Space Physics

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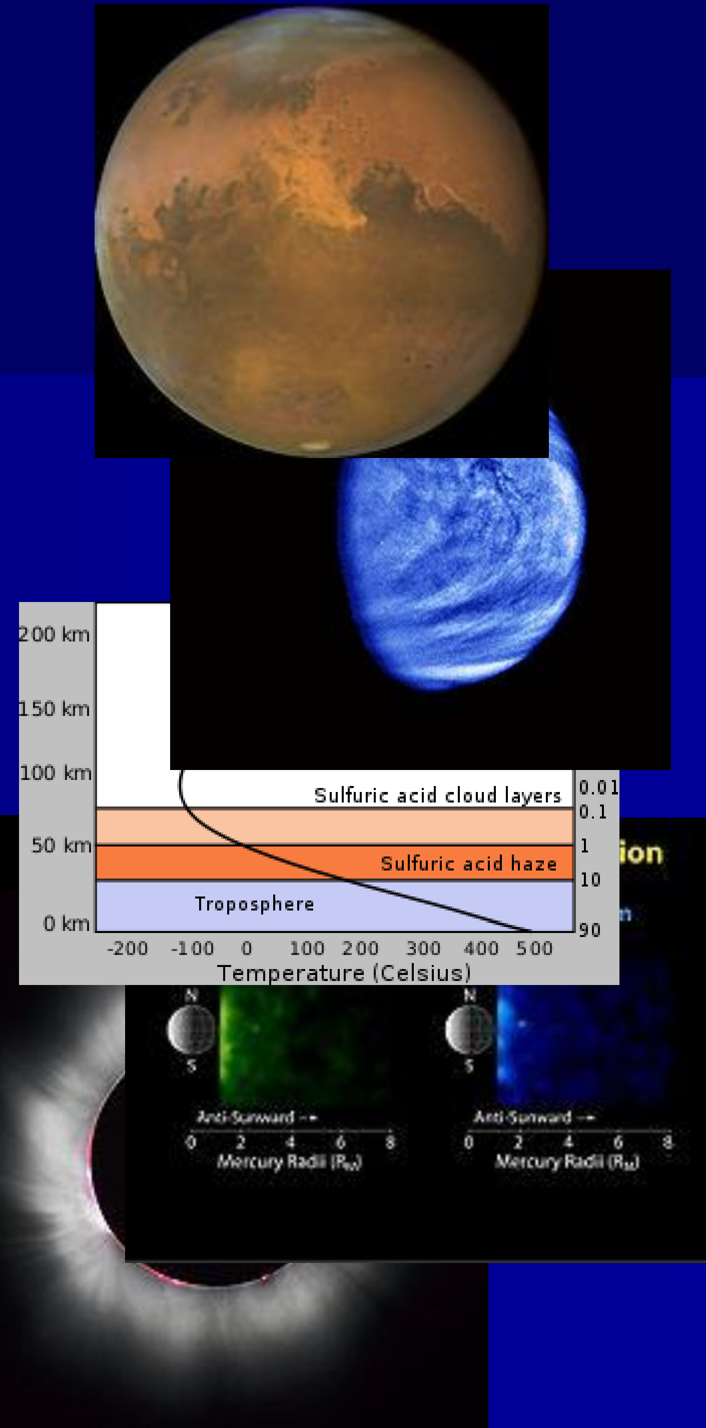


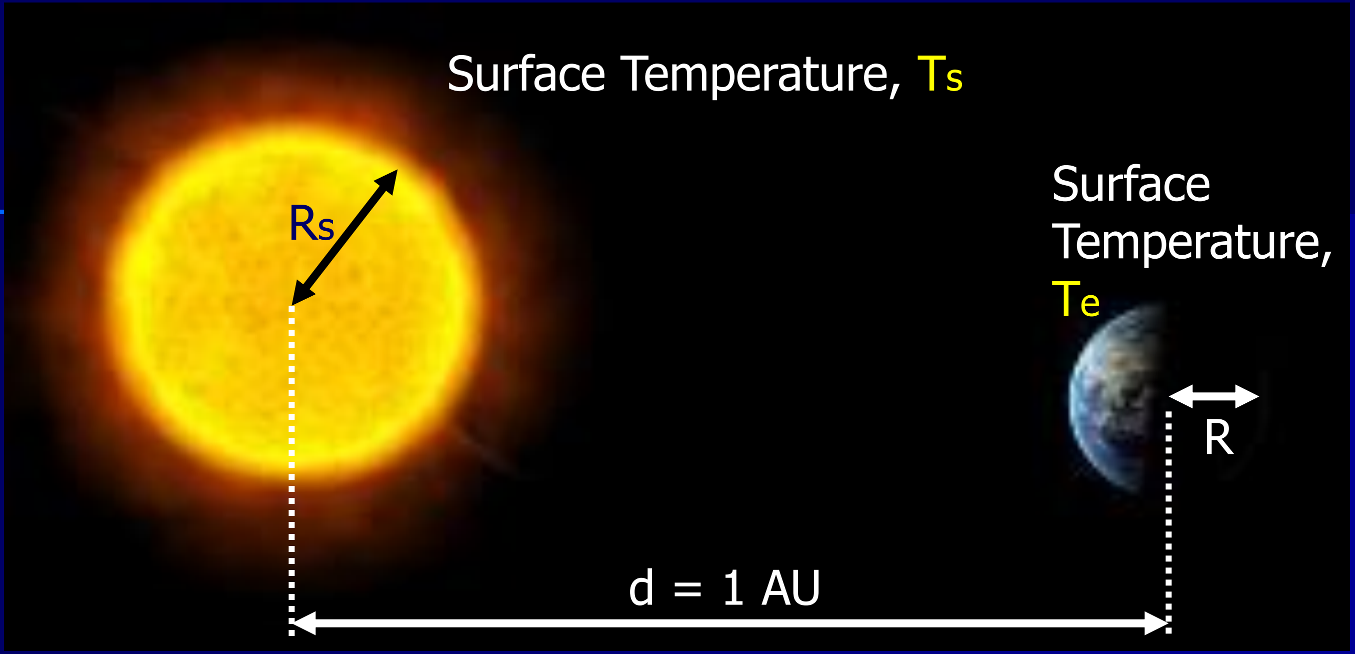
Lecture – 03

Planetary Atmospheres

Planetary Atmospheres

The Structure of the Terrestrial Atmosphere
The Temperature of the Neutral Atmosphere
The Escape of the Atmospheric Gases
The Atmospheres of the Earth

