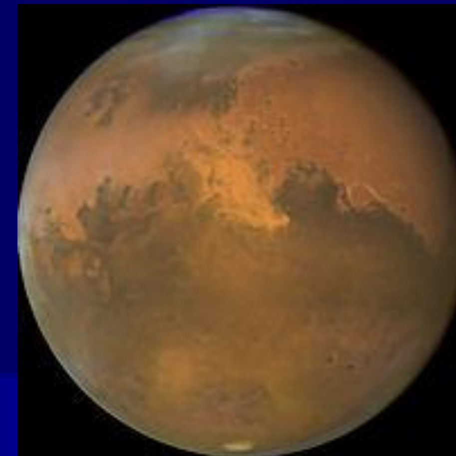
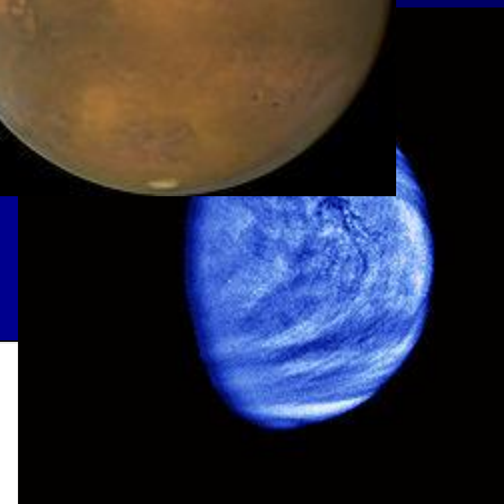
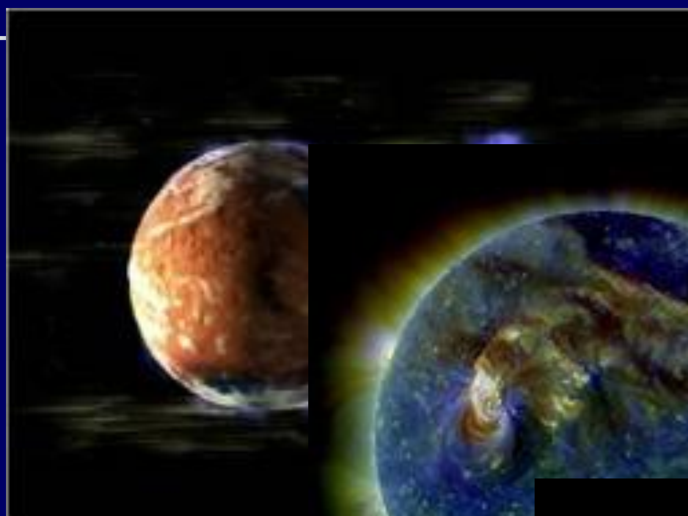
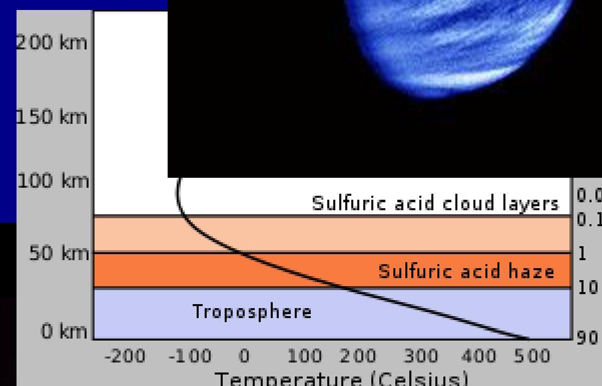
Space Physics

