M.Sc Semester-III, Paper: CC-12 (Environmental Chemistry)

Unit-1 Environment (Contd.) [By Dr. Birendra Kumar, Maharaja College]

⇒ Atmosphere?

Atmosphere is one of the most important segment of the environment. 'Atmosphere' word is derived from Greek words: 'atoms', meaning 'vapours' and 'sphaira', meaning 'sphere'. Thus, atmosphere is protective blanket of gases/vapours held bound to earth by earth gravitational force. The mixture of gases surrounds the sphere of the earth. It is source of O_2 & CO_2, essential both for life and plants. It is also source of N_2, essential for fixing bacteria and manufacture of ammonia (NH_3). It is a part of hydrological cycle.

⇒ Composition of the atmosphere:

The atmosphere has three categories of constituents: Major, Minor or Trace components. Pollution free dry air at ground level, the components may be expressed as % by volume.

1. Major components: Nitrogen (N_2): 78.09%, Oxygen (O_2): 20.94%, water vapour (H_2O): 1-5%.
2. Minor components: Argon (Ar): 0.934%, Carbon dioxide (CO_2): 0.0325%.
3. Trace components: Neon (Ne): 1.82×10^{-3}%, Helium (He): 5.24×10^{-4}%, Methane (CH_4): 2×10^{-4}%, Krypton (Kr): 1.14×10^{-4}%, Hydrogen (H_2): 0.5×10^{-5}%, Xenon (Xe): 8.7×10^{-8}%, SO_2 - 2×10^{-8}%, Carbon monoxide (CO): 1.2×10^{-5}%, Nitrogen dioxide (NO_2): 1×10^{-5}%, Ozone (O_3) - trace amt.

The earth's atmosphere is air envelop of gases exceeding to a height of 200nm. It constitutes protective cover of gases surrounding the earth which protects life and lives it from harmful environment of outer sphere/face. Oceans is the most important sink for most atmosphere gases. Plants (Vegetation) are also capable of taking up atmospheric gases.

⇒ Atmospheric structure/Regions of atmosphere:

Atmosphere may be divided into five regions on the basis of height from earth and temperature.

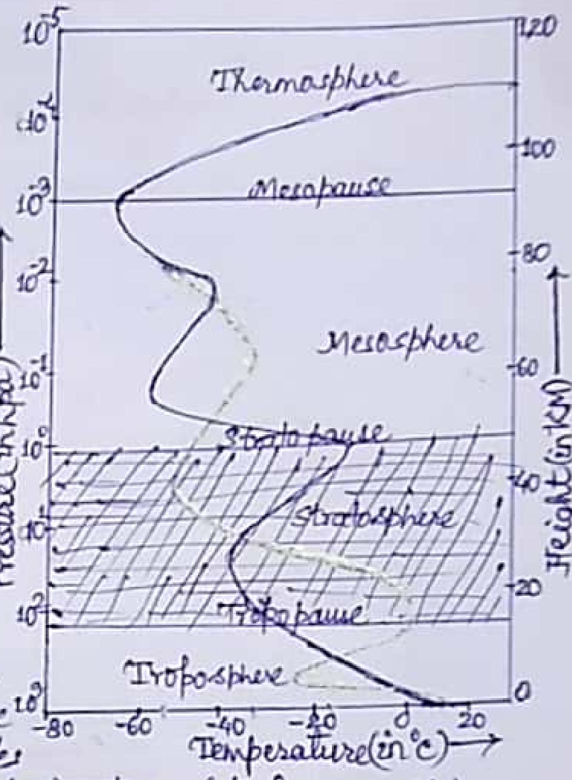
Name of the region	Temp. range (°C)	Average height (in KM)	Special features
1. Troposphere	-15 to -55	0-11	Very dynamic, turbulent, snow, fog, rain, dust, N_2, O_2, CO_2, NO_2, SO_2, particulates etc. present. (+) lapse rate
2. Stratosphere (Ozonosphere)	-55 to -2	11-50	Calm & quite long resident time high stability. Existence of ozone layer, Sun is exothermic, UV radiation. (-) lapse rate.
3. Mesosphere (Ionosphere)	-2 to -90	50-87	Region of lowest temperature, thin atmosphere consisting of N_2^+, O_2, small quantities of O_2^+, NO^+. (+) lapse rate
4. Thermosphere	-90 to 1200	87-550	Very thin atmosphere of ionic species consisting of O_2^+, O^+, NO^+, important for radio communication network. (-) lapse rate.
5. Exosphere	High temp.	Above 550	Later planetory space where geomagnetic field is predominant.

