atmosphere
–19 units of latent heat lost through evaporation
+
–4 units lost from Earth's surface by conduction and convection
+
–22 units net loss of longwave radiation
=
–45 units of energy lost by Earth's surface
+45 units of solar radiation absorbed by Earth's surface

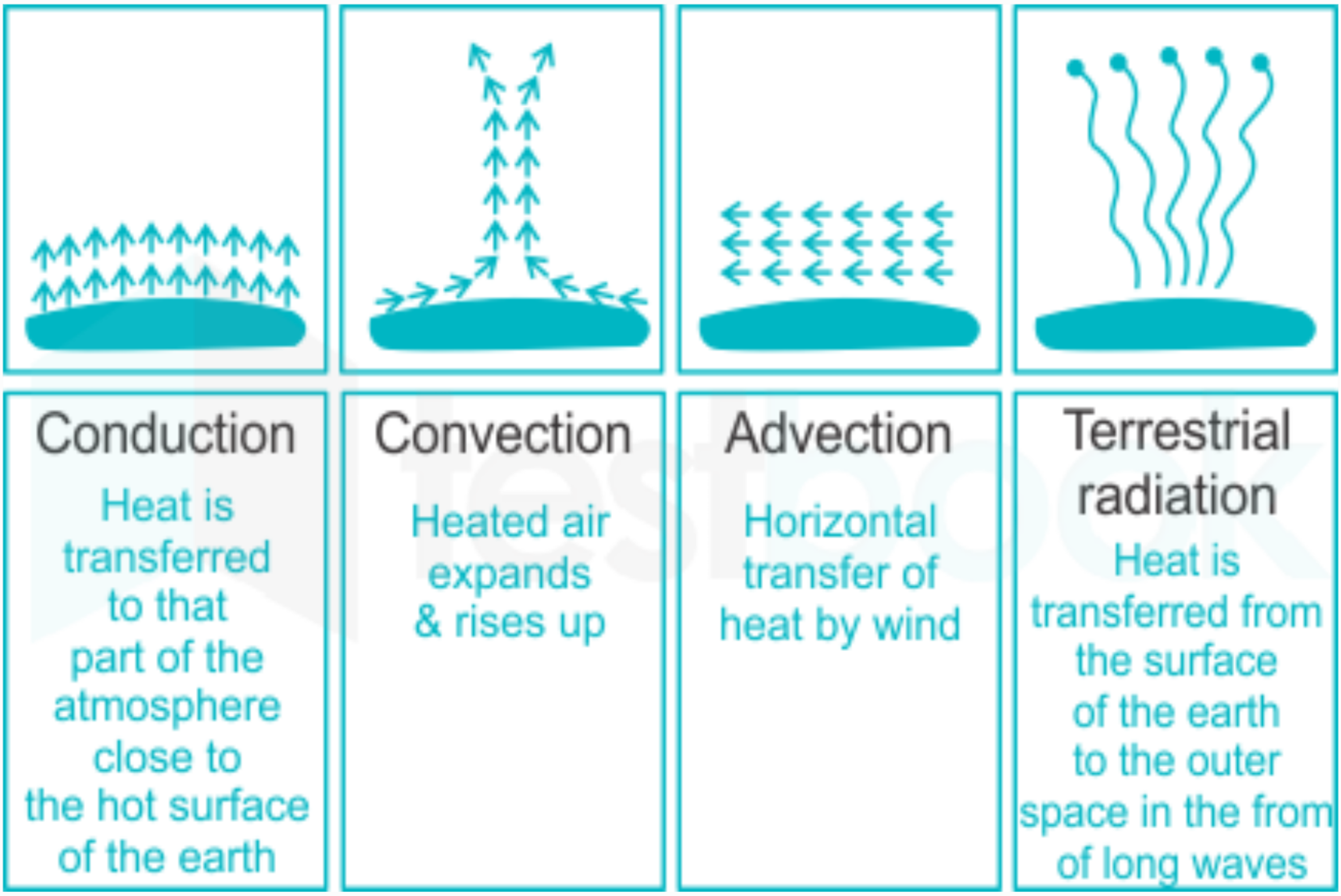

testbook
SHORT WAVE SOLAR RADIATION
TOTAL SOLAR RADIATION
100%
Scattered to space -6
Reflected by space
-27 by clouds
-2 by earth
radiation
Scattered radiation
Clouds
Direct
+14 Absorbed by atmosphere
+17 Absorbed by the earth
+34 Absorbed by the earth
LONG WAVE SOLAR RADIATION
Radiated to space from earth -17
Radiated to space by atmosphere -48
+6
+9
+19
Radiated from earth
Turbulance and convection
Condensation
-23
-9
-19

