OZONE DEPLETION

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Stratospheric Ozone

For the last 450 million years the earth has had a natural sunscreen in the stratosphere called ozone layer.

This layer filters out harmful ultraviolet radiations from the sunlight and thus protects various life forms on the earth.

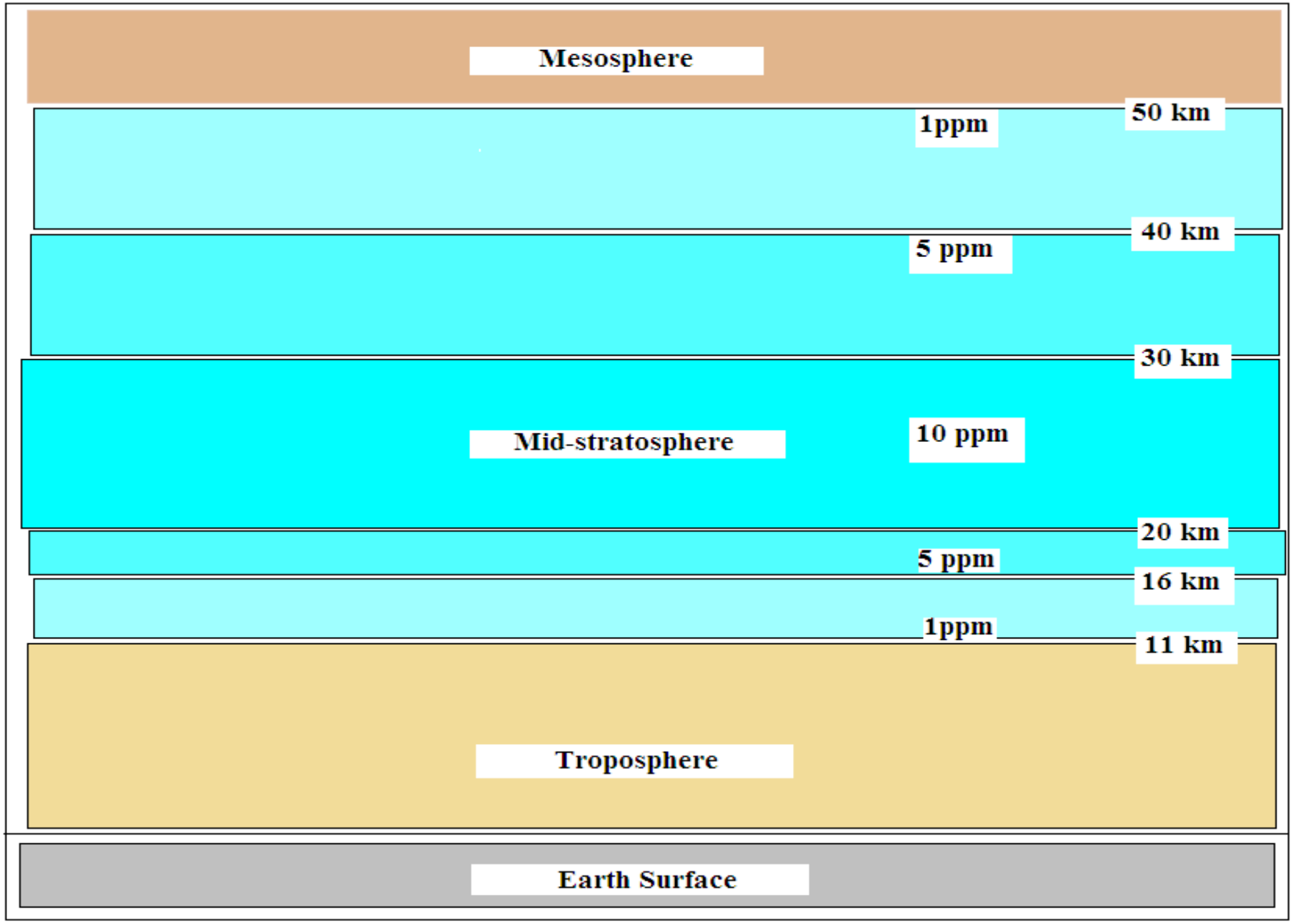
Ozone Distribution

Stratosphere, second zone of atmosphere, begins from 11 km from the earth surface and extends up to 50 km in the space.