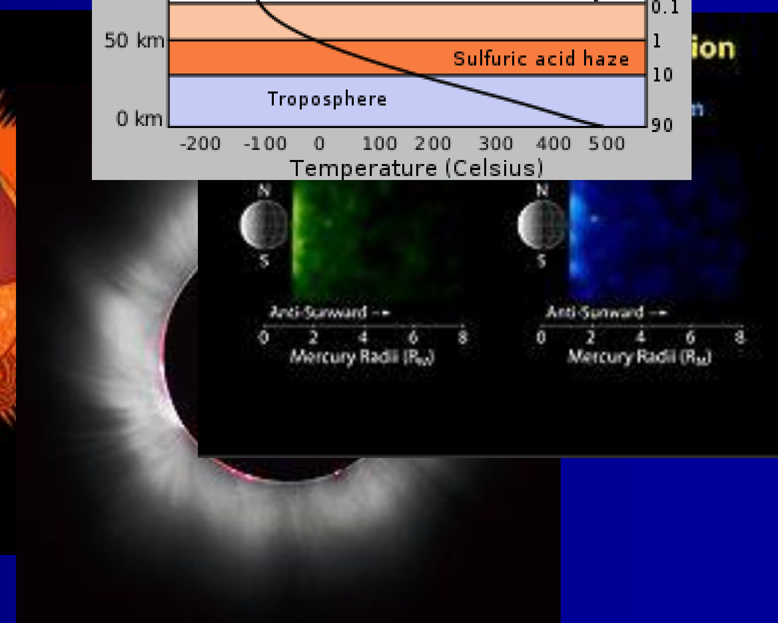
Space Physics

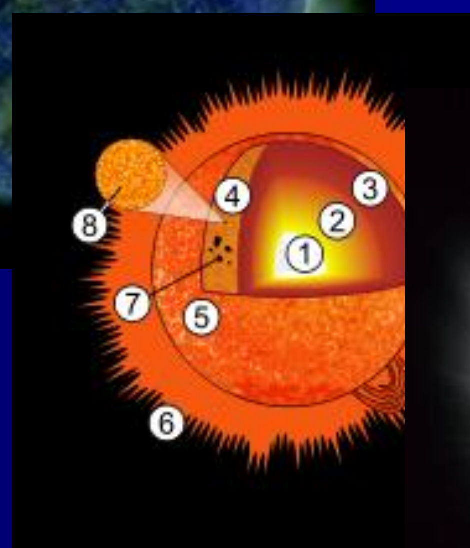








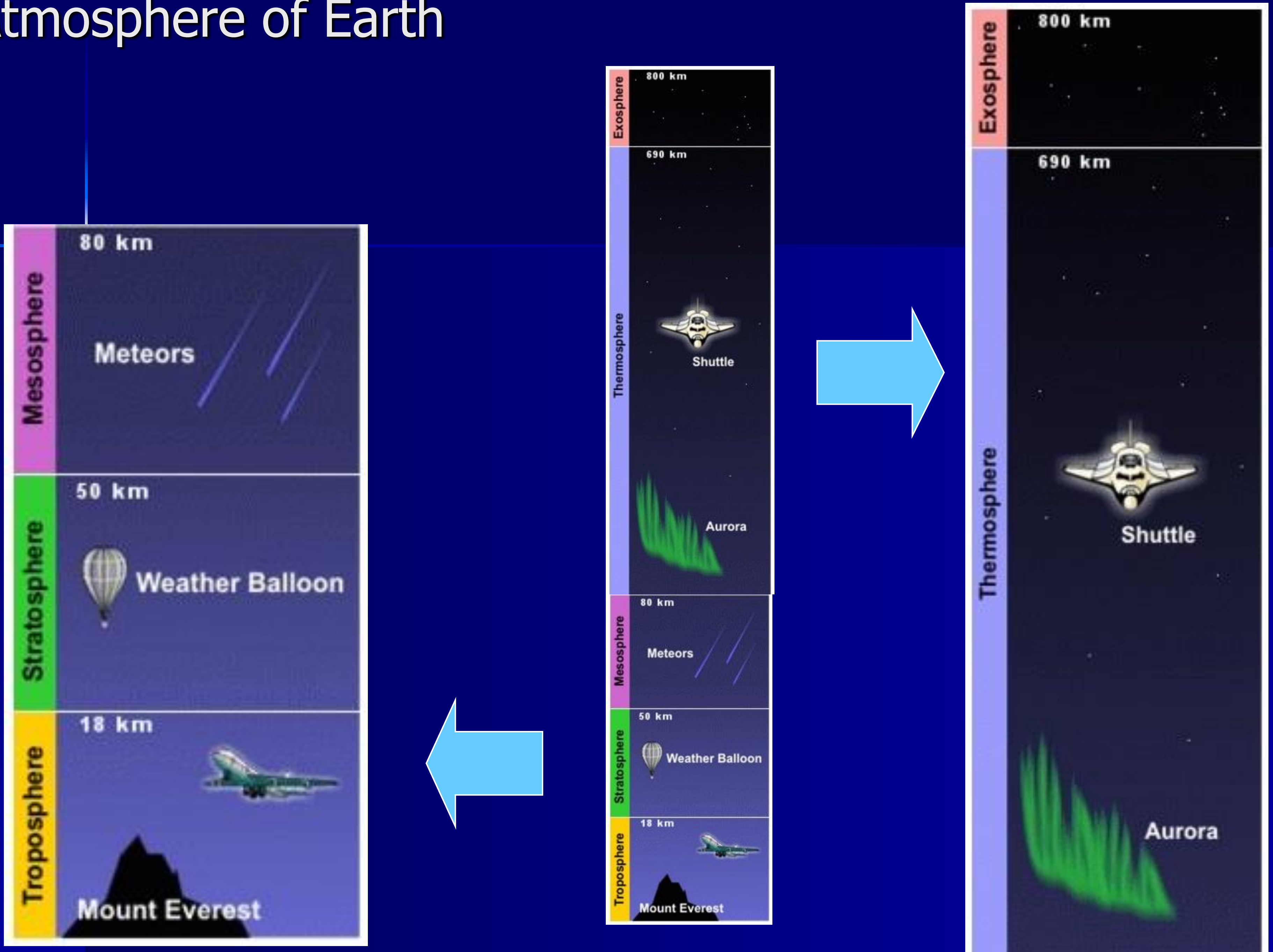




Lecture – 03

Atmosphere of Earth

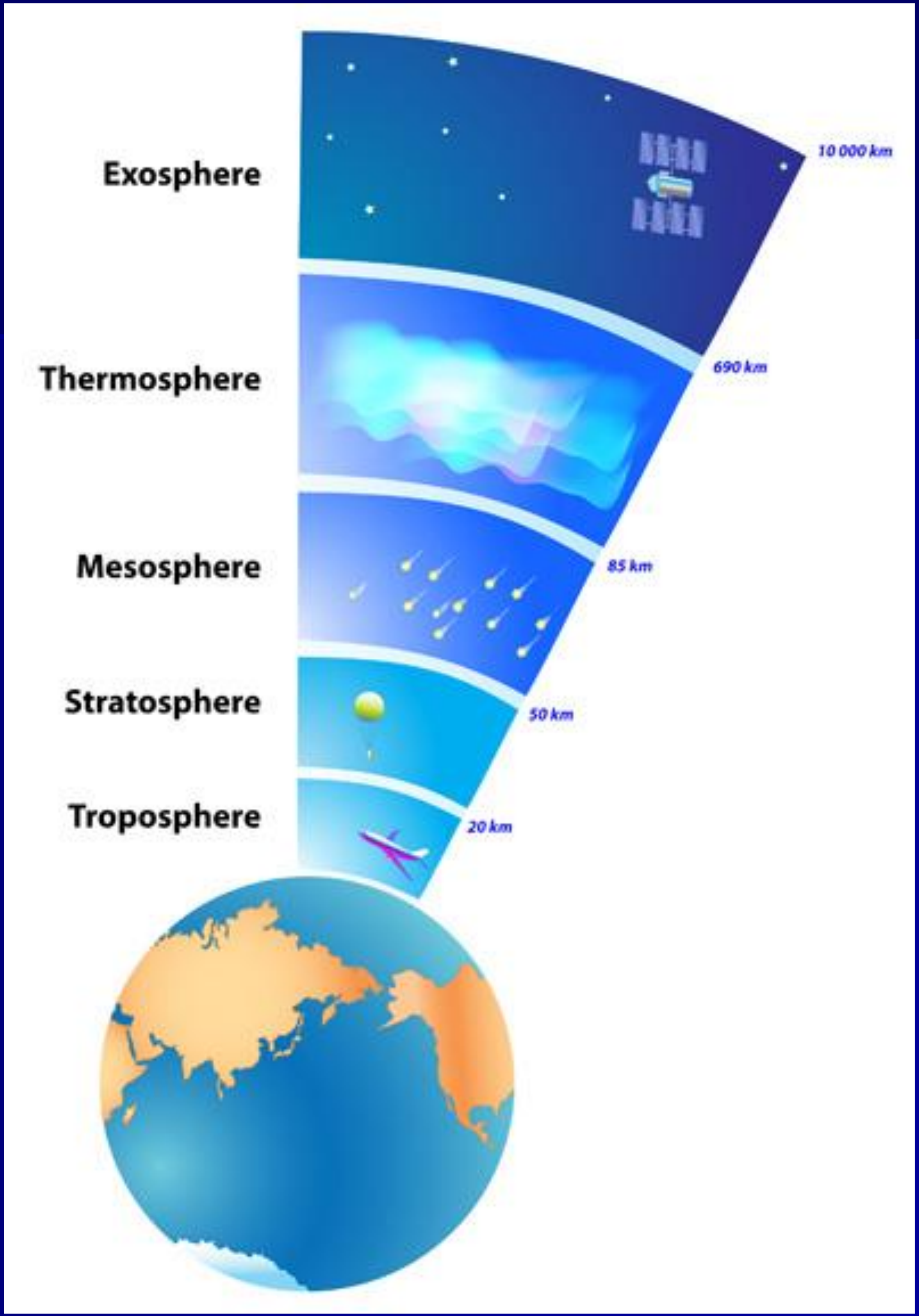
Atmosphere of Earth



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

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

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.

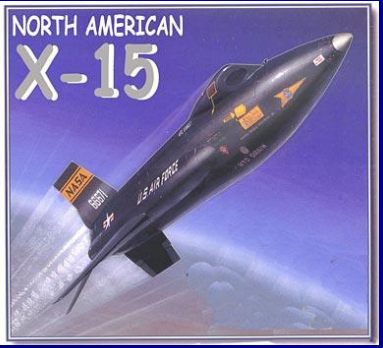
Atmosphere of Earth

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.

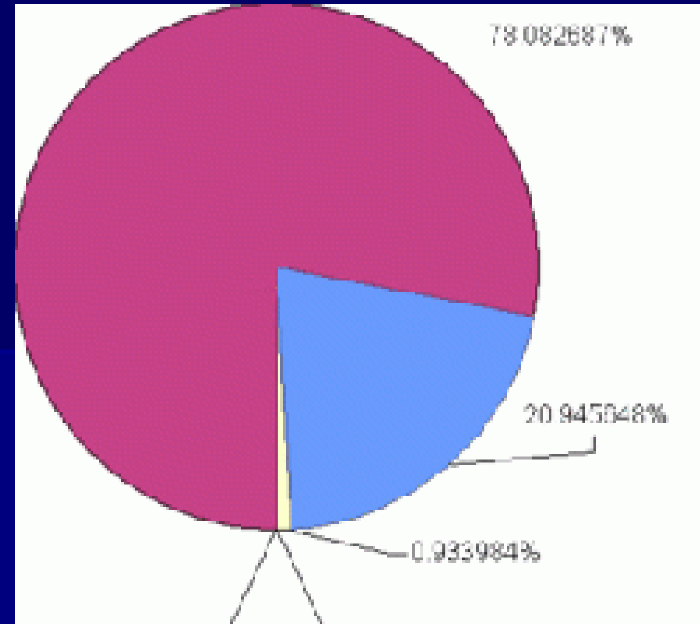


The atmosphere exists at altitudes of 1,000 km and higher, but it is so thin as to be considered nonexistent.