⇒ Vertical temperature:

Temperature of atmosphere decreases with height above 11-12 km from the Earth's surface. This fact results from the Sun's radiation stricking the earth and the earth then warming the air above it. So the closer the air to the ground, the warmer it. The atmosphere has five regions on temperature range: Exosphere, Thermosphere, Mesosphere, Stratosphere & Troposphere.

* Exosphere: This is outermost layer of the atmosphere. It extends from the top of the thermosphere to 10,000 KM above the earth. In this layer, atoms and molecules escape into space and satellites orbit

of the earth. At the bottom of the exosphere is the thermo-pause located around 600km above the earth.

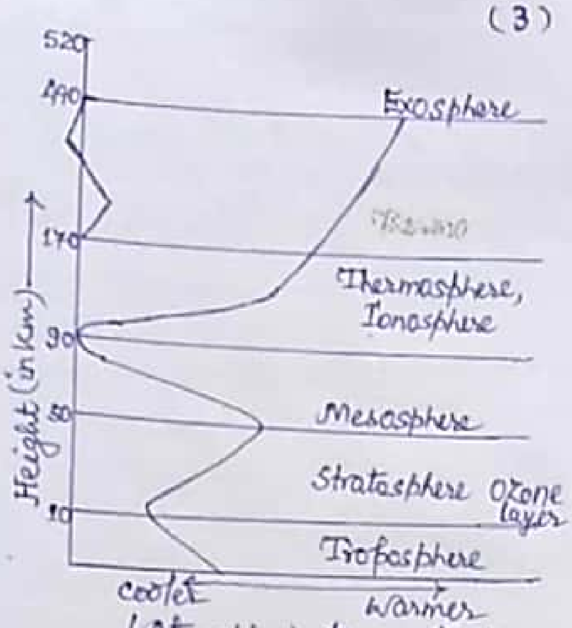


*Thermosphere: This lies between 87km & 550km in the atmosphere. This layer is known as the upper atmosphere while still extremely thin, the gases of thermosphere become increasingly denser as one descends toward the earth. As such incoming high energy ultraviolet and x-ray radiation from the sun begins to be absorbed by the molecules in this layer and causes a large temperature increase. Because of the absorption, the temperature increases with height. From as low as -90°C at the bottom of this layer, temperatures can reach as high as 1200°C near the top. However, despite the high temperature, this layer of the atmosphere would still feel very cold to our skin due to the very thin atmosphere. The high temperature indicates the amount of the energy absorbed by the molecules but with so few in this layer, the total number of molecules is not enough to heat our skin.

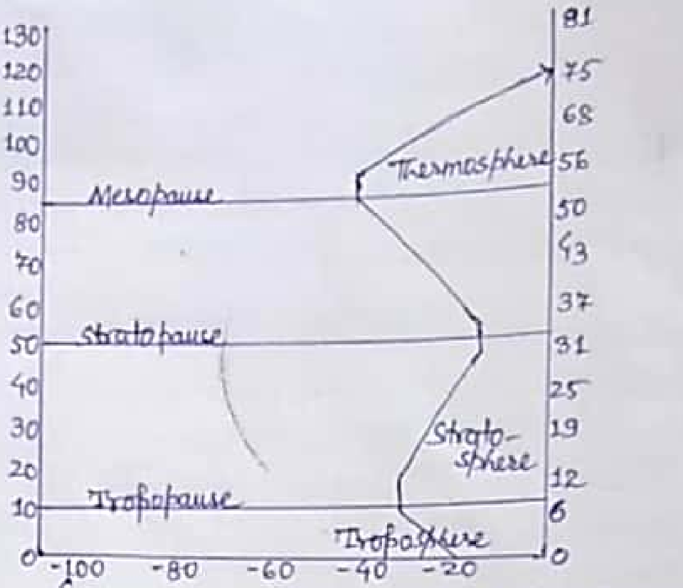
*Mesosphere: This layer extends from around 50km above the earth's surface to 87km. The gases including the O_3, continue to become denser as one descends. As such, temperatures increase as one descends rising to about -2°C near the bottom of this layer. The gases in the mesosphere are now thick enough to slow down meteors hurtling into the atmosphere, where they turn up, leaving fiery trails in the high sky. Both the stratosphere (next layer down) and the mesosphere are considered the middle atmosphere. The transition boundary which separates the mesosphere from the stratosphere is called the stratopause.

*Stratosphere: The stratosphere extends around 50km down to anywhere from 6-20km above the earth's surface. This layer holds 19% of the atmosphere's gases but very little water vapour. In the region, the temperature increases with height. Heat is produced in the process of the formation of ozone and this heat is responsible for temperature increases from an average -55°C at tropopause to a maximum of about -2°C at the top of the stratosphere. This increase in temperature with height means warmer air is located above cooler air. This prevents convection as there is no upward vertical movement of the gases. As such the location of the bottom of this layer is readily seen by the 'anvil shaped' tops of cumulonimbus clouds.

