1. History of the Earth's Atmosphere

Earth is believed to have formed about 5 billion years ago. In the first 500 million years a dense atmosphere emerged from the vapor and gases that were expelled during degassing of the planet's interior. These gases may have consisted of hydrogen (H_2), water vapor, methane (CH_4) , and carbon oxides. Prior to 3.5 billion years ago the atmosphere probably consisted of carbon dioxide (CO_2), carbon monoxide (CO), water (H_2O), nitrogen (N_2), and hydrogen.
The hydrosphere was formed 4 billion years ago from the condensation of water vapor, resulting in oceans of water in which sedimentation occurred.

The most important feature of the ancient environment was the absence of free oxygen. Evidence of such an anaerobic reducing atmosphere is hidden in early rock formations that contain many elements, such as iron and uranium, in their reduced states. Elements in this state are not found in the rocks of mid-Precambrian and younger ages, less than 3 billion years old.

One billion years ago, early aquatic organisms called blue-green algae began using energy from the Sun to split molecules of H_2O and CO_2 and recombine them into organic compounds and molecular oxygen (O_2). This solar energy conversion process is known as photosynthesis. Some of the photosynthetically created oxygen combined with organic carbon to recreate CO_2 molecules. The remaining oxygen accumulated in the atmosphere, touching off a massive ecological disaster with respect to early existing anaerobic organisms. As oxygen in the atmosphere increased, CO_2 decreased.