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.

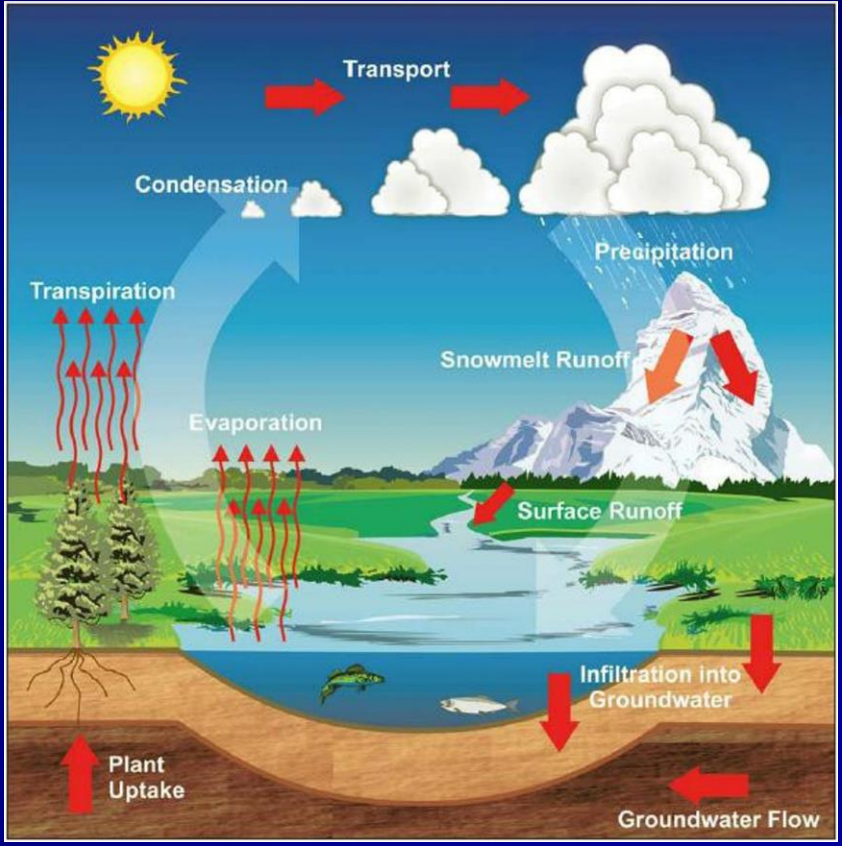
Carbon dioxide and water vapor act as "greenhouse gases" that keep the Earth sufficiently warm to maintain life.

Atmosphere of Earth

Biological significance

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**.

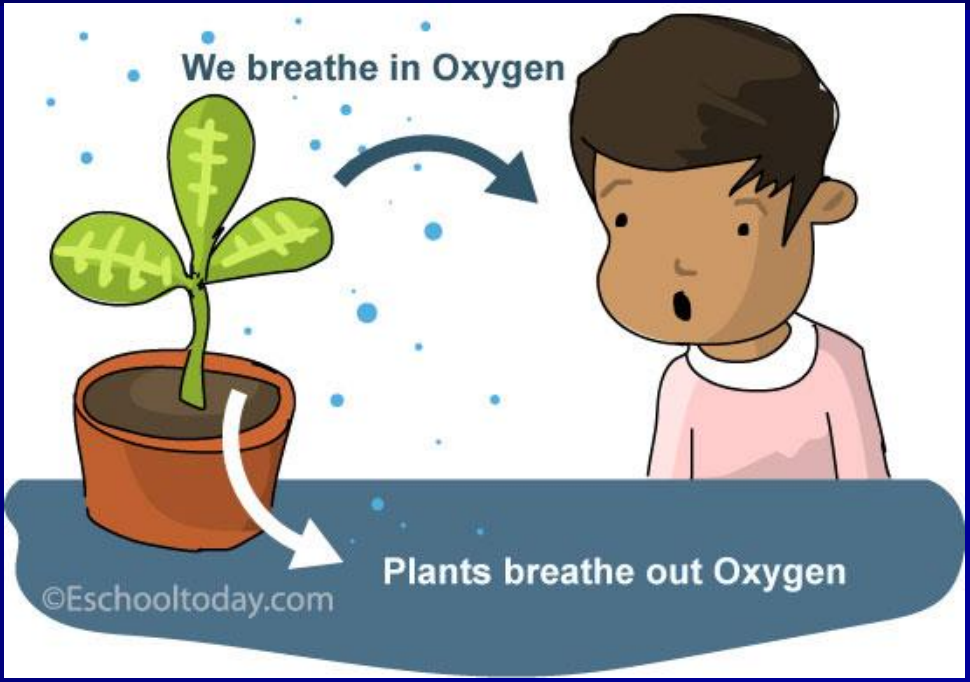
In addition, water vapor prevents **exposed living tissue** from drying up.



Biological significance

Oxygen & Water

Oxygen helps organisms grow, reproduce, and turn food into energy. Humans get the oxygen they need by breathing through their nose and mouth into their lungs. Oxygen gives our cells the ability to break down food in order to get the energy we need to survive.



Atmosphere of Earth

Biological significance

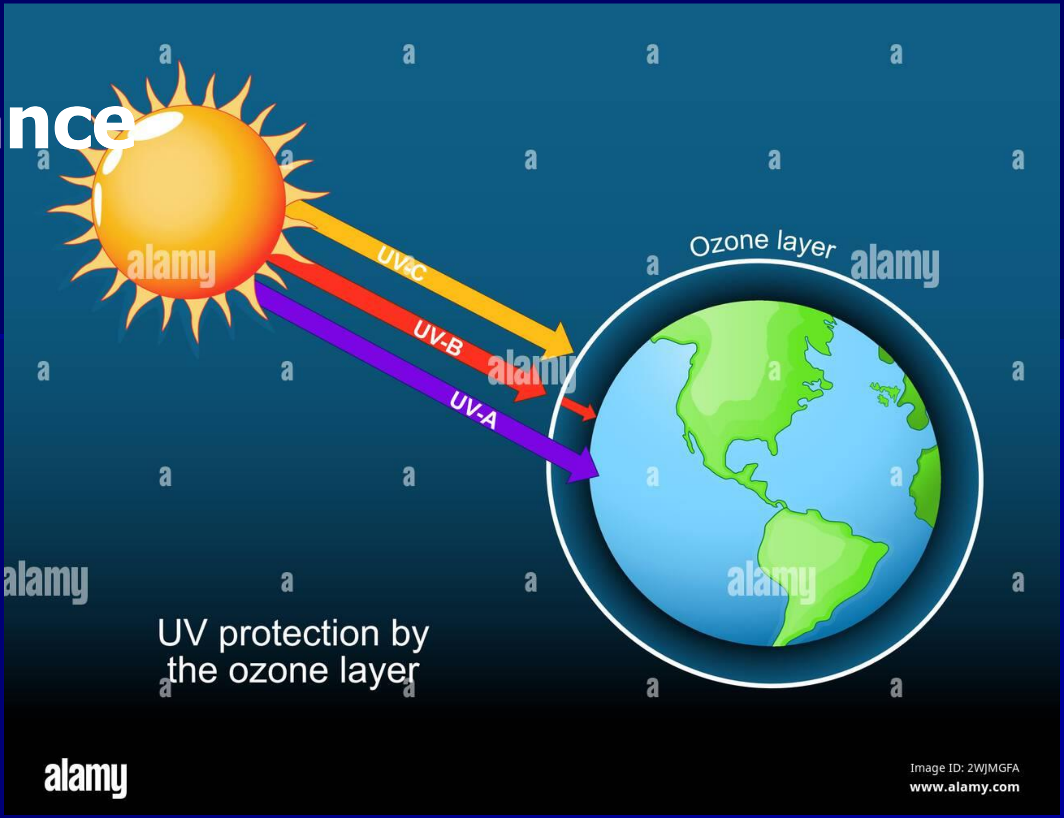
Oxygen & Water

On a biological level, **water**'s role as a solvent helps cells transport and use substances like oxygen or nutrients. Water-based solutions like blood help carry molecules to the necessary locations.