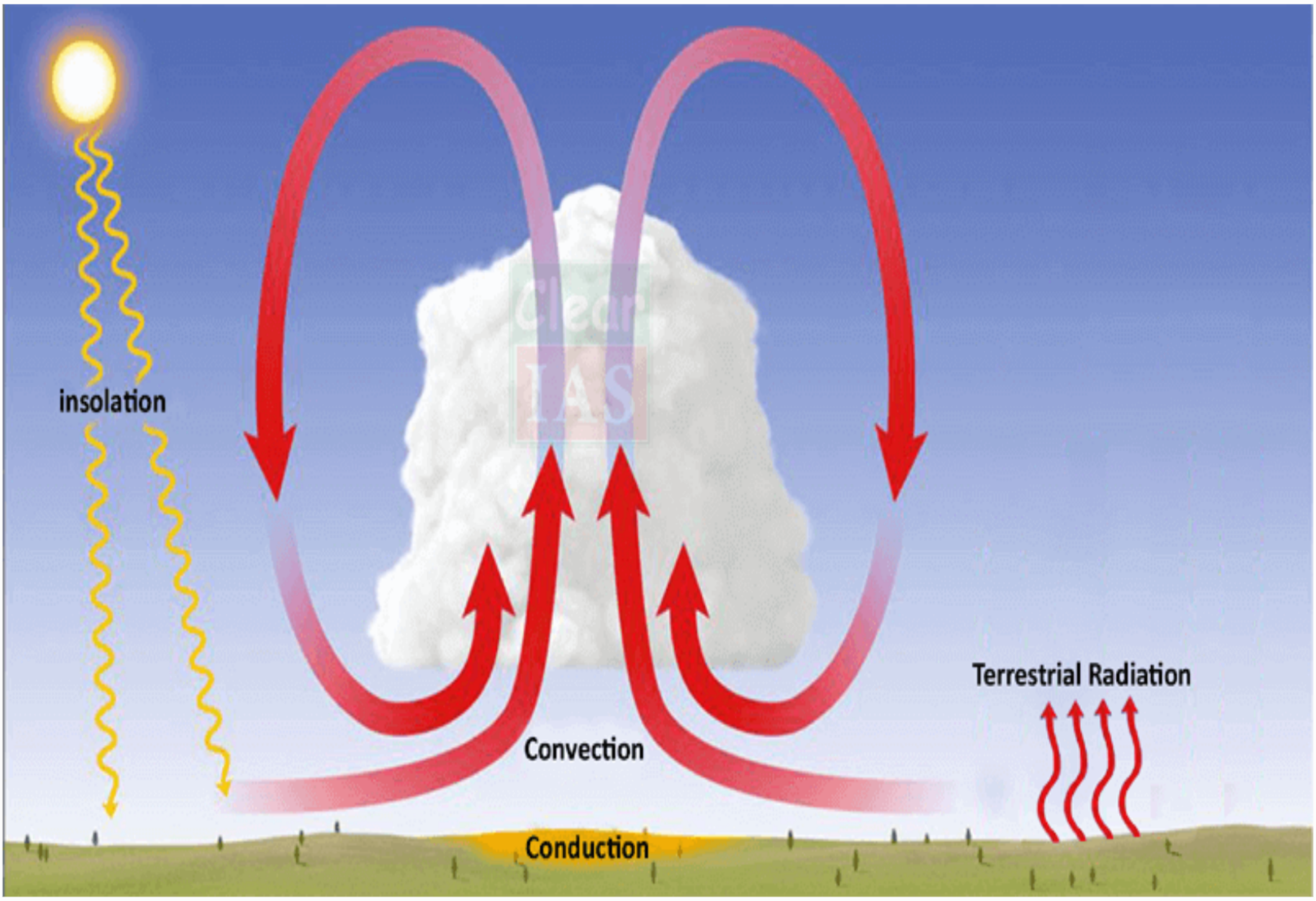
- If the total insolation received at the top of the atmosphere is considered to be 100%, a certain amount of energy is reflected, scattered and absorbed while passing through Earth's atmosphere and only the remaining amount of radiation reaches the earth's surface.
- Approximately 35 units are reflected to space even before reaching the earth's surface.
- Of these, 27 units are reflected from the top of the clouds and 2 units from the snow and ice-covered areas of the earth. The reflected amount of radiation is called the **albedo of the earth**.
- The remaining **65 units** are absorbed, 14 units within the atmosphere and 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 space directly and the remaining 34 units are absorbed by the atmosphere
- The 48 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 balance the total of **65 units received from the sun**.

- **Heat Budget Components**
- Insolation – Insolation refers to the incoming shortwave solar radiation to the earth's surface. The processes involved with insolation in maintaining heat balance include:
- Reflection – Reflection occurs when incoming solar waves bounce back from a surface that it strikes in the atmosphere, on land, or water, and are not transformed into heat.
- Absorption – Absorption of radiation involves the conversion of electromagnetic radiation into heat energy.
- Scattering – Scattering of solar waves takes place when the radiation strikes small objects in Earth's atmosphere, such as air molecules or water droplets or aerosols which disperse the solar waves in all directions.


Incoming Solar Radiation
Top of Atmosphere
Transmission
Reflection
Refraction
Absorption
Scattering

- **Terrestrial Radiation** – Terrestrial Radiation refers to longwave radiation that is emitted by the Earth's surface or by the atmosphere. The processes involved with Terrestrial Radiation in maintaining heat balance include
    - **Latent heat transfer** – It is the amount of heat transferred during the point where one substance is ready to change its state.
    - Example: From solid to liquid or from liquid to gas,
    - **Sensible heat transfer** – It is the energy that is transferred as heat to an object, without any change in the state
    - **Emission by vapour and clouds** – Huge amounts of terrestrial radiation are also released by the water vapour and clouds.