The Temperature of the Neutral Atmosphere



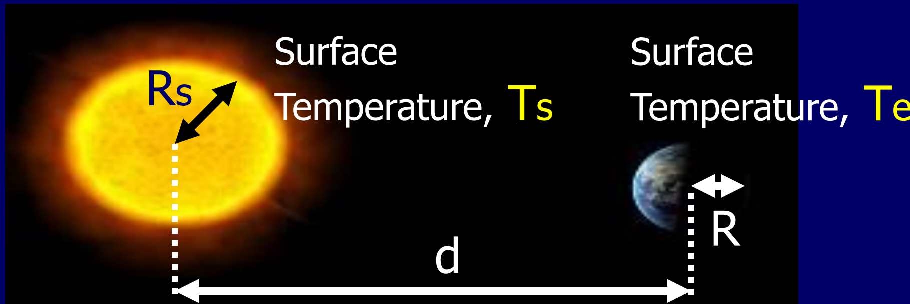
AL Method

$$\sigma = 5.67 \times 10^{-8}\ Js^{-1}m^{-2}K^{-4}$$

$$T_s = 5778\,K \ \ (\sim 6000\,K)$$

$$R_s = 695500\ km \ (\sim 7 \times 10^5\ km)$$

$$d = 149\,598\,000\ km\ \ (1AU)$$



$$T_e = \left(\frac{T_S^{\,4} \times R_S^{\,2}}{e\ d^2 \times 2} \right)^{1/4}$$

$$T_e = \{1047.62, 589.123, 393.97, 340.13, 332.121, 331.288\}\ C$$

???

The value of the effective temperature of the Earth :

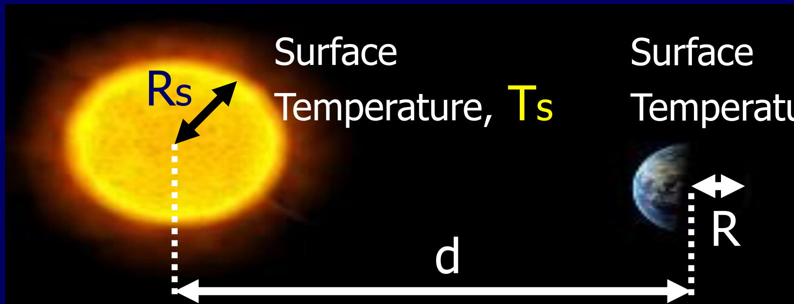
$$T_e = \left(\frac{R_S}{d} \right)^{1/2} \left(\frac{1-A}{4} \right)^{1/4} T_S$$

Where, $A = 0.4$

Albedo of the Earth…

Let the reflectivity of this sphere be such that it reflects a fraction *A* (Albedo) and absorbs the remaining fraction (*1 – A*) of the incoming solar radiation.