Atmosphere of Earth

Biological significance

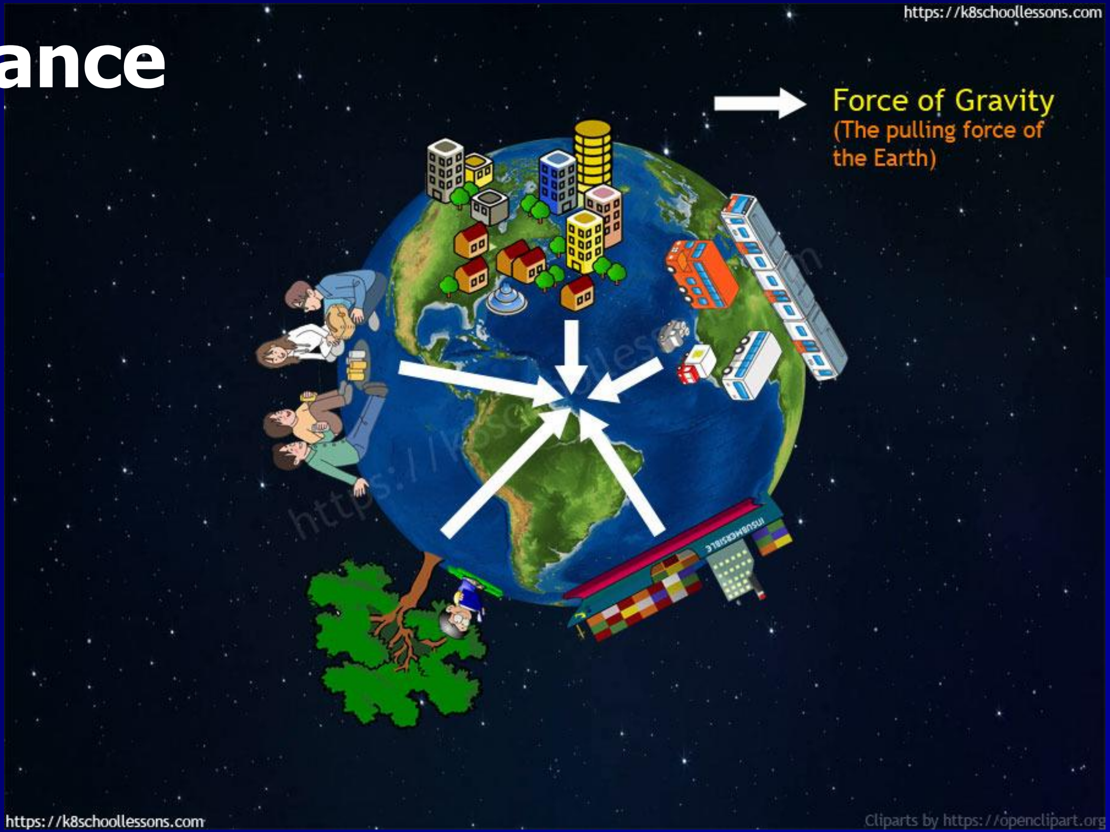
Ozone Layer



The ozone layer **protects us from the UV radiation**, known as UV-B, which causes sunburn. Long-term exposure to high levels of UV-B threatens human health and damages most animals, plants and microbes, so the ozone layer protects all life on Earth.

Atmosphere of Earth

Biological significance

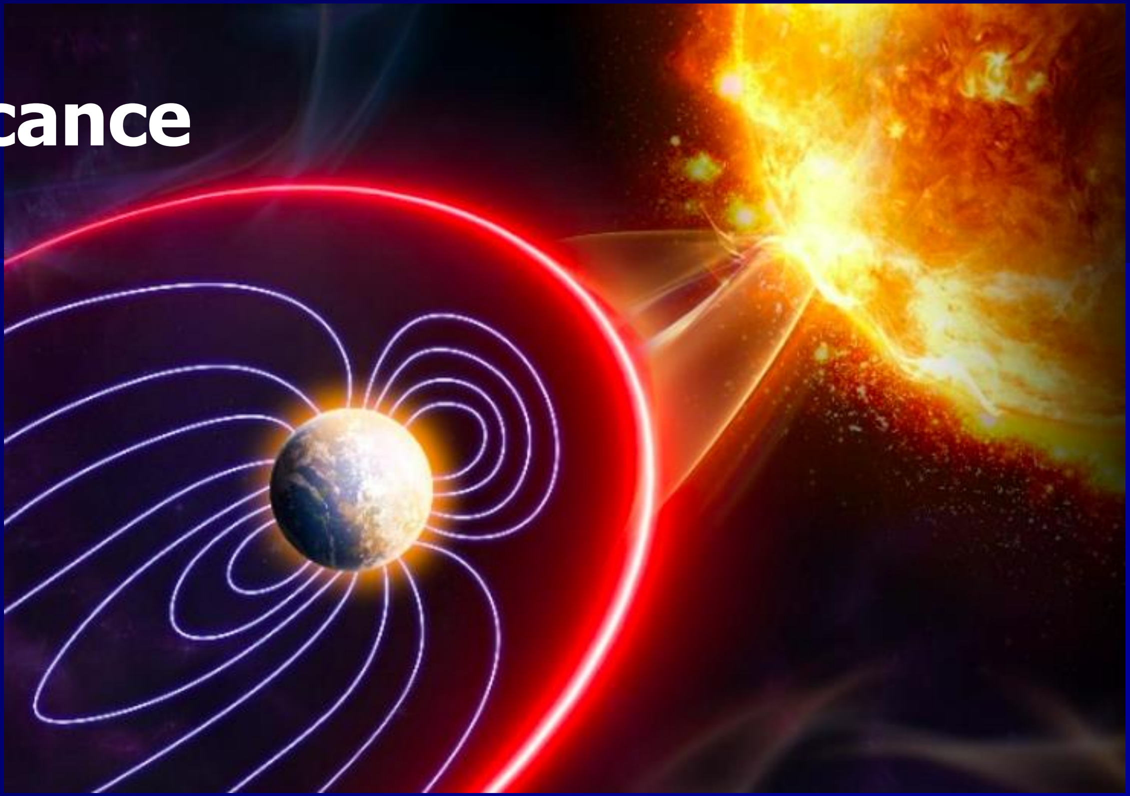


Gravity

We could not live on Earth without it. The sun's gravity keeps Earth in orbit around it, keeping us at a comfortable distance to enjoy the sun's light and warmth. It holds down our atmosphere and the air we need to breathe. Gravity is what holds our world together.

Atmosphere of Earth

Biological significance



Magnetic Field

Generated by the motion of molten iron in Earth's core, the magnetic field protects our planet from cosmic radiation and from the charged particles emitted by our Sun

....