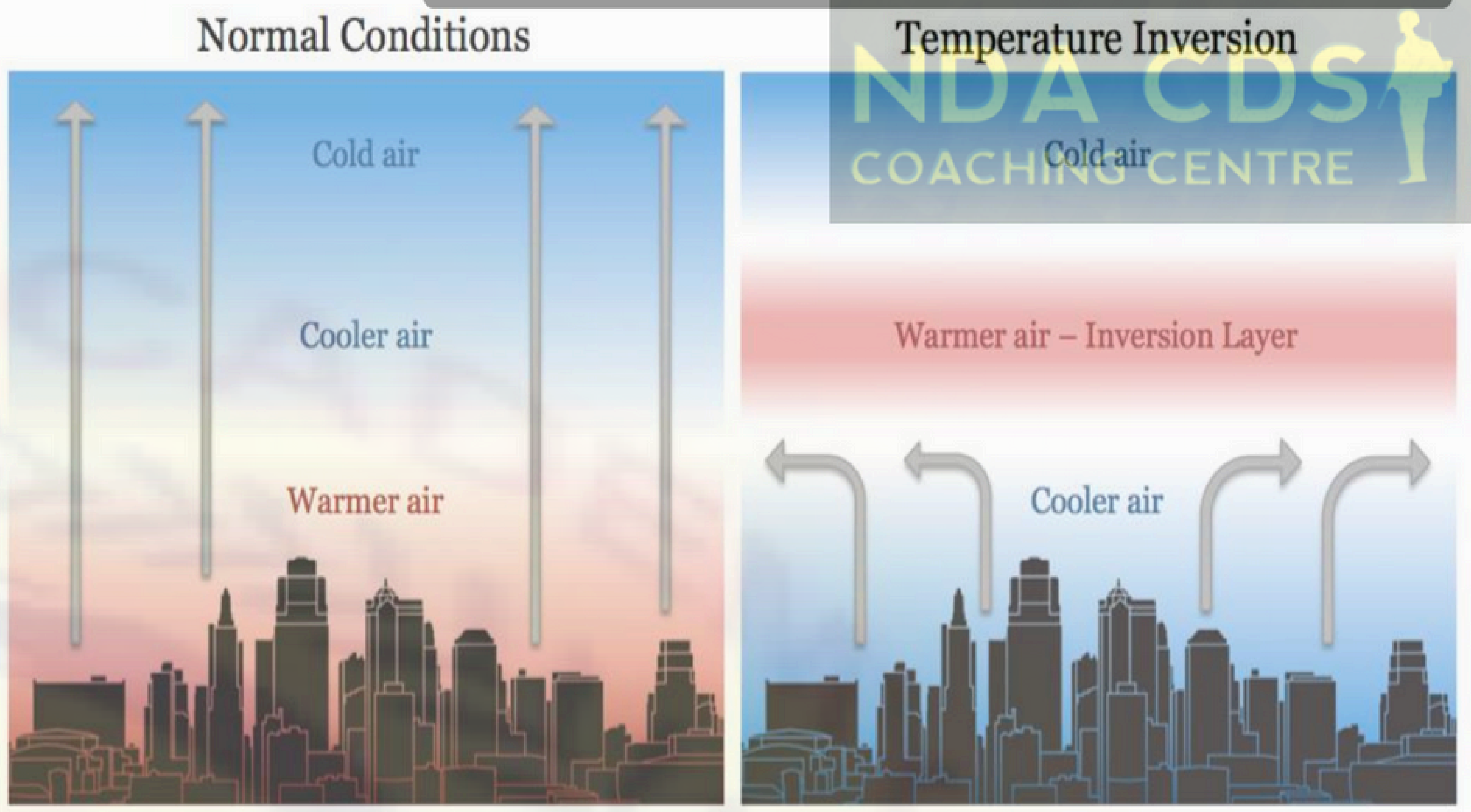

Conduction
Heat is transferred to that part of the atmosphere close to the hot surface of the earth
Convection
Heated air expands & rises up
Advection
Horizontal transfer of heat by wind
Terrestrial radiation
Heat is transferred from the surface of the earth to the outer space in the from of long waves