$$T_e = 245.181\,K$$



The value of the **effective temperature of the Earth**,

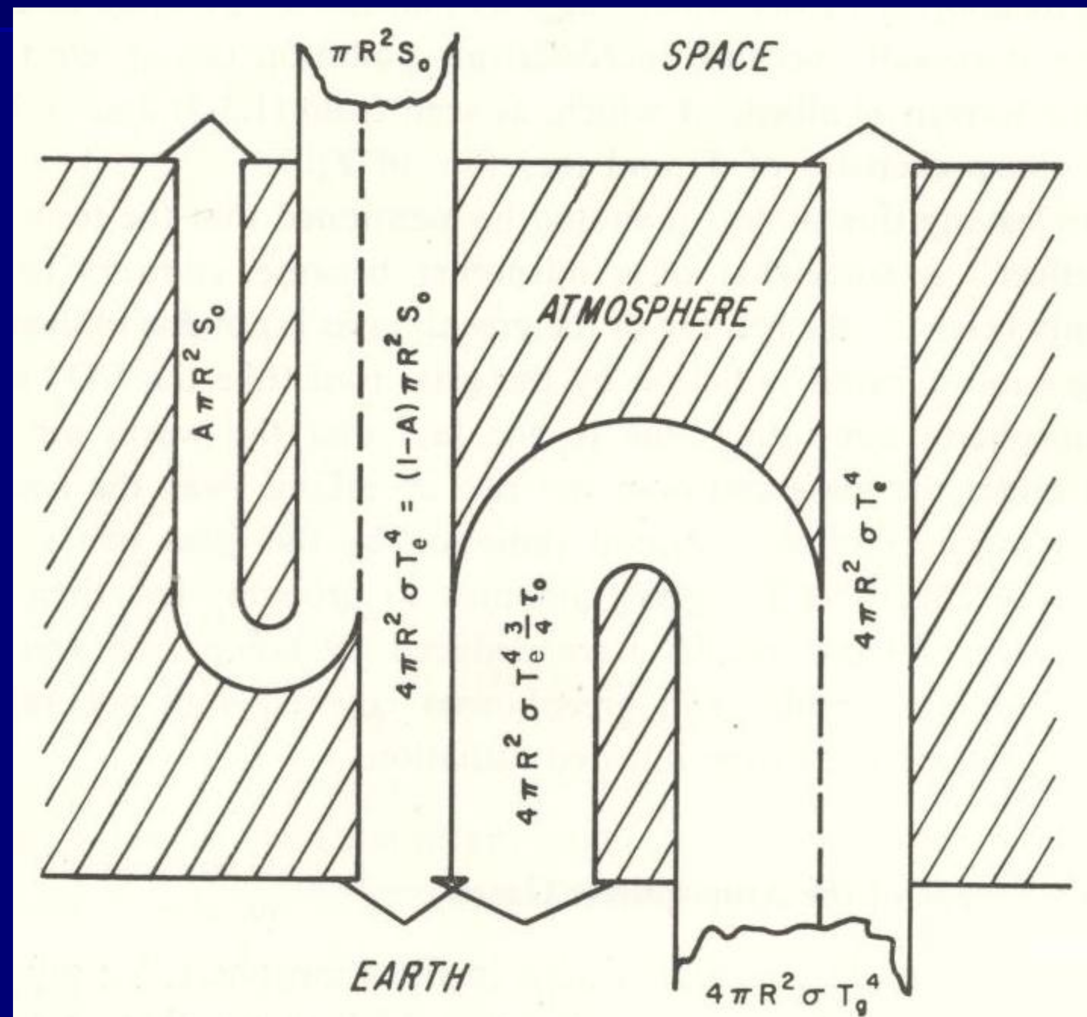
$$T_e = 245.181\,K$$

Consider the Green House Effect…

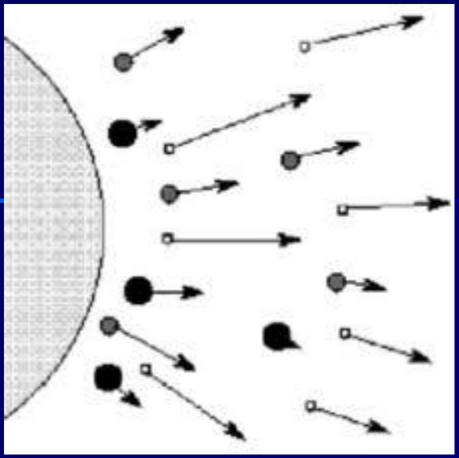
$$T_e = 305\,K$$

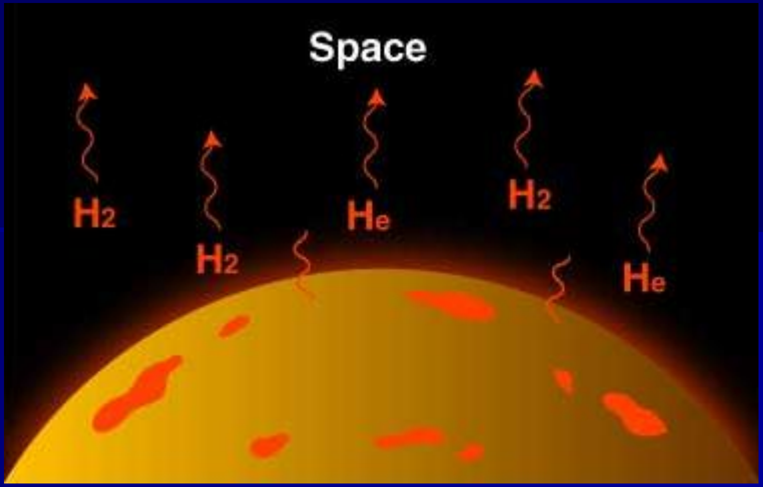
Convective transport of heat in the lower atmosphere, which would tend to cool down the surface of the Earth.

$$T_a = 288\,K$$



The Escape of the Atmospheric Gases





The most probable speed (Vm)

$$V = \left(\frac{2kT}{M}\right)^{1/2}$$

Therefore, the Escape Velocity of a planet:

$$V_e = (2gR)^{1/2}$$

The ratio of $V_e : V_m$

$$\frac{V_e}{V_m} = \left(\frac{R}{H}\right)^{1/2} \Rightarrow \frac{V_e}{V_m} = \left(\frac{6400\,km}{8.7\,km}\right)^{1/2} \Rightarrow V_e \approx 28 V_m$$

Most Probable Velocity

Escape Velocity

Planetary Atmospheres

Planetary Atmospheres

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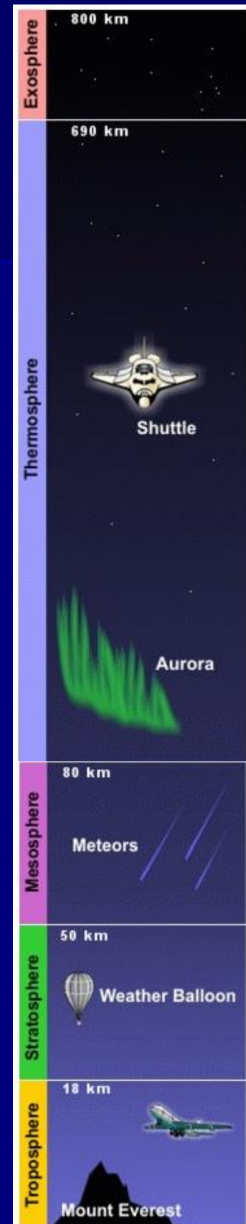
The Escape of the Atmospheric Gases
The Atmospheres of the Earth