Atmosphere of Earth

Air pollution

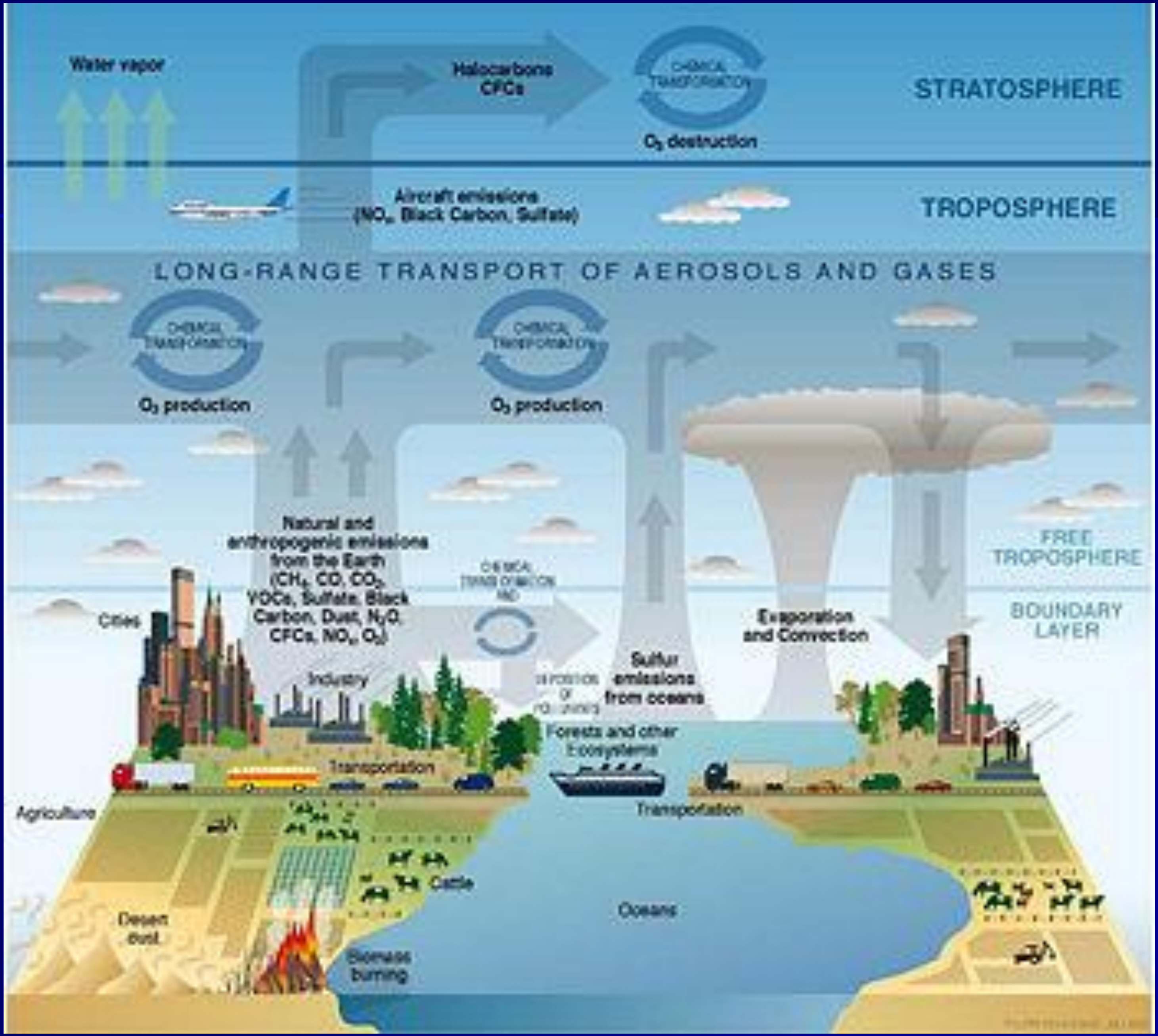


Diagram of chemical and transport processes related to atmospheric composition.

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.

Atmosphere of Earth

Air pollution

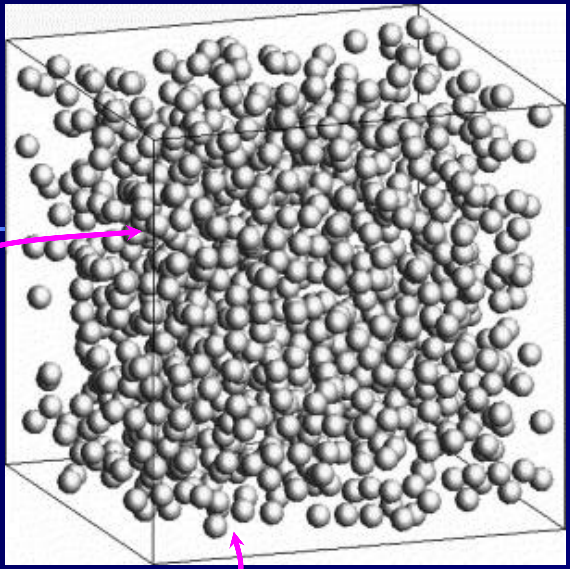
To reduce such pollutants, the governments of various nations have mandated measures such as the use of reformulated gasoline, catalytic converters in motor vehicle exhaust systems, and effluent traps for industrial wastes.

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.

Earth Atmosphere

Retaining of Gases in the Earth
Major / Minor constituents
Barometric Equation
Scale Height
Number Density Profiles
Atmospheric Regions
Temperature Profiles
Retaining of Gases

Density of the Atoms



Atoms, *r*

Volume, 1 m³

Assume there are *r* atoms in this volume

Masses of the atoms are:

$$m_1, m_2, m_3, \ldots, m_r$$

Number densities of those atoms are:

$$N_1, N_2, N_3, \ldots, N_r$$

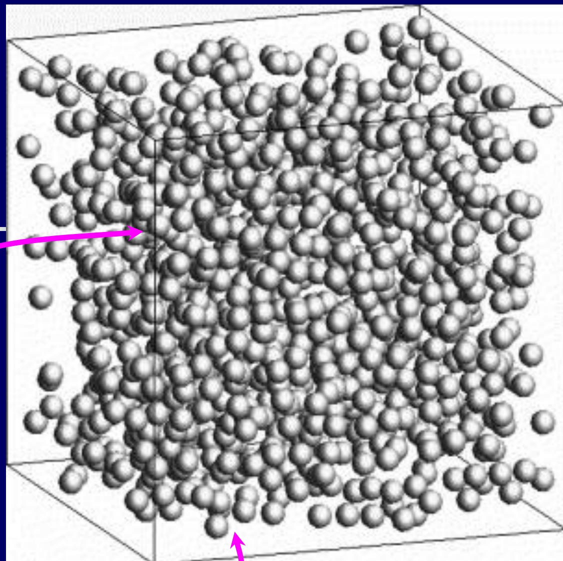
Total Mass of the atoms in the above volume:

$$m_1.N_1 + m_2.N_2, + m_3.N_3, \ldots, + m_r.N_r$$

(This is called the **density** because we consider the unit volume)