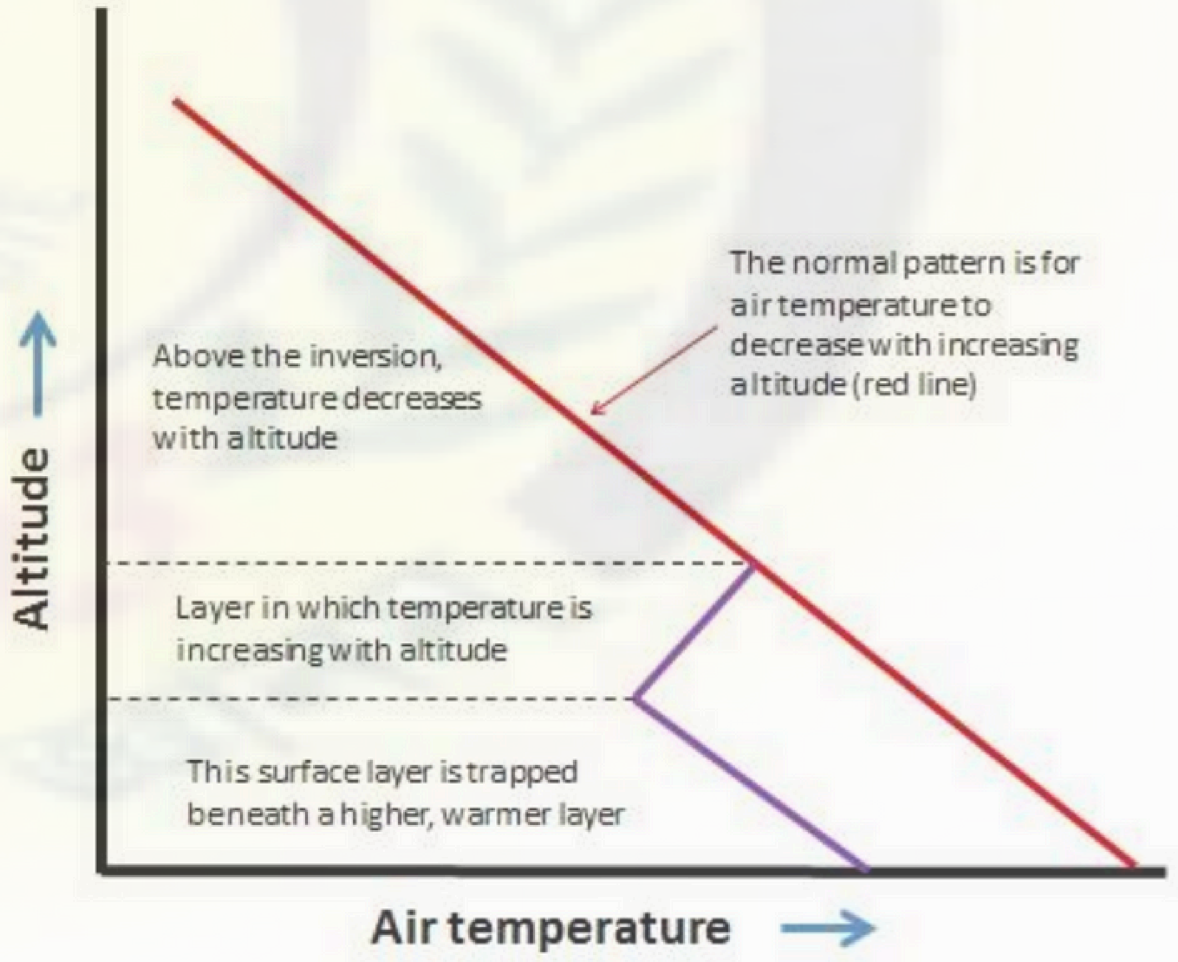

insolation
Convection
Terrestrial Radiation
Conduction
Clear IAS

Inversion of Temperature

INVERSION OF TEMPERATURE

- **Temperature inversion**, also called **thermal inversion**, a reversal of the normal behaviour of temperature in the troposphere.
- Normally, temperature decreases with increasing altitude in troposphere at the rate of 6.5^{0} C (normal lapse rate).
- At times, the situation is reversed, i.e. warm air lies over cold air and the normal lapse rate is inverted. It is called Inversion of temperature.
- Inversion may occur near the earth's surface or upper troposphere