Atmosphere of Earth

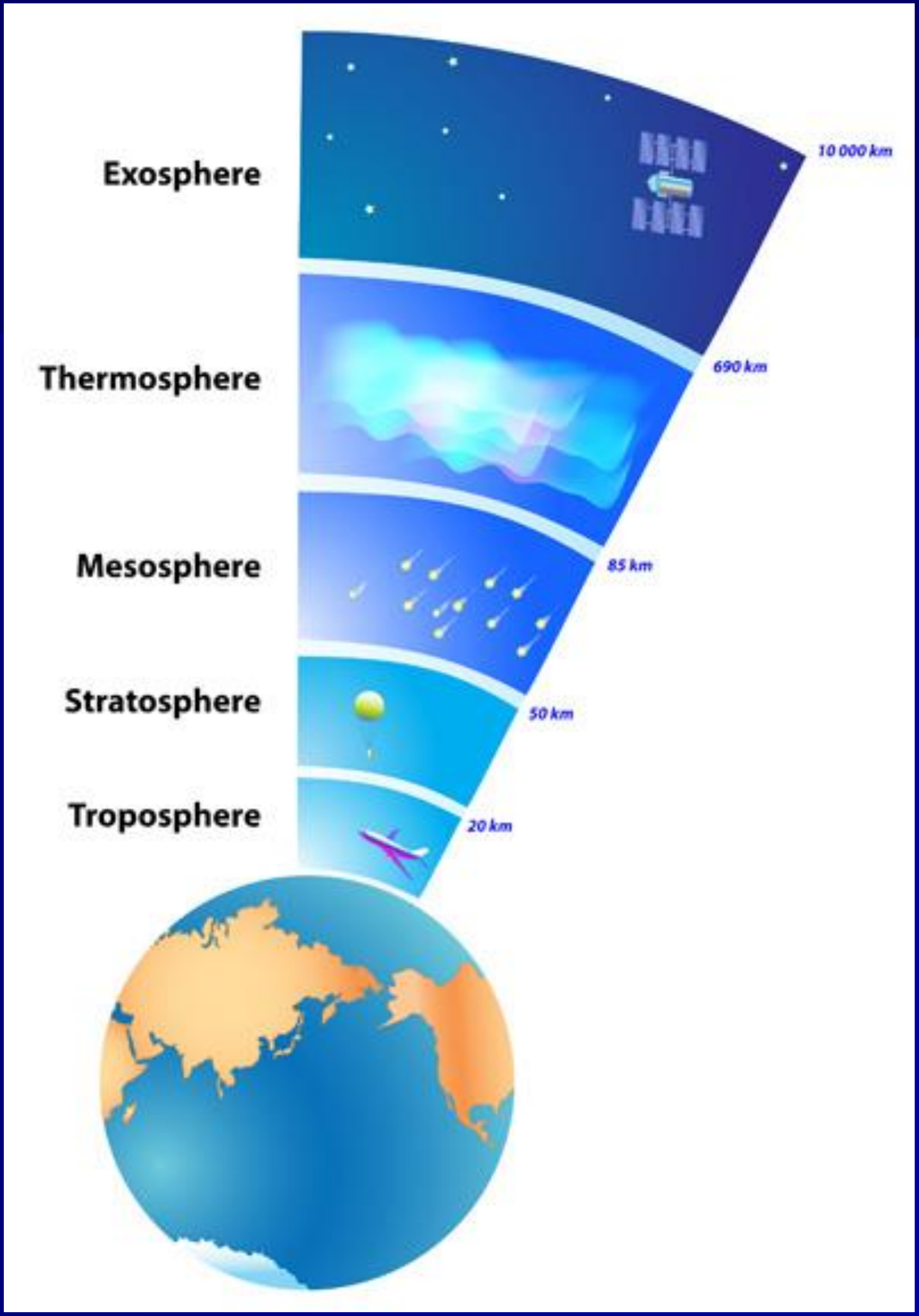
Atmosphere of Earth



Atmosphere of Earth

Atmospheric layers

The properties of the Earth's atmosphere vary with altitude. Based on these properties, the atmosphere may be regarded as having different layers or zones. According to one system of nomenclature, there are five layers: the troposphere, stratosphere, mesosphere, thermosphere, and exosphere. The boundaries between these regions are called the tropopause, stratopause, mesopause, and exobase.



Atmosphere of Earth

Troposphere

The troposphere is the atmosphere's lowest and densest layer, and it is also known as the *lower atmosphere*. It starts from the Earth's surface and reaches up to about 7 km at the poles and 17 km at the equator, with some variation caused by weather factors. The upper boundary of this layer is called the *tropopause*.

Atmosphere of Earth

Stratosphere

The stratosphere is situated directly above the troposphere and just below the mesosphere. In terms of its altitude range, it lies between about 10 km and 50 km at moderate latitudes, but it starts at about 8 km at the poles. This layer is dynamically stable, with no regular mixing of air and associated turbulence.

The upper layers of the stratosphere are heated by the presence of an ozone layer that absorbs ultraviolet (UV) radiation from the Sun radiation that would otherwise be harmful to living organisms on Earth.

Atmosphere of Earth

Mesosphere

The mesosphere is the layer between about 50 km and about 80–85 km above the Earth's surface. It is sandwiched between the stratosphere and the thermosphere. The temperature in this layer decreases with increasing altitude and can be as low as 200K (≈ -73° C), **varying according to latitude and season.**

Millions of meteors burn up daily in the mesosphere, as a result of collisions with the gas particles contained there, leading to a high concentration of iron and other metal atoms.

Atmosphere of Earth

Thermosphere

The thermosphere extends from an altitude of 80–85 km to 640+ km. It lies directly above the mesosphere and right below the exosphere.

The temperature in this layer increases with altitude, **due to the absorption of extremely energetic solar radiation by the small amount of oxygen present.** Temperatures are highly dependent on solar activity and can rise to 2,000° C.

Astronauts travel at altitudes that exceed 80 km, which means that they travel within or go beyond the thermosphere.

Atmosphere of Earth

Atmosphere of Earth

Exosphere

The exosphere is the uppermost layer of the atmosphere. Its lower boundary at the edge of the thermosphere is estimated to be 500 km to 1,000 km above the Earth's surface, and its upper boundary at about 10,000 km.

It is only from the exosphere that atmospheric gases can, to any appreciable extent, escape into outer space. The main gases in the exosphere are the lightest ones, mainly hydrogen and helium, with some atomic oxygen near the exobase (the lowest altitude of the exosphere). The few particles of gas here can reach 2,500° C during the day.