Total Molecular Number density: $N = N_1 + N_2, + N_3, \ldots, + N_r$

Density of the Atoms



Atoms, *r*

Volume, 1 m³

Mean Molecular mass : $\overline{m}$

$$\overline{m} = \frac{Total\ \ Mass}{Total\ \ Molecular\ \ Number\ \ Density}$$

$$\overline{m} = \frac{m_1.N_1 + m_2.N_2 + m_3.N_3 + \ldots. + m_r.N_r}{N_1 + N_2 + N_3 + \ldots. + N_r}$$

$$\overline{m} = \frac{m_1.N_1 + m_2.N_2 + m_3.N_3 + \ldots. + m_r.N_r}{N}$$

Total Mass per unit volume

$$N.\overline{m} = m_1.N_1 + m_2.N_2 + m_3.N_3 + \ldots. + m_r.N_r$$

Density

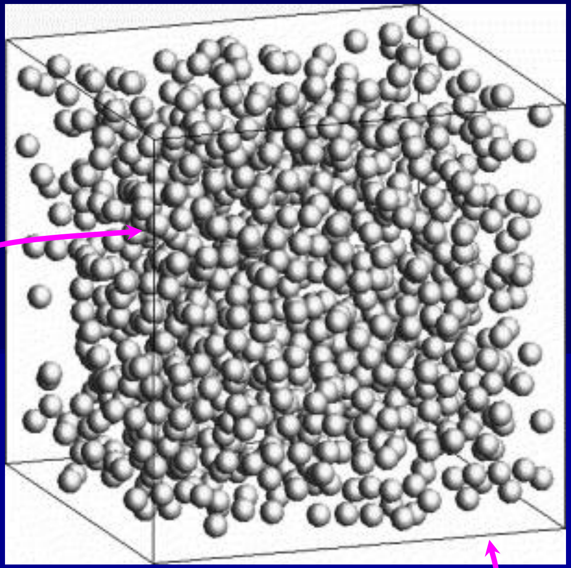
Density of the Atoms

Mean Molecular Number Density

Density

$$\rho = N \times \overline{m}$$

Total Molecular Number Density



Atoms, *r*

Volume, 1 m³

For the Ideal Gas

$$PV = nRT$$

Number of molecules per volume, V

$$PV = \frac{NV}{N_o} RT$$

Avogadro Number (Number of molecules in a molecular weight)

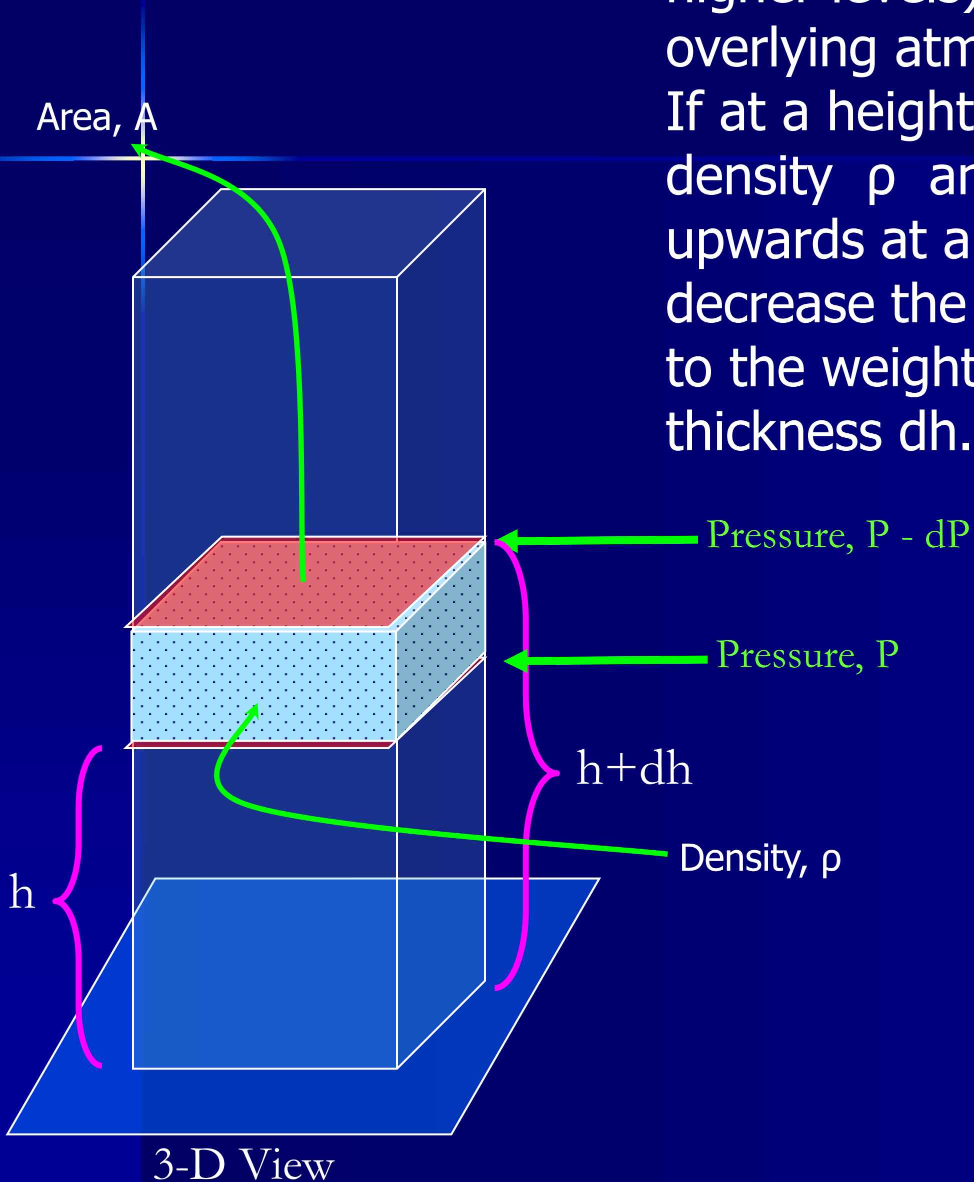
Boltzmann Constant

$$P = NkT$$

Where,

$$k = \frac{R}{N_o}$$

Pressure Profile



The pressure at the Earth's surface (or at higher levels) is a result of the weight of the overlying atmosphere [force per unit area]. If at a height of h the atmosphere has density ρ and pressure P then moving upwards at an infinitesimally small dh will decrease the pressure by amount dP equal to the weight of the layer of atmosphere of thickness dh.

Pressure of the Lower Layer =

Pressure of the Higher Layer +

$$\frac{\text{Weight of the air molecules in the selected part}}{\text{Cross area of the selected part}}$$

$$P = P - dP + \frac{A.dh.\rho.g}{A}$$

Pressure Profile

$$dP = -\rho g.dh$$

This minus (-) sign indicates that as the height h is increases, the pressure P is decreases.

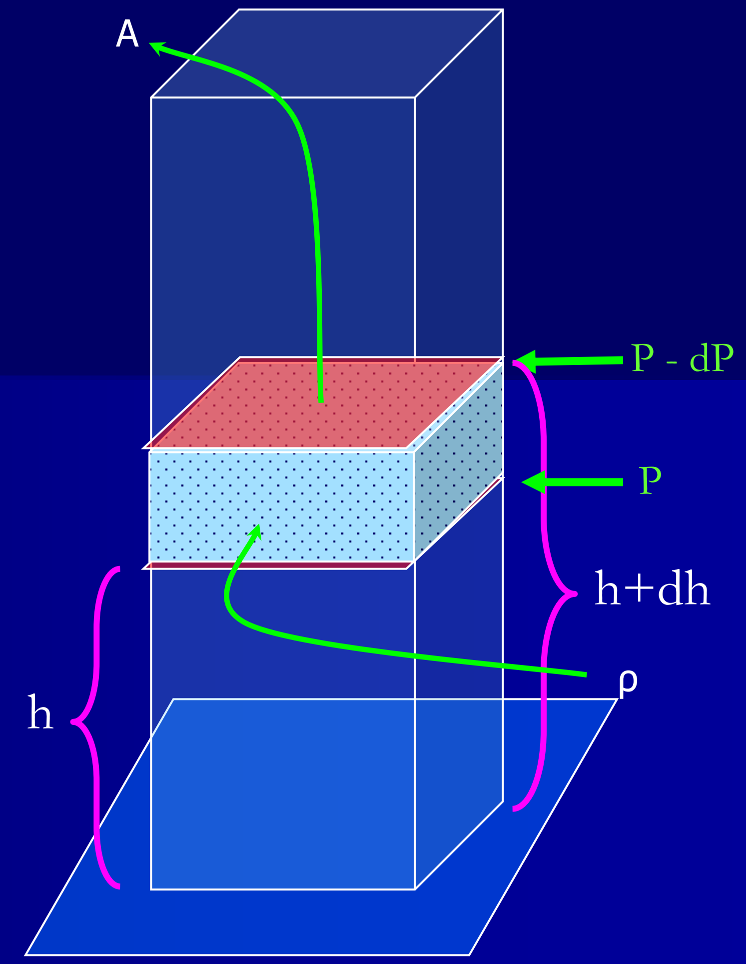
Where g is used to denote the acceleration due to gravity. For small dh it is possible to assume g to be constant. Also, $\rho = N \times \overline{m}$