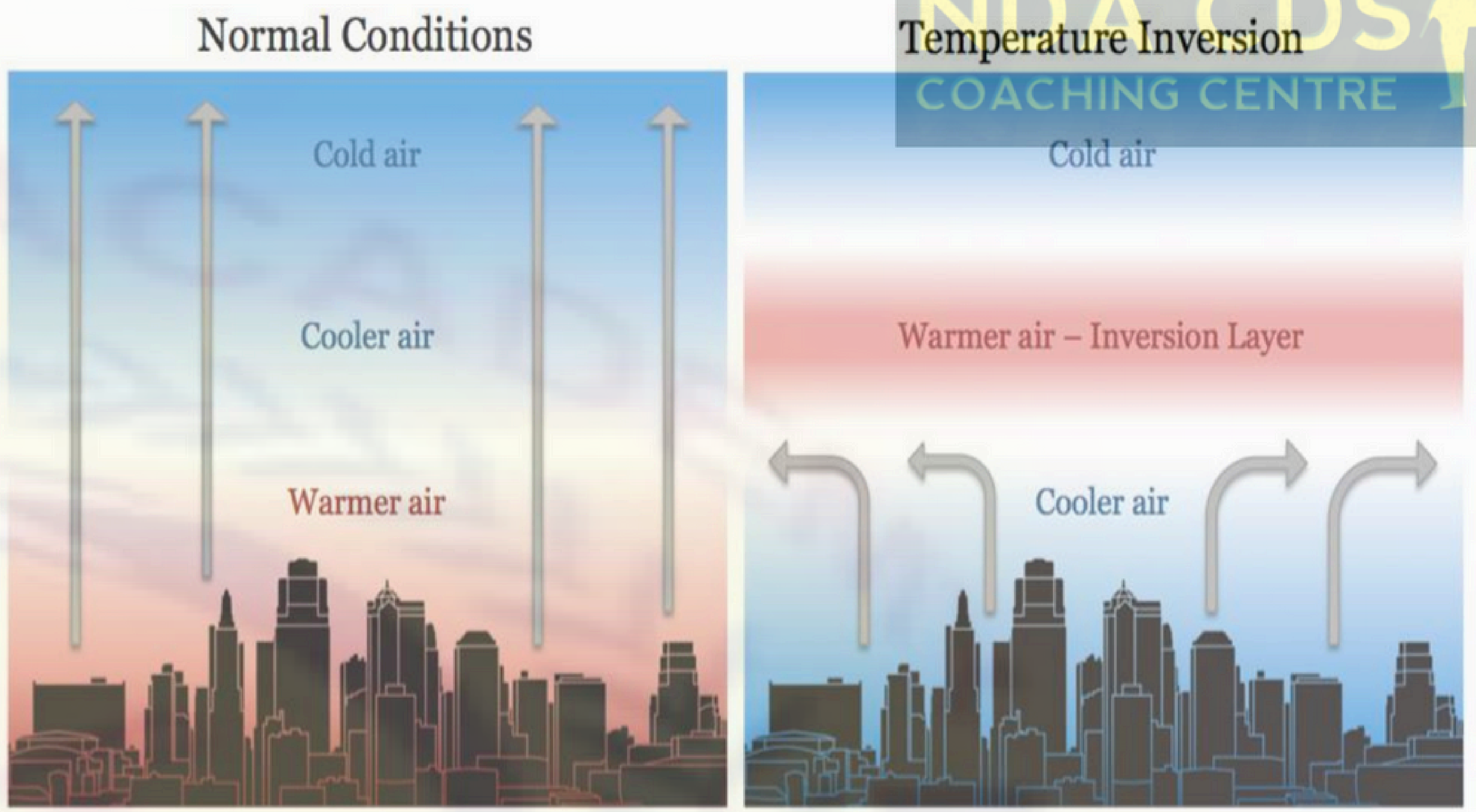


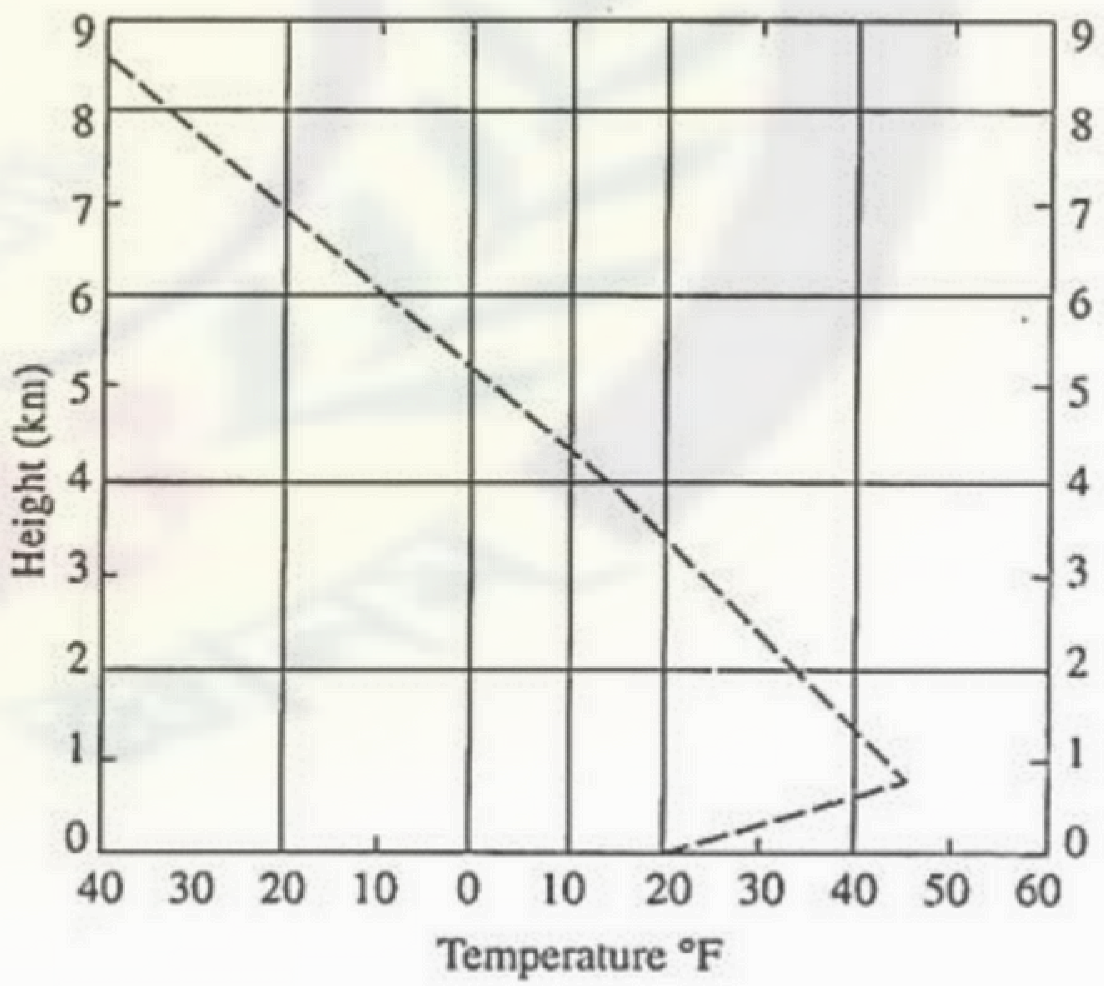
Types of Temperature Inversion

- **Non-Advectional (static) Temperature Inversion**
    - ➢ Ground/Surface/Radiation Inversion
- **Upper Air Inversion:**
    - **Thermal Temperature Inversion (Stratospheric Inversion)**
    - **Mechanical Temperature Inversion**
        - ➢ Subsidence Inversion
        - ➢ Turbulence & Convective Inversion
- **Advectional (dynamic) Temperature Inversion**
    - ➢ Frontal or Cyclonic inversion
    - ➢ Valley Inversion

Ground Inversion

- Occurs near Earth's surface due to radiation mechanism.
- Develops when air is cooled by contact with a colder surface until it becomes cooler than the overlying atmosphere;
- This occurs most often on clear nights, when the ground cools off rapidly by radiation (excessive nocturnal cooling).
- Common during winters in mid & higher latitudes, polar regions and tropical deserts.