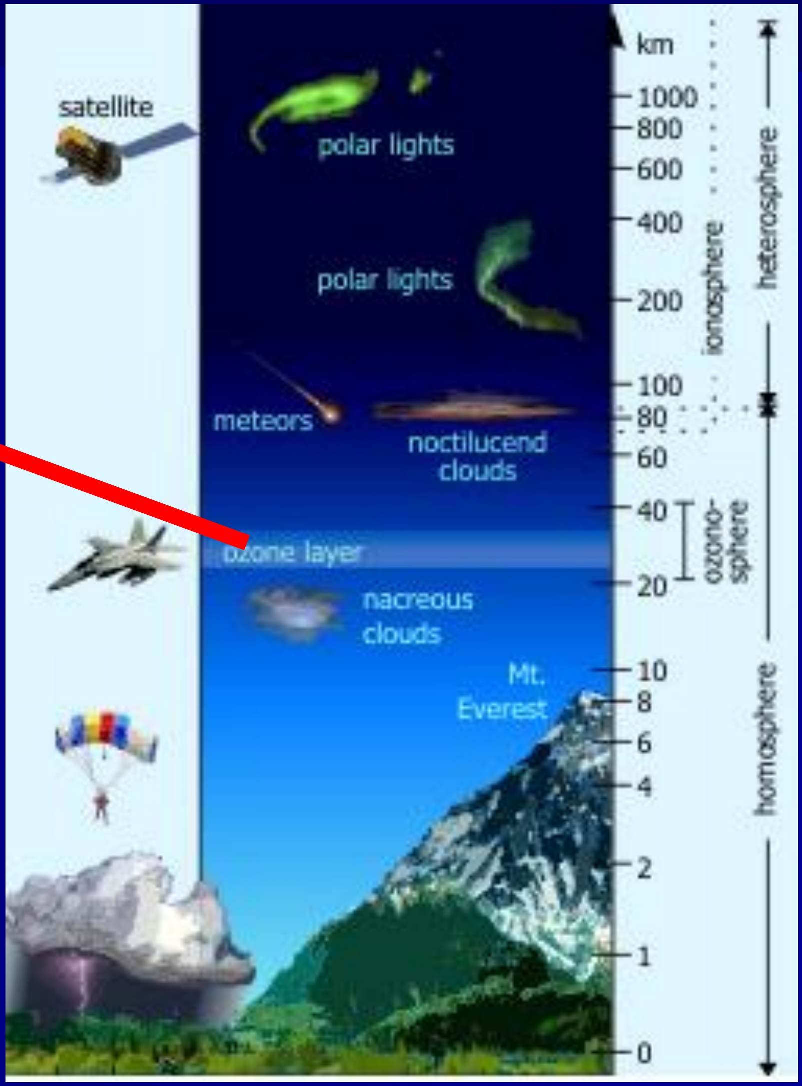
Atmosphere of Earth

Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.

Ozone layer (Ozonosphere):

In the stratosphere, in an altitude range of about 10–50 km, the concentration of ozone (O3) is a few parts per million, which is much higher than the ozone concentration in the lower atmosphere **This layer, absorbs biologically harmful UV radiation from the Sun**.

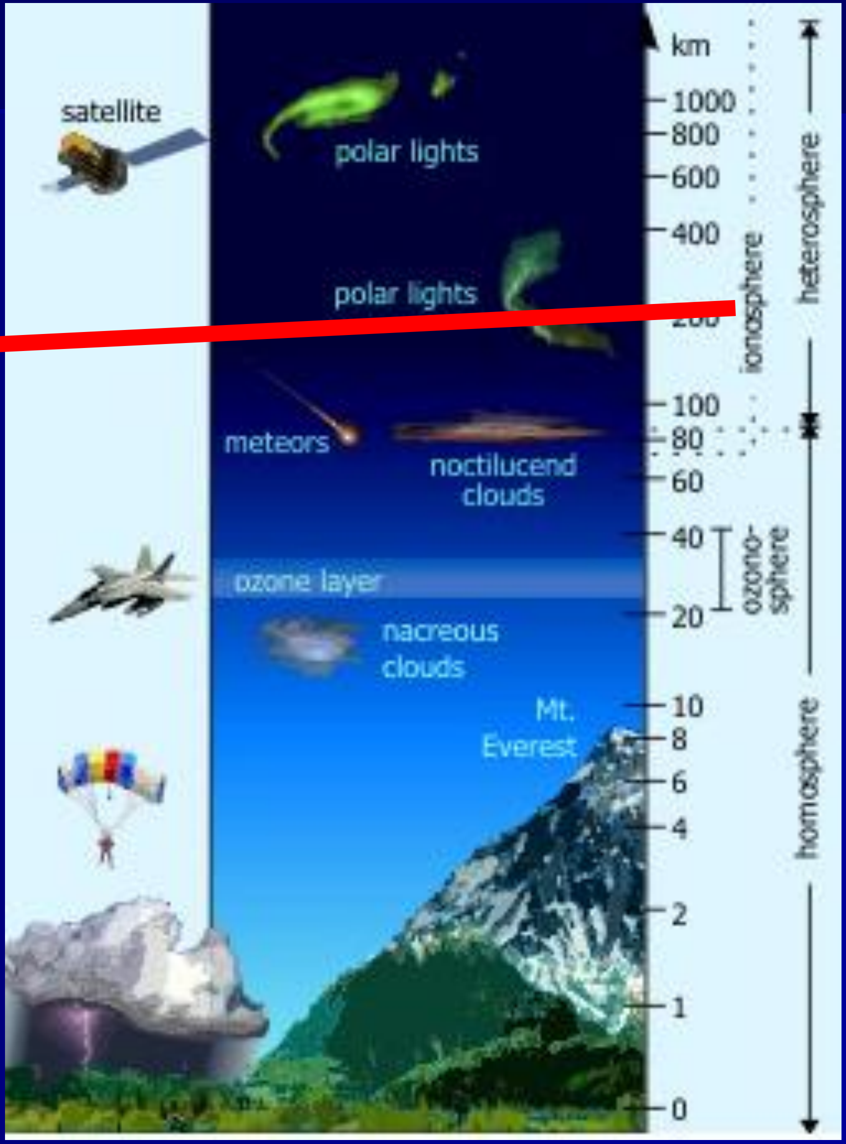


Atmosphere of Earth

Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.

Ionosphere: This is the region of the atmosphere that contains ions (that form a "plasma"), created by the interaction of solar radiation with gas particles.



Atmosphere of Earth

Additional atmospheric regions

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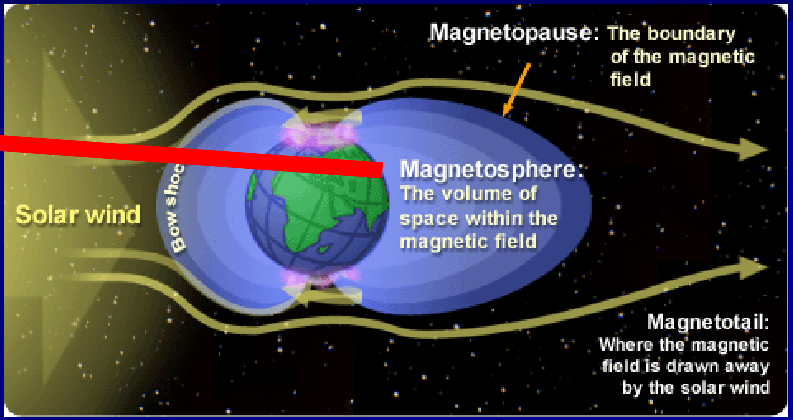
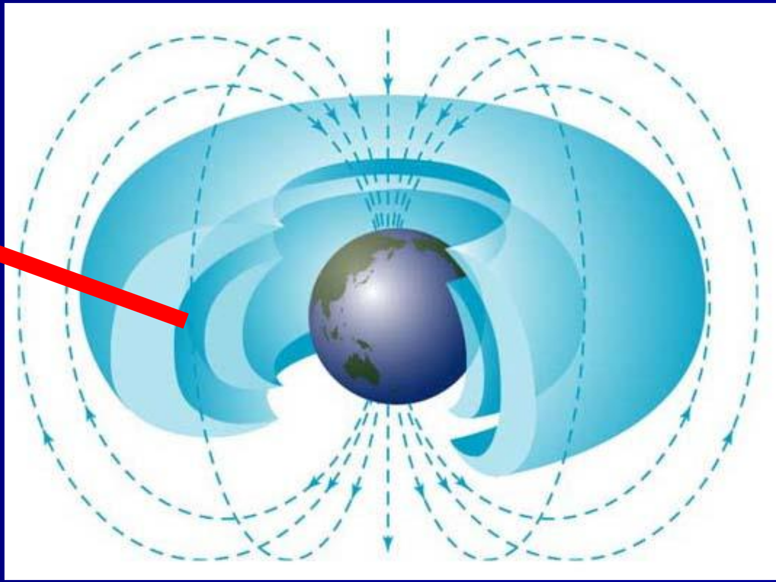