$$dP = -N.\overline{m}.g.dh \quad \text{— 1}$$

Also, we know

$$P = NkT \quad \text{— 2}$$

Using 1 & 2 ; $\dfrac{dP}{P} = -\dfrac{\overline{m}g}{kT}dh$



3-D View

Pressure Profile

$$\frac{dP}{P} = -\frac{\overline{m}g}{kT}\,dh$$

The Pressure at height h can be written as:

$$P(h) = P_o\, e^{\frac{-\overline{m}g}{kT}h}$$

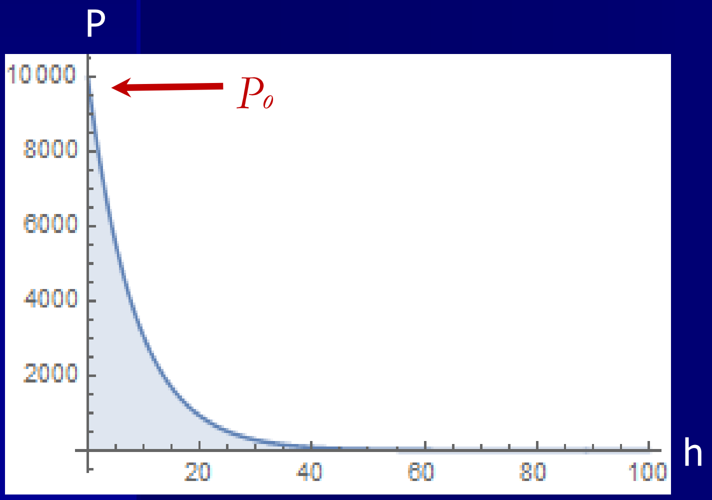
This is the general formula as the Pressure at height; This translate as the pressure decreasing exponentially with height !

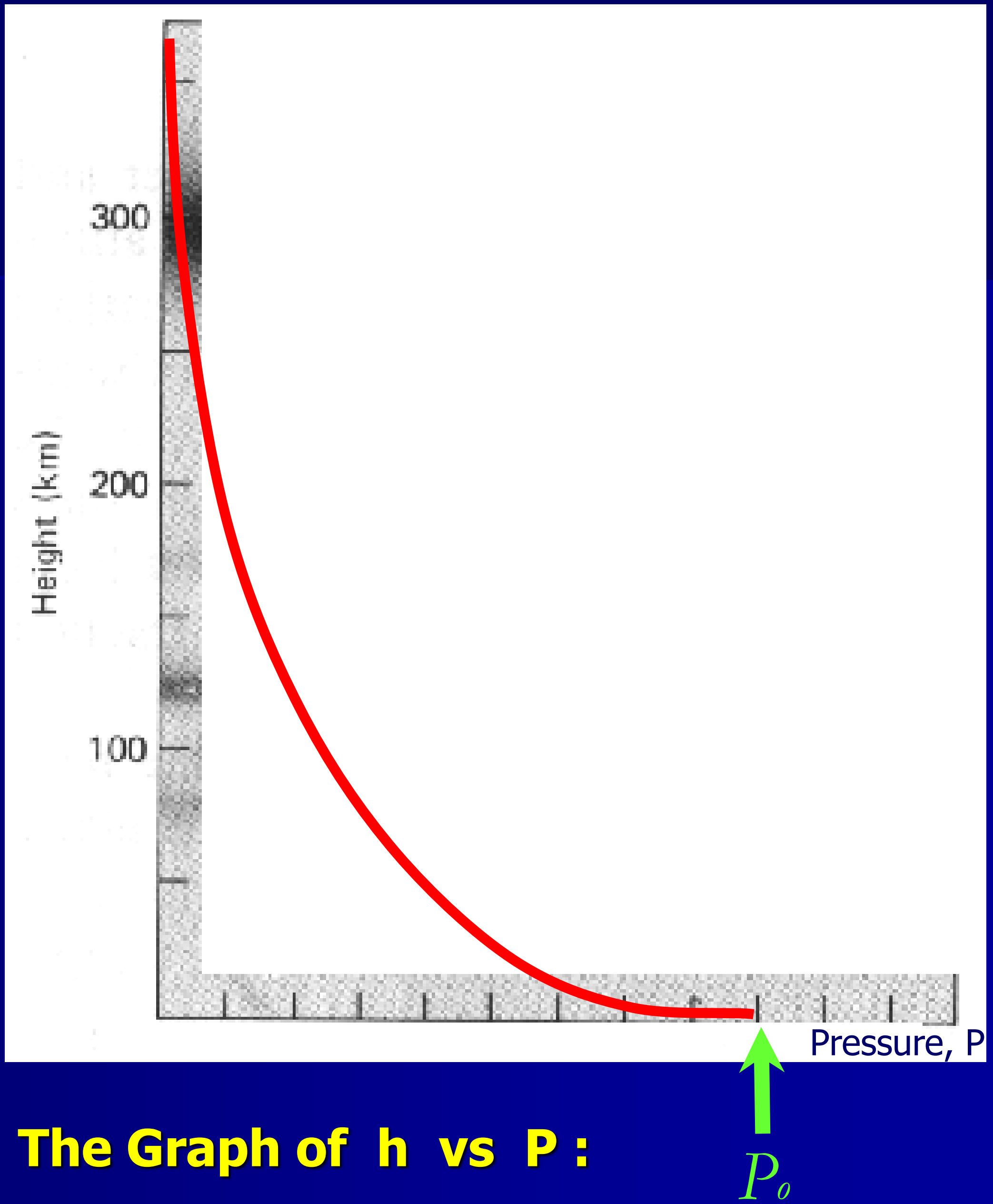
If h=0 then P=Po (1); That means Po is the pressure at h=0 level or The Ground Level.

Also $\frac{-\overline{m}g}{kT}h$ is independent of the units. That means $\frac{kT}{\overline{m}g}$ is also a some height !

The Graph of P vs h :