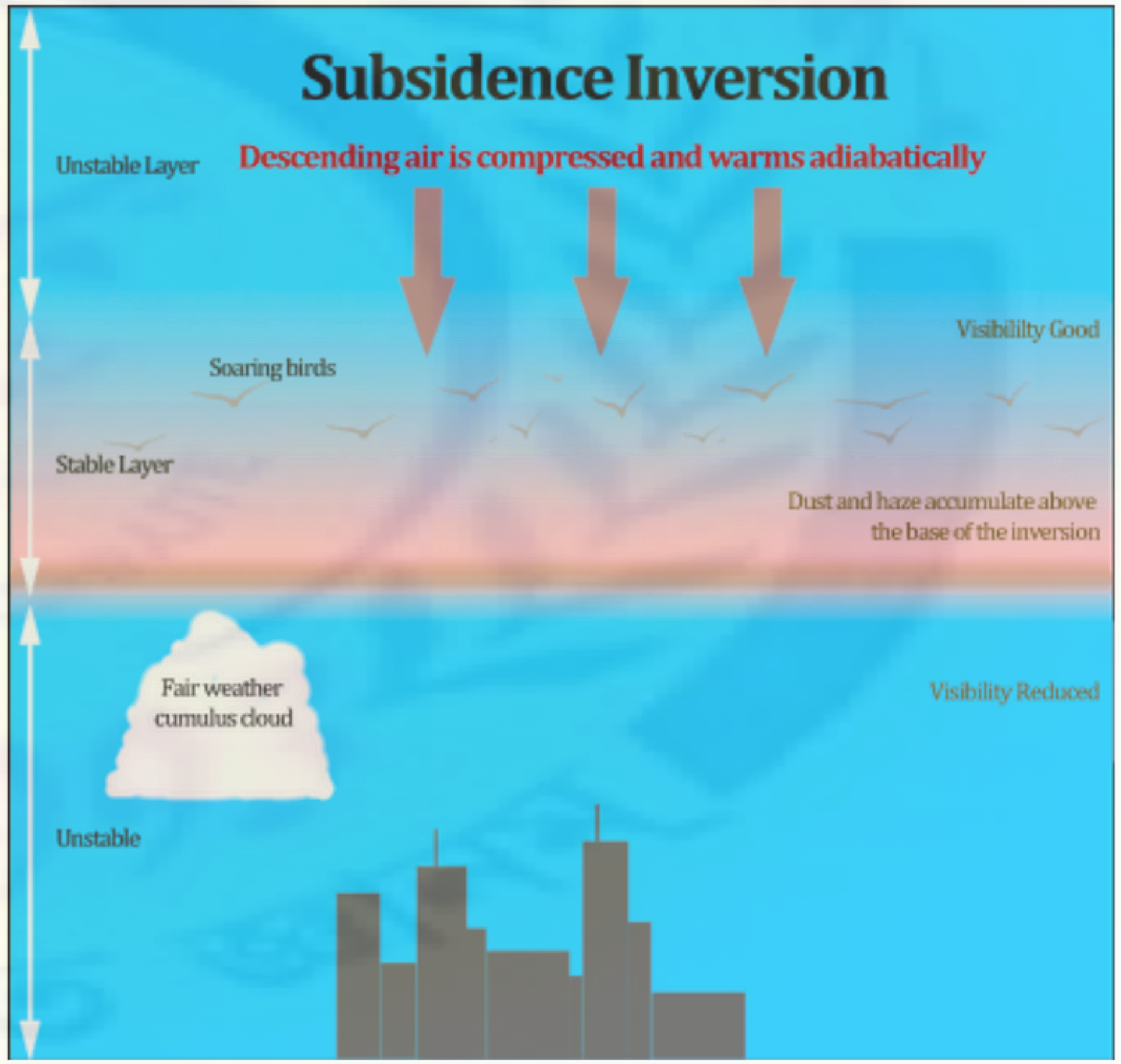


Conditions for Ground Temperature Inversion

- **Long winter night :** enables earth's surface to cool down more (loss of heat by terrestrial radiation during night exceeds heat from insolation)
- **Clear sky:** Clouded sky doesn't let the temperature escape from the ground by acting like a shield.
- **Calm and stable air:** If there is turbulence going on in the air, mixing of heat happens, preventing inversion. Calm and stable air enables the warm air to rise smoothly.
- **Dry air near the ground:** so that it may not absorb much terrestrial radiation