Ozone is an important chemical species in stratosphere and its concentration varies between 10 to 1 ppm from mid portion to the peripheries of the zone, as under:

- 10 ppm between 20 to 30 km (mid 10 km)
- 5-10 ppm between 16 to 40 km (24 km)
- 1-10 ppm between 11 to 50 km (40 km)

Ozone Distribution



Ozone as protective shield

Ozone layer acts as a protective shield for the life on the Earth. It screens out about 99% of the incoming UV solar energy.

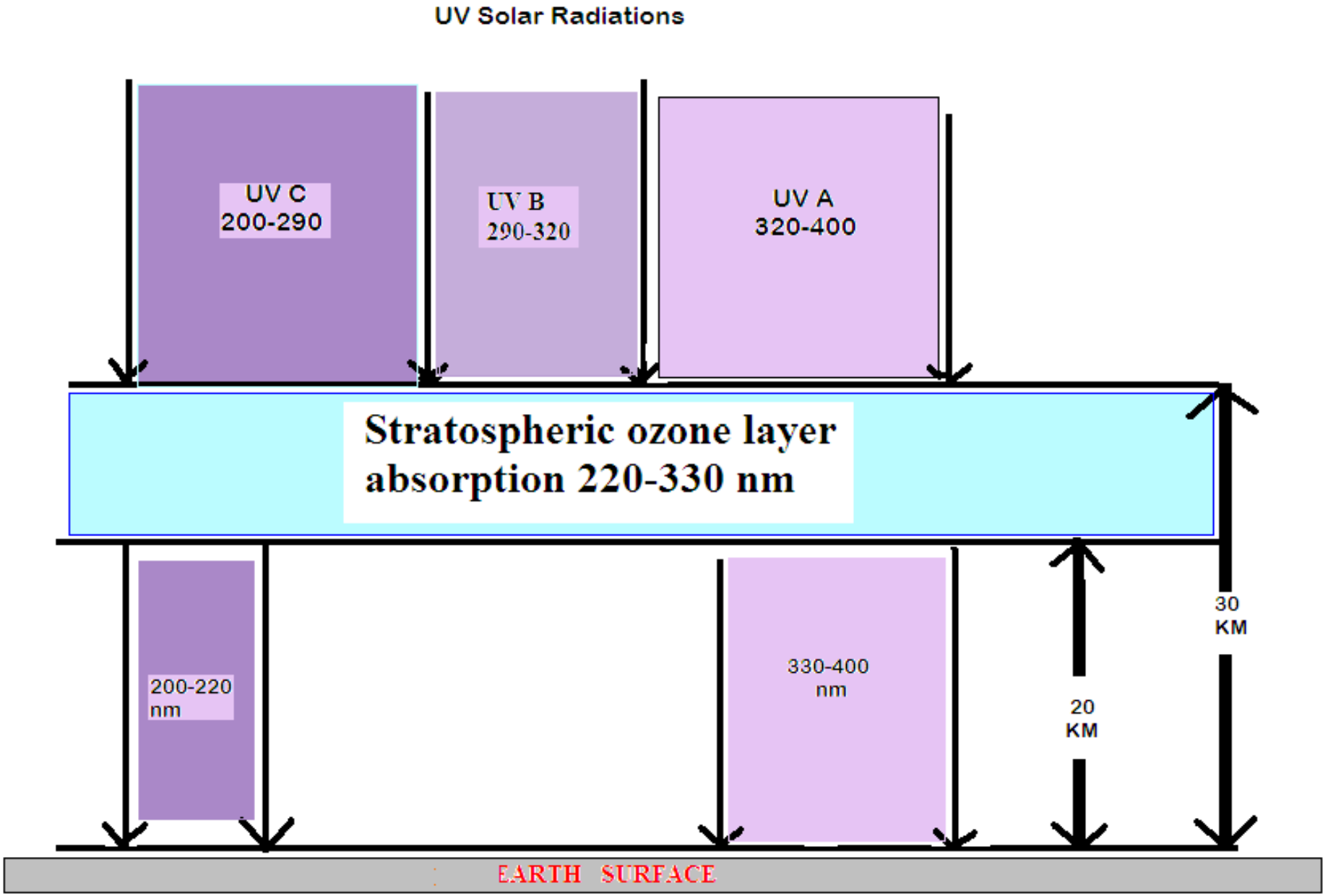
It strongly absorbs UV radiations from sun in the region 220 to 330 nm. As such it plays a critical role in protecting living organisms from the harmful effects of the solar UV radiations.