$$P(h) = P_o \, e^{\frac{-\overline{m}g}{kT} h}$$



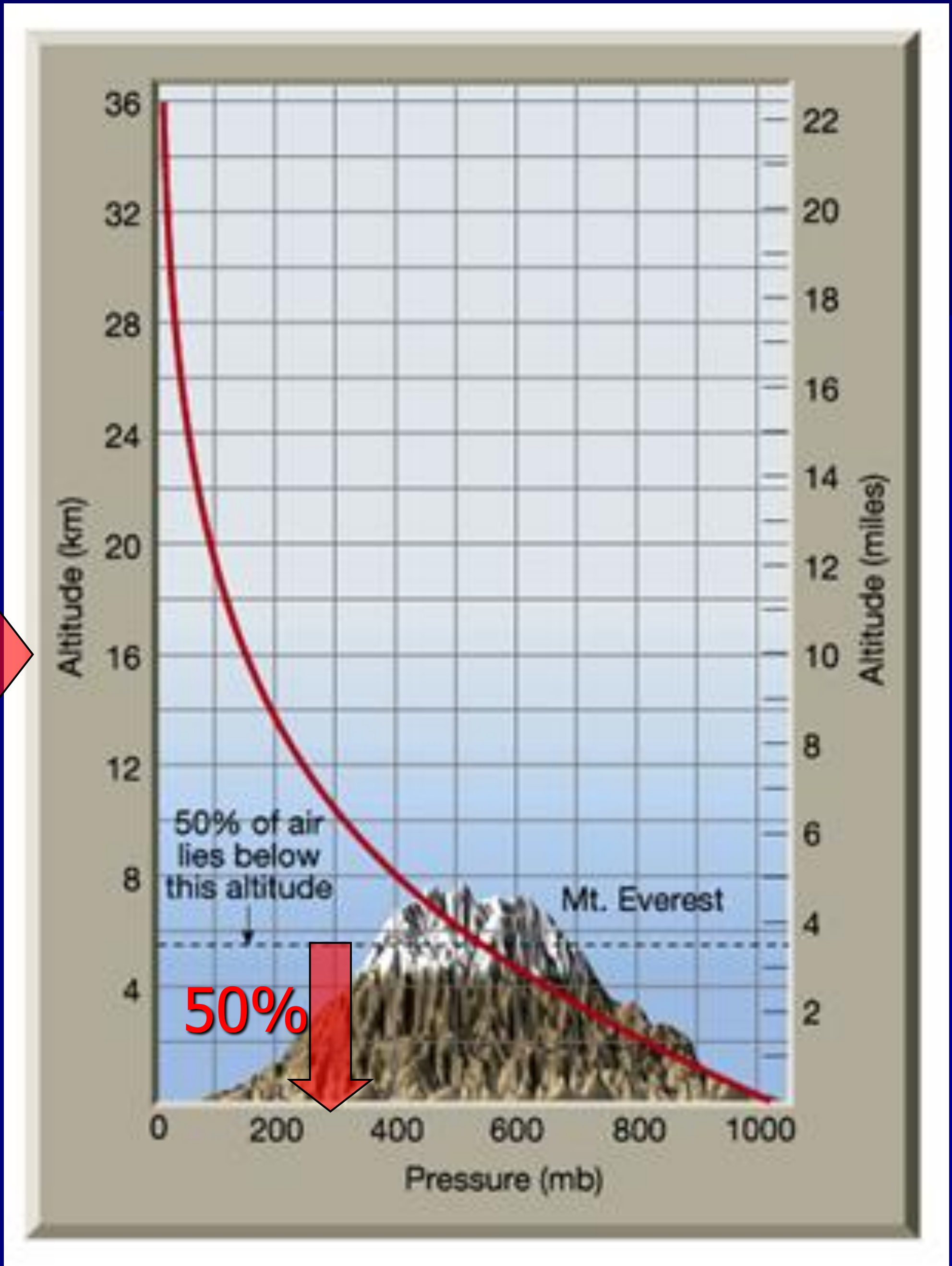


The Graph of h vs P :

The Graph of h vs P :

Percent sea level pressure	Altitude (km)
100	0
50	5.6
10	16.2
1	31.2
0.1	48.1
0.01	65.1
0.001	79.2
0.00003	100

Practical Values



Scale Height (H)

A scale height is a term often used in scientific context for a distance over which a quantity decreses by a factor of *e* (the base of natural logarithms). It is usually denoted by the capital letter H.

$$P(h) = P_o\, e^{\frac{-\overline{m}g}{kT}h}$$

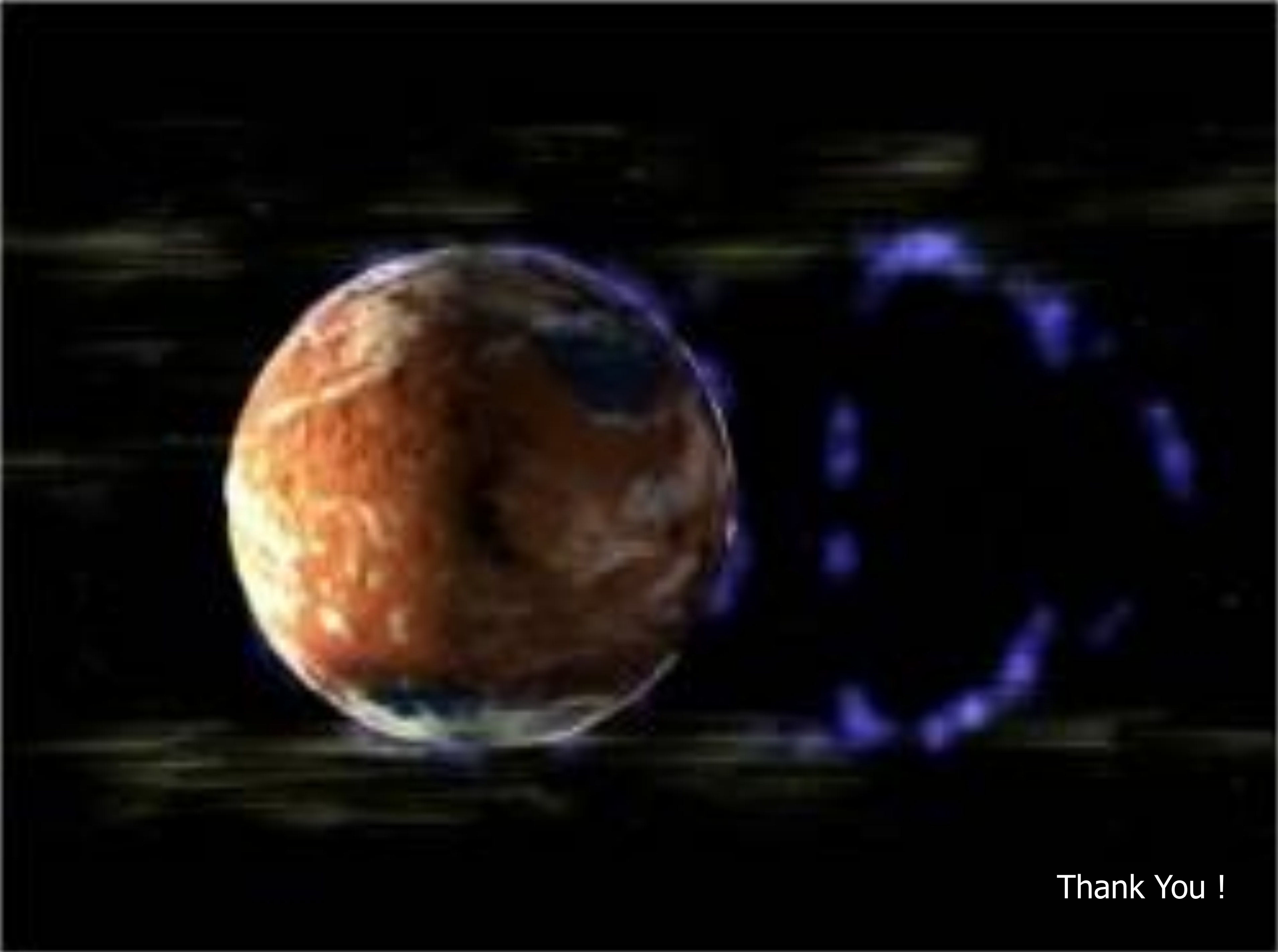
For planetary atmosphere, it is the vertical distance upwards, over the which the pressure of the atmosphere decreases by a factor of e. The scale height remains constant for a particular temperature. It can be calculated by,

If P = Po/e then h = H,

$$\frac{P_o}{e} = P_o\, e^{\frac{-\overline{m}g}{kT}h} \Rightarrow H = \frac{kT}{\overline{m}g}$$

where:

- k = Boltzmann constant = 1.38 x 10^{-23} J·K^{-1}
- T = mean planetary surface temperature in kelvins
- $\overline{m}$ = mean molecular mass of dry air (units kg)
- g = acceleration due to gravity on planetary surface (m/s²)


Thank You !