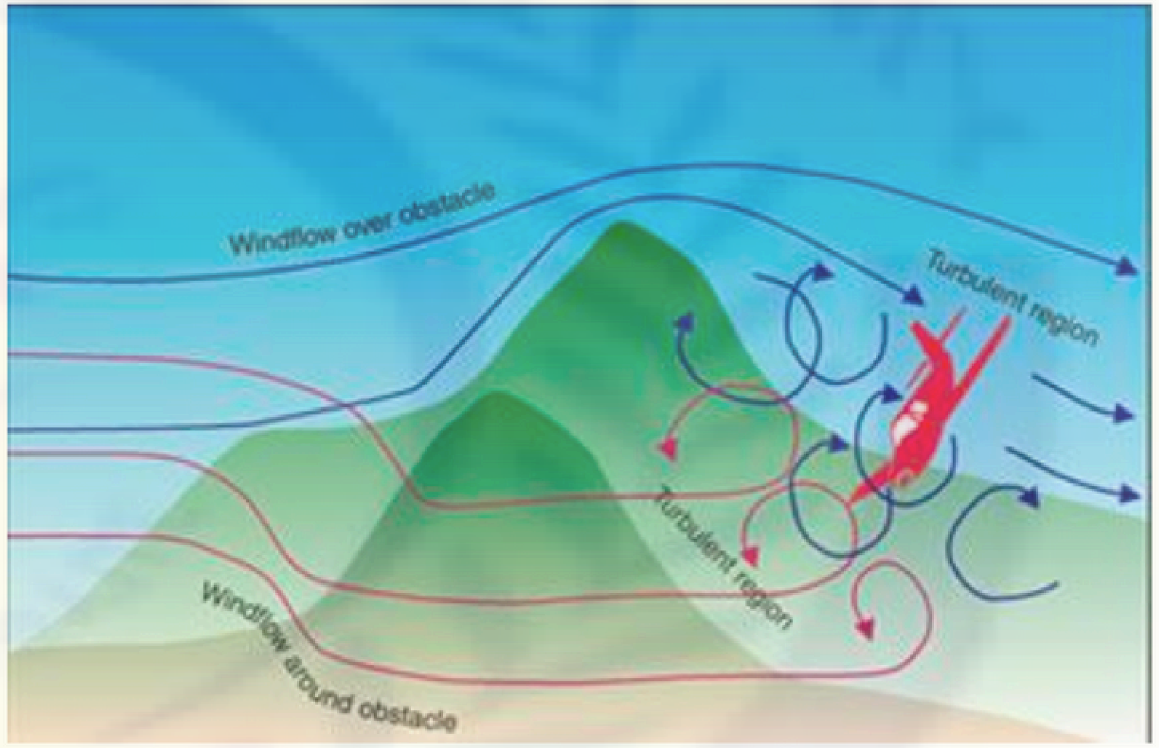
Subsidence Inversion

- When in upper troposphere a widespread layer of air descends.
- The descending layer is compressed and adiabatically heated by the increase in atmospheric pressure (dry adiabatic rate of 9.8^0 C/ km.)
- Thus, causing lying of warm air above cold air, producing a temperature inversion.
- Such inversions are common over middle latitudes, northern continents in winter and over subtropical oceans (high pressure areas) & associated with anticyclone conditions



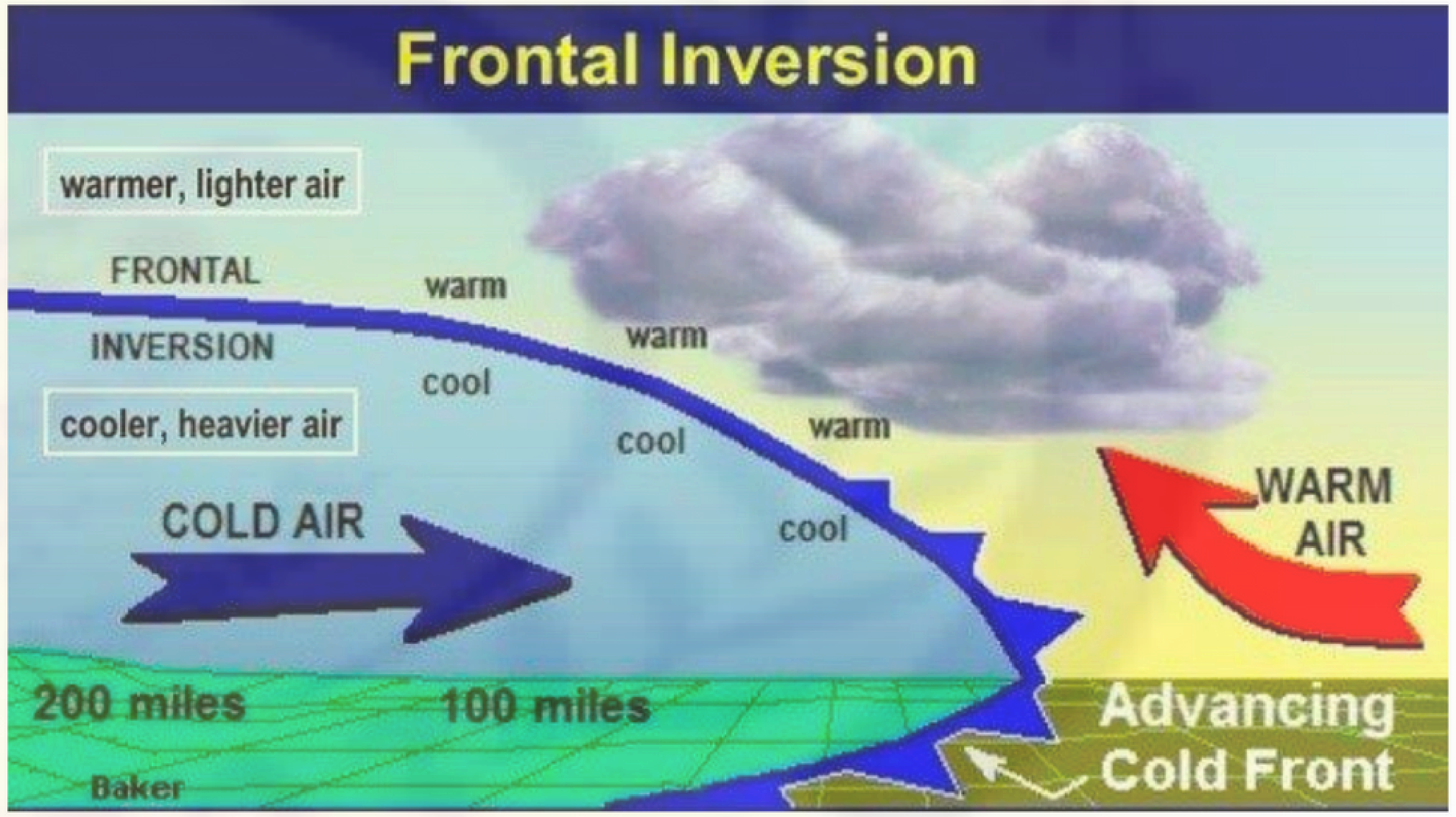
Turbulence Inversion

- Sometimes due to eddies (whirls of winds) formed by frictional forces, warm air is suddenly transported upwards to the zone of cold air
- Warm air being less dense, settle over cold air, causing inversion



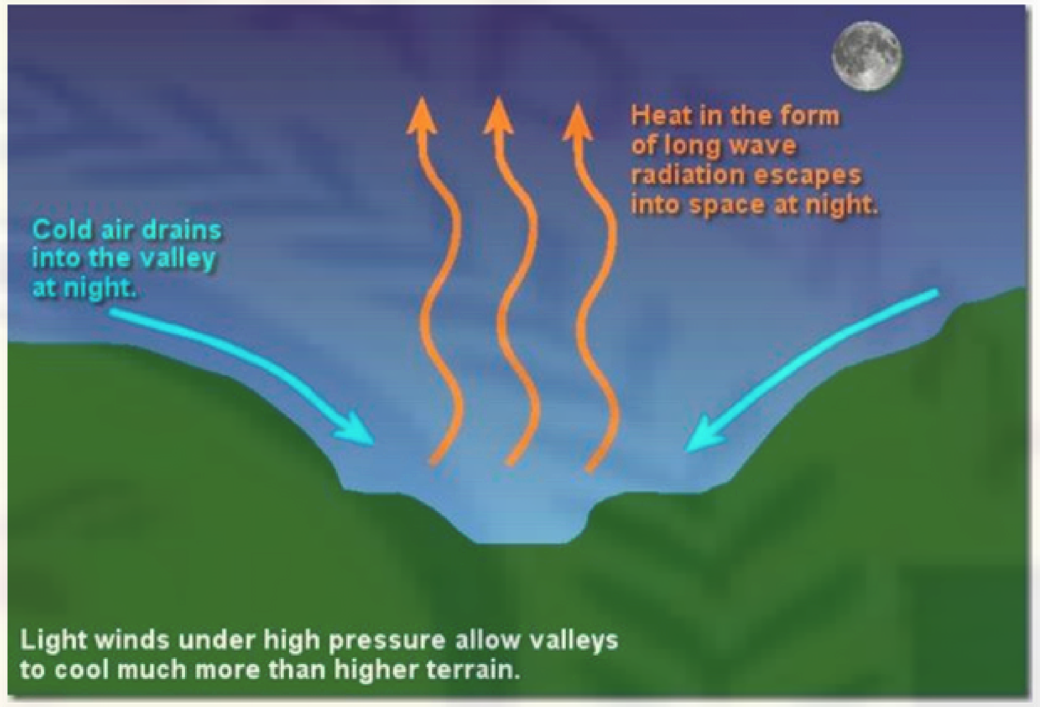
Frontal temperature inversion

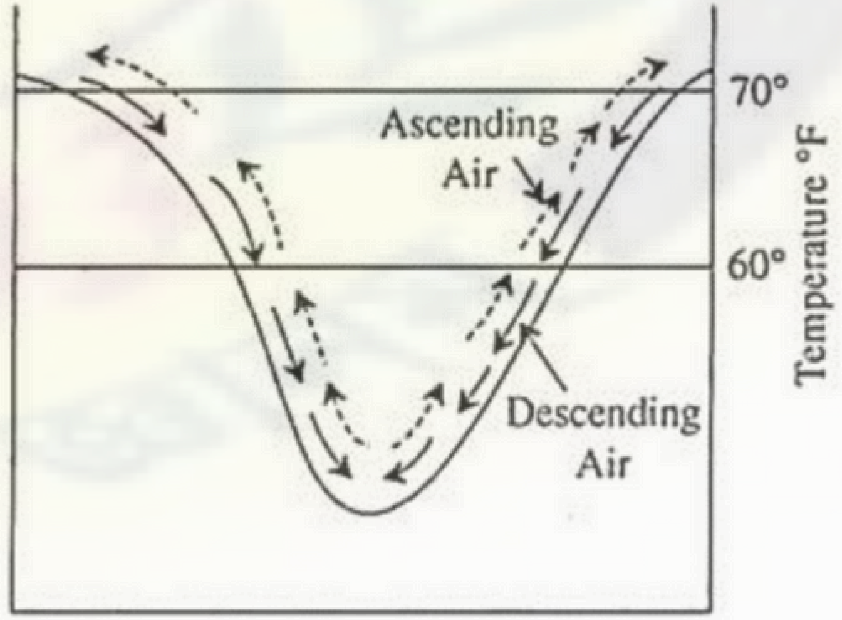
- In this type of inversion there is a convergence of warm and cold air mass.
- The warm air being lighter goes upward and the cool air being heavier sinks down.
- This kind of inversion has a considerable slope, whereas other inversions are nearly horizontal.
- It often happens in temperate zones (convergence of warm westerlies and cold polar winds) and creates temperate cyclones.



Valley Inversion

- Generally occur in mountainous valleys due to radiation.
- During winter nights, the upper surface radiates heat and get cooled.
- The air become denser and descends downhill into the valley under the influence of gravity to pile up in pockets and valley bottoms with warm air above.
- This is also called air drainage.





Effects of Temperature Inversion

- **Fog formation –** Foggy condition is created near the ground because the water vapour is trapped.
- **Less Visibility** – due to accumulation of smoke, dust particles & fog (air is cooler) beneath the inversion layer
- **Health Hazards** – trapping of smog (smoke + fog)
- **Frost -** Inversion of temperature causes frost when the condensation of warm air due to its cooling by cold air below occurs at temperature below freezing point.
- **Dry Conditions** - Inversion of temperature causes atmospheric stability (no movements of air). This discourages rainfall and favours dry condition.