UV absorption

Solar UV radiations are in the range of 200 to 400 nm. The radiations of 200 to 290 nm are most harmful and termed as UV-C, that of 290 to 320 are named as UV-B and the rest of 320 to 400 nm are called UV-A.

Ozone absorbs completely UV-B and much of the UV-C radiations. This accounts for the absorption of about 99% of the total UV solar Energy. Only some of the UV-A reach the Earth's surface, those correspond to just 1 % of the total UV solar energy.

UV absorption in mid-stratosphere



Formation of Ozone

Ozone is constantly created in the stratosphere from oxygen by a photochemical reaction as under:

- UV radiations of less than 242 nm cause photolytic decomposition of molecular oxygen to atomic oxygen (endothermic).

$$O_2 + h\nu \rightarrow O + O$$

- The atomic oxygen thus created rapidly reacts with molecular oxygen to form ozone.

$$O + O_2 + M \rightarrow O_3 + M$$

(M is a third body necessary to carry away the excess energy released in the reaction thereby stabilizing the O_3)

Dissociation of Ozone

Ozone formed in the previous photolytic reaction distributes itself in the stratosphere. It absorbs harmful ultraviolet solar radiations in the region 220 to 330 nm and is continuously being converted back to molecular oxygen (endothermic).

$$O_3 + h\nu \rightarrow O_2 + O$$

As such in the formation of ozone as well as dissociation of ozone the ultraviolet solar energy is absorbed.

UV energy absorption in both the reactions results in heating of the stratosphere.

Net Ozone Balance

Thus Ozone is simultaneously formed and destroyed in the stratosphere in the process of absorption of ultraviolet solar energy.

$$2\ O_3 \rightleftharpoons 3\ O_2$$

This reversible reaction maintains a net 0zone balance of 10 ppm in the mid-stratosphere.

Depletion of Ozone

Ozone balance in the stratosphere may be decreased by the action of certain pollutants on ozone molecules. This phenomenon of Ozone destruction is commonly known ozone depletion.

Pollutants:- Molecular species like Nitric Oxide, reactive atoms such as atomic Oxygen, Chlorine, Bromine, etc and Hydroxyl free radicals in troposphere reach to stratosphere and destroy the ozone molecules that results is thinning of ozone layer.

Depleting action of Pollutants

1. Action of Nitric Oxide:

$$O_3 + NO \rightarrow O_2 + NO_2$$

2. Action of Atomic Oxygen:

$$O_3 + O \rightarrow 2\,O_2$$

3. Action of Atomic Chlorine:

$$O_3 + Cl \rightarrow O_2 + ClO$$

$$ClO \rightarrow O + Cl$$

$$ClO + O \rightarrow O_2 + Cl$$

4. Action of Hydroxyl free radical:

$$O_3 + HO^* \rightarrow O_2 + HOO^*$$

$$HOO^* \rightarrow O + HO^*$$

$$HOO^* + O \rightarrow O_2 + HO^*$$

Chlorofluorocarbons

Among the various pollutants Chlorofluorocarbons (CFCs / Ferrons) are mainly responsible for depletion of ozone in the stratosphere.

CFCs are a group of synthetic chemicals discovered by Thomas Midgley Jr. in 1930. Most commonly used CFCs are CFC-11(CCl_3F) and CFC-12(CCl_2F_2)

CFCs are used as coolants in refrigerators and air conditioners, as propellants, cleaning solvents, sterilant and in Styrofoam etc.

CFCs released in the troposphere reach the stratosphere and remain there for 65 - 110 years destroying the equilibrium concentration of ozone molecules.

Consequences

The existing stratospheric Ozone layer screens out about 99% of the incoming solar ultravoilet energy. The 1 % radiations reaching to the earth, many a times show harmful effects over most of the territorial ecosystems.

It is estimated that 5% decrease in Ozone concentration may cause a net 10% increase in amount of radiations reaching to the earth and 5 times increase in skin cancer every year.