*Troposphere: This is known as the lower atmosphere almost all weather occurs in this region. The troposphere begins at the earth's surface and extends from 6-11 km high. The height of the troposphere varies from the equator to the poles. At the equator it is around 11 km high, at 50°N & 50°S, ≃8km and at the poles just under 6.4km high. As the density of the gases in this layer decrease with height, the air becomes thiner. Therefore, the temperature in the troposphere also decreases with height in response. As one climbs higher, the temperature drops from an average -15°C to 55°C at the troposphere.



(Atmospheric temperature)



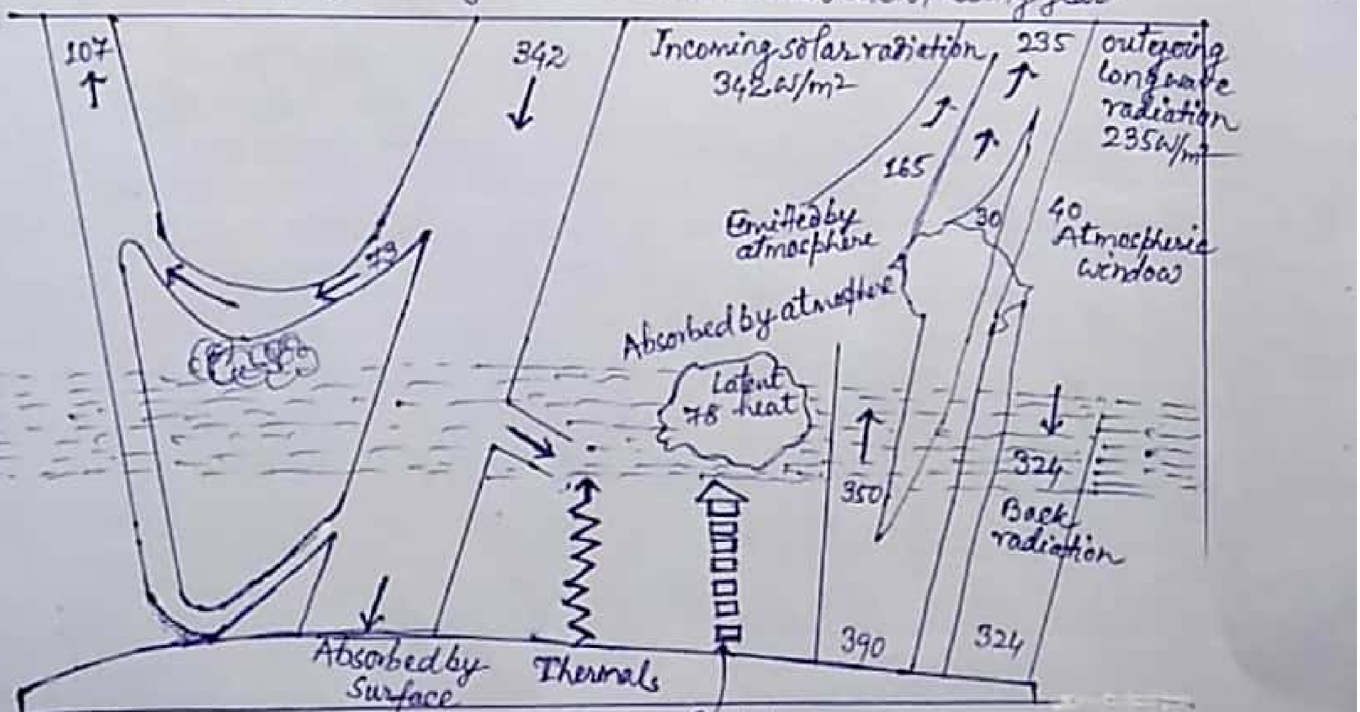
(Average temperature profile for the lower layers of the atmosphere)

⟹ Heat budget of the Earth atmosphere System:

For the energy budget at Earth's surface to balance processes on the ground must get rid of the 48% of incoming solar energy that the ocean and land surfaces absorb. Energy leaves the surface through three processes: evaporation, convection and emission of thermal infrared energy.

The average energy from Sunlight coming to the top of Earth's atmosphere is around 341.3 W/m². Less than half of the incoming sunlight heats the ground. The rest is reflected by bright white clouds or ice or gets absorbed by the atmosphere. The Sunlight that makes it to the ground warms the Earth's surface.

Heat budget: A heat budget is the perfect balance between incoming heat absorbed by the Earth and outgoing heat escaping it in the form of radiation. If the balance is distributed, then the earth would get progressively warmer or cooler with each passing year.



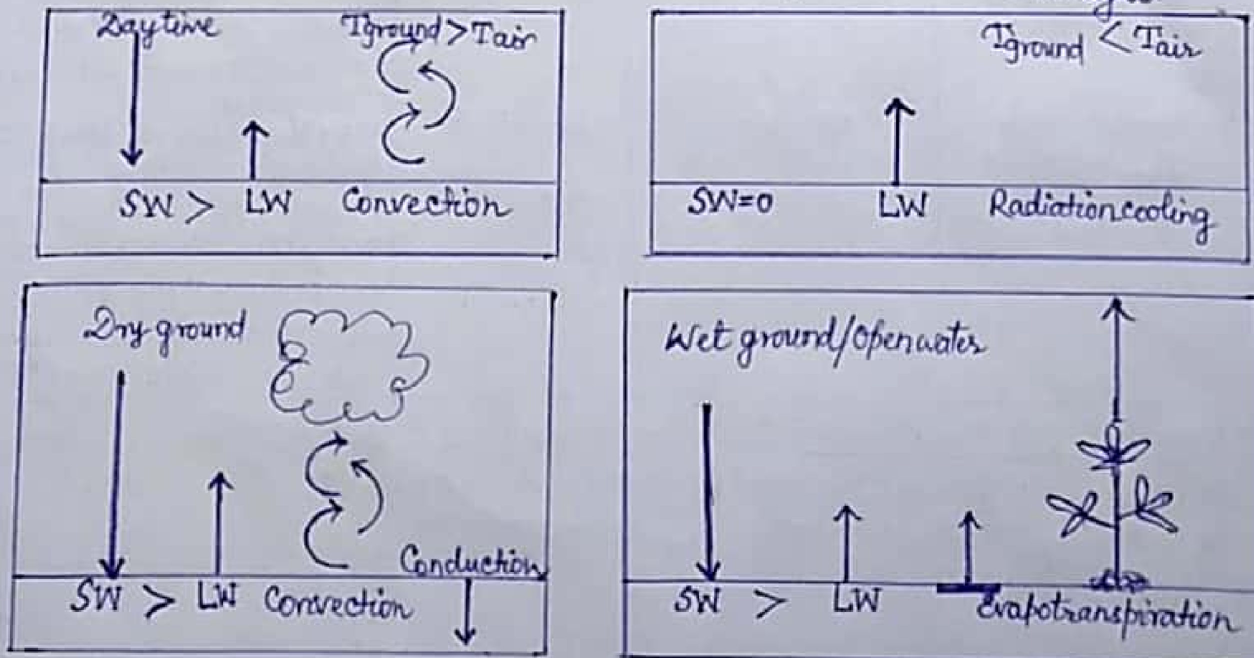
(The earth's radiation balance)

The net incoming solar radiation of 342 W/m^2 is partially reflected by clouds and the atmosphere or at the surface, but 49% is absorbed by the surface. Some of that heat is returned to the atmosphere as sensible heating and most as evapotranspiration that is realized as latent heat in precipitation. The rest is radiated as thermal infrared radiation and most of that is absorbed by the atmosphere and re-emitted both upwards and downwards producing green house effect, as the radiation lost to space comes from cloud tops and parts of the atmosphere much colder than the surface.

* <u>The global energy budget</u>: 31% of the incoming solar radiation is reflected or scattered back to space - the ALBEDO. 235 W/m^2 corresponds to a black body temperature of -19°C, thermal emission at 10 um. This is colder than Earth's surface and is reached at around 5 km. Thus, the peak terrestrial emission is in the atmospheric window in the Infrared. This fraction is transmitted directly to space, but majority is intercepted and interacts. Clouds can absorb and emit thermal radiation but are also reflector of solar radiation and so act to cool the surface. Strong cancellation between these effects the global net effect appears to be a slight cooling at the surface. 235 W/m^2 equates to 120 PW (120×10^{15} W) globally. A 1% in this value (around 2.5 W/m^2) will dominate over other present man made energy inputs.

* <u>Surface radiation budget</u>: Surface rock or soil partly reflects and partly absorbs incoming radiation. Absorption leads to an increase in surface temperature. Heat is lost to balance the SW input by LW radiation from the surface and conduction into the ground and convection in the atmosphere.

If the surface is damp then evaporation will lead to the removal of heat by evaporation. Vegetation uses some of the incoming radiation for photosynthesis. It has been estimated that around 5% of the incident solar radiation (12% of the visible radiation) is used in producing biomass. The reflected radiation depends the available sunlight. However, dense forests absorb 70%, reflect 17% and transmit to the soil 13% of the available sunlight.



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