Magnetosphere: It is the region where the Earth's magnetic field interacts with the solar wind.



Van Allen radiation belts: These are regions where charged particles (forming a plasma) from the solar wind are trapped by the Earth's magnetic field.

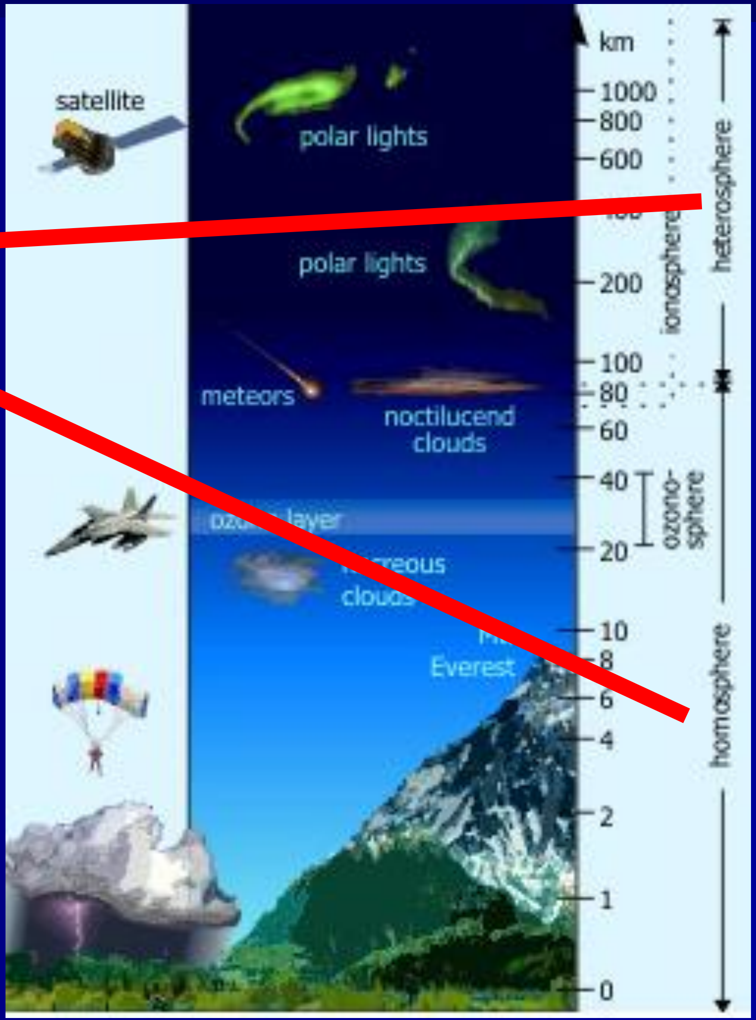
Atmosphere of Earth

Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.

Homosphere (or Turbosphere) and Heterosphere:

The region below the turbopause (that is, below an altitude of about 100 km) is known as the *homosphere* or *turbosphere*, where the chemical constituents are well mixed and the composition of the atmosphere remains fairly uniform.



Atmosphere of Earth

Pressure, density, and mass

Atmospheric pressure (or barometric pressure) is a direct result of the weight of the air. It is highest at the Earth's surface and decreases with altitude. This is because air at the surface is compressed by the weight of all the air above it. Air pressure varies with location and time, because the amount (and weight) of air above the Earth varies with location and time.

Atmospheric pressure drops by approximately 50 percent at an altitude of about 5 km. The average atmospheric pressure at sea level is about 101.3 kilopascals.

The density of air at sea level is about 1.2 kg/m3, and it decreases as altitude increases.

The average mass of the atmosphere is about 5,000 trillion metric tons.

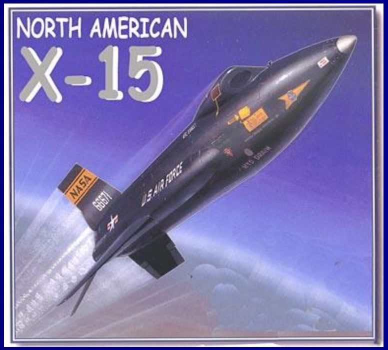
Atmosphere of Earth

Thickness of the atmosphere

57.8 percent of the atmosphere is below the summit of Mount Everest.

72 percent of the atmosphere is below the common cruising altitude of commercial airliners (about 10,000 m).

99.99999 percent of the atmosphere is below the highest flight altitude of the aircraft X-15, which reached 108 km on August 22, 1963. Therefore, most of the atmosphere (99.9999 percent) is below 100 km, although in the rarified region above this there are auroras and other atmospheric effects.

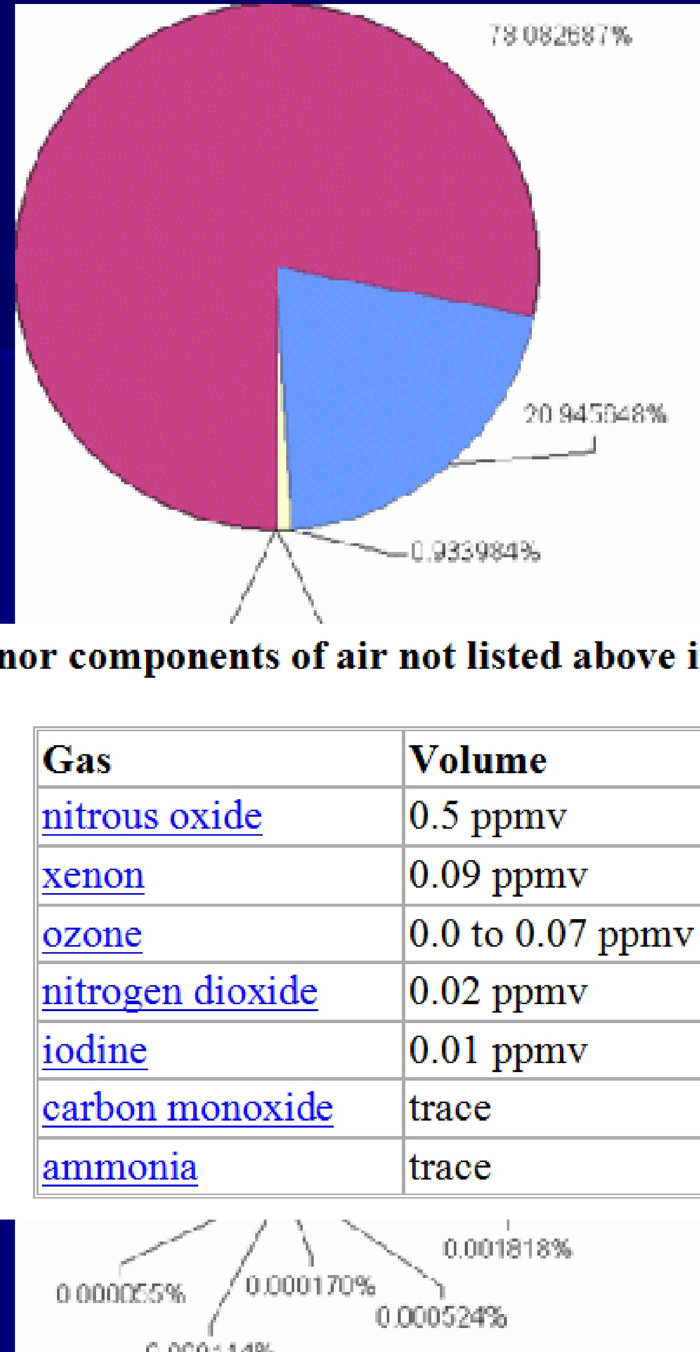


The atmosphere exists at altitudes of 1,000 km and higher, but it is so thin as to be considered nonexistent.

Atmosphere of Earth

Composition of the atmosphere

Composition of dry atmosphere (homosphere), by volume	
ppmv: parts per million by volume	
Gas	**Volume**
Nitrogen (N_2)	780,840 ppmv (78.084%)
Oxygen (O_2)	209,460 ppmv (20.946%)
Argon (Ar)	9,340 ppmv (0.9340%)
Carbon dioxide (CO_2)	350 ppmv
Neon (Ne)	18.18 ppmv
Helium (He)	5.24 ppmv
Methane (CH_4)	1.745 ppmv
Krypton (Kr)	1.14 ppmv
Hydrogen (H_2)	0.55 ppmv
Not included in above dry atmosphere:	
Water vapor (highly variable)	typically 1%



Minor components of air not listed above include:

Gas	Volume
nitrous oxide	0.5 ppmv
xenon	0.09 ppmv
ozone	0.0 to 0.07 ppmv
nitrogen dioxide	0.02 ppmv
iodine	0.01 ppmv
carbon monoxide	trace
ammonia	trace

Atmosphere of Earth

Biological significance

The Earth's atmosphere plays a vital role in sustaining life on this planet. **Oxygen is needed for respiration by animals, plants, and some bacteria.**

Plants that perform photosynthesis take up carbon dioxide from the air and release oxygen. **Carbon dioxide and water vapor act as "greenhouse gases" that keep the Earth sufficiently warm to maintain life.** Water vapor in the air is part of the water cycle that produces precipitation (such as rain and snow) that replenishes moisture in the soil. In addition, water vapor prevents exposed living tissue from drying up.

Atmosphere of Earth

Air pollution

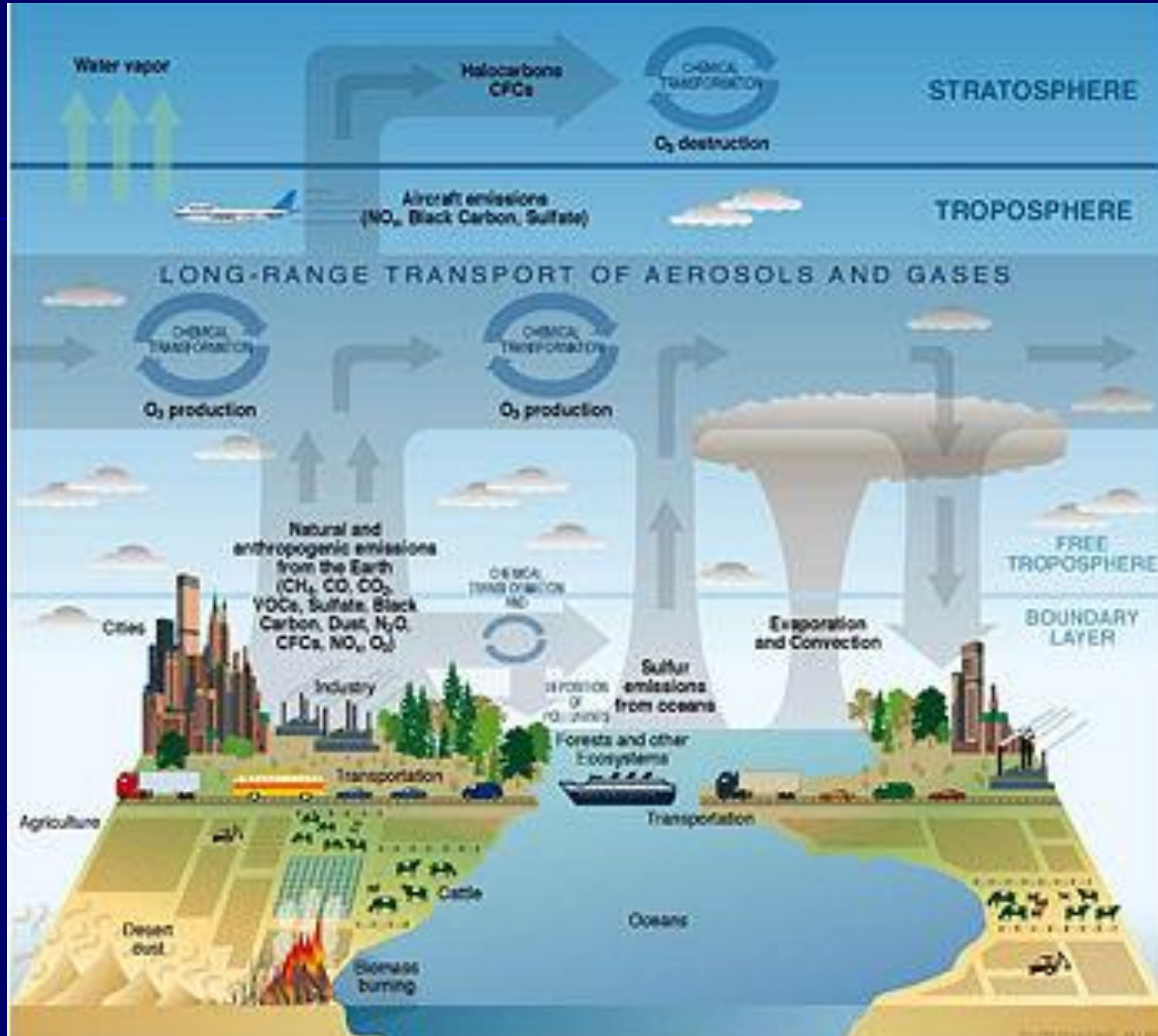


Diagram of chemical and transport processes related to atmospheric composition.

Atmosphere of Earth

Air pollution

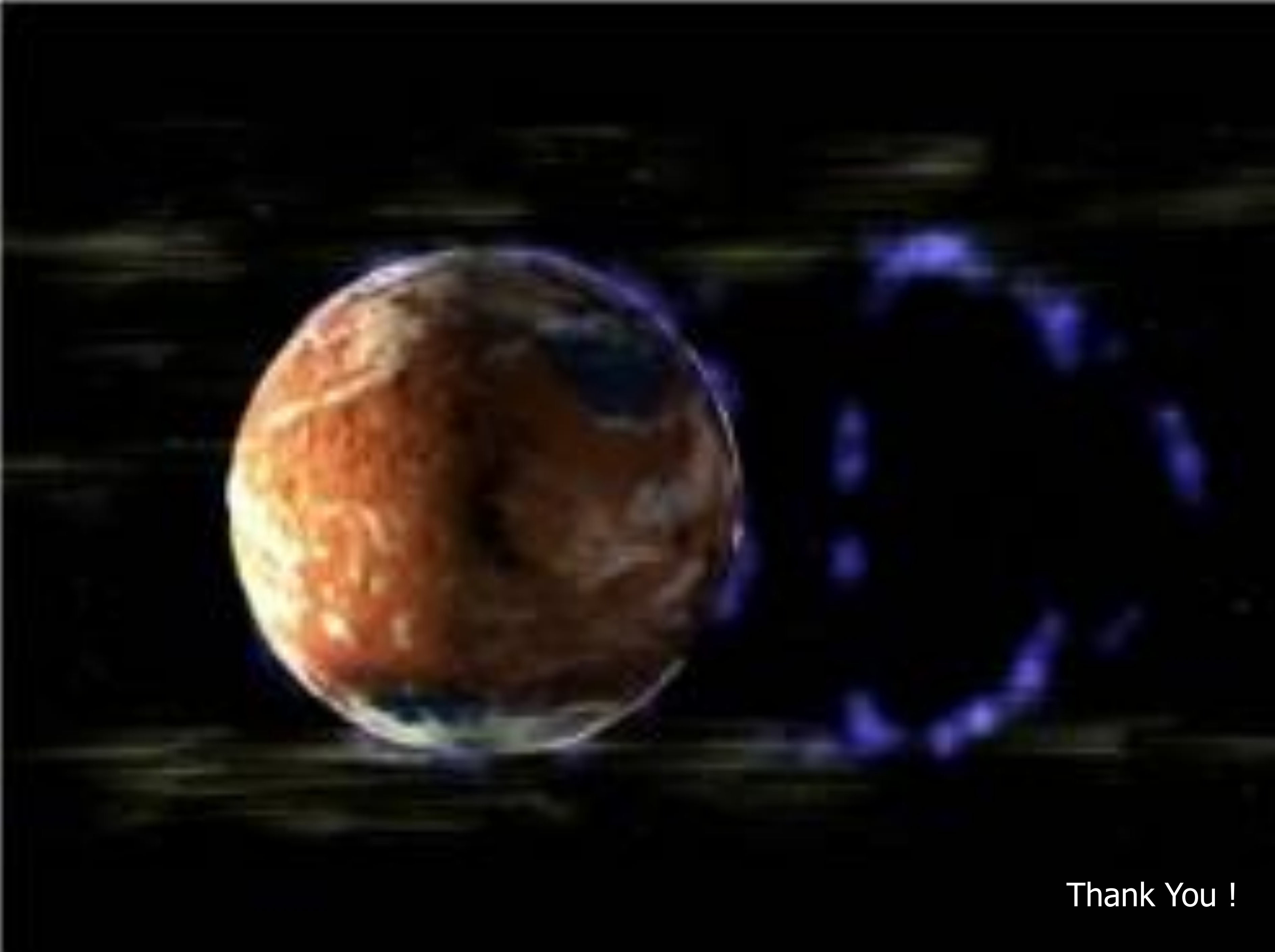
Although technological advances have benefited humankind in numerous ways, they have been accompanied by adverse effects on the environment, including pollution of the air.

Common air pollutants include carbon monoxide (**CO**), nitrogen oxides (NOx), sulfur oxides (SOx), ozone, and particulate matter (PM). They are generally produced by such activities as

(a) combustion (burning) of fuels for transportation and the generation of heat and electricity, and
(b) industrial processes, including petroleum refining, cement manufacturing, and metal processing.

To reduce such pollutants, the governments of various nations have mandated measures such as the use of reformulated gasoline, catalytic converters in motor vehicle exhaust systems, and effluent traps for industrial wastes.

In addition to the problem of pollution, there is concern that global temperatures are rising as a result of increasing levels of greenhouse gases such as carbon dioxide and methane in the atmosphere.


Thank You !