Damage

Ozone depletion will result in more UV radiation reaching the earth especially UV-B (290 - 320 nm) that affect DNA & photosynthetic chemicals.

1. Non-biological damage
2. Biological damage

Non-biological damage

Increase in UV radiations may cause faster deterioration of Fabrics, Plastics, Paints and other similar type materials.

Biological Damage

- **Cancer:** Exposure of plants and animals to increased solar uv radiations causes loss of the bio-sensivity of the genetic material (protein i.e. DNA). Any change in DNA can result in mutation and cancer. Cases of skin cancer (basal and squamous cell carcinoma), which do not cause death but cause disfigurement, will increase.
- **Sunburn:** Melanin producing cells of the epidermis (important for human immune system) will be destroyed by UV-rays resulting in immuno-suppression. Fair people (can't produce enough melanin) will be at a greater risk of UV exposure.

Biological Damage

- **Eye damage:** Increased absorption of solar UV radiations by the lens and cornea of eye will result in increase in incidents of cataract.
- **Adverse impact on population growth:** Phytoplankton's are sensitive to UV exposure. Ozone depletion will result in decrease in their population thereby affecting the population of zooplankton, fish, marine animals, in fact the whole aquatic food chain.
- **Decrease in food production:** Yield of vital crops like corn, rice, soybean, cotton, bean, pea, sorghum and wheat will decrease.

Ozone Hole

The pollutants, more particularly the reactive atoms of chlorine, bromine, etc. cause intense and localized destruction of stratospheric ozone molecules.

This results in vertical thinning of ozone layer in a small region, generally called ozone hole.

Antarctic Ozone Hole

The Antarctic ozone hole was discovered by Dr Joe C. Farman and his colleagues in the British Antarctic Survey who had been recording ozone levels over this region since 1957.

Ozone depletion was observed at south pole (Antartica) during the spring season *i. e.* September to November each year.

Steep decline has been observed since mid 1970s with a record low concentration of 90 DU in early October of 1993.

Ozone hole at Antarctica

In 1974, Rowland and Molina warned that CFC are lowering the concentration of ozone in the stratosphere and predicted severe consequences.

It was however, in 1985 that scientists for the first time discovered that 50% of upper stratospheric ozone (98% in some areas) over Antarctica was destroyed during the Antarctic spring and early summer (September-December).

Ozone hole at Antarctica ...cont...

At Antarctic region the temperature during winter drops to - 90°C. The winds blowing in a circular pattern over earth's poles create polar vortices.

Water droplets in clouds when enter these vortices form ice crystals.

CFCs get collected on the surfaces of these ice crystals and destroy ozone much faster.

Ozone hole at North Pole

Similar destruction of ozone over North Pole occurs during Arctic spring and early summer (February-June) every year.

The depletion is 10-25% and it is less than that observed at South Pole.

Ozone hole & Pollutants

Nitrous oxide emitted by supersonic aircrafts, during combustion of fossil fuel and use of nitrogen fertilizers breaks ozone molecules.

Chlorine liberated from chlorofluorocarbons also break ozone molecules.

The chain reaction started in Antarctic spring *i.e.* August / September continues till nitrogen dioxide is liberated from nitric acid formed in the stratosphere by photolysis.

Nitrogen dioxide combines with chlorine and stops further destruction of ozone.

Measurement of stratospheric Ozone

Dobson Spectrometer: Amount of atmospheric ozone is measured by Dobson Spectrometer and is expressed in Dobson units (DU).

DU: One DU is equivalent to a 0.01 mm thickness of pure ozone at the density it would possess if it were brought to ground level (l atm) pressure.

Normally over temperate latitude its concentration is about 350 DU, over tropics it is 250 DU whereas at sub polar regions (except when ozone thinning occurs) it is on an average 450 DU.

It is because of the stratospheric winds which transport ozone from tropical towards polar regions.

Conclusion

About 80% of the worlds production of CFCs was done by America & Canada up to 1990. However in 1995 its production was totally stopped in response to agenda-21 of Earth Summit 1992. By 2010 the world has to ban the use of CFCs and adopt vapour technology in air conditioning.

The ban on production of CFCs is proved to be very fruitful. As per a report-2007 on environment the radius of Antarctic ozone hole was reduced by 40% and it is estimated that by 2050 the hole will be completely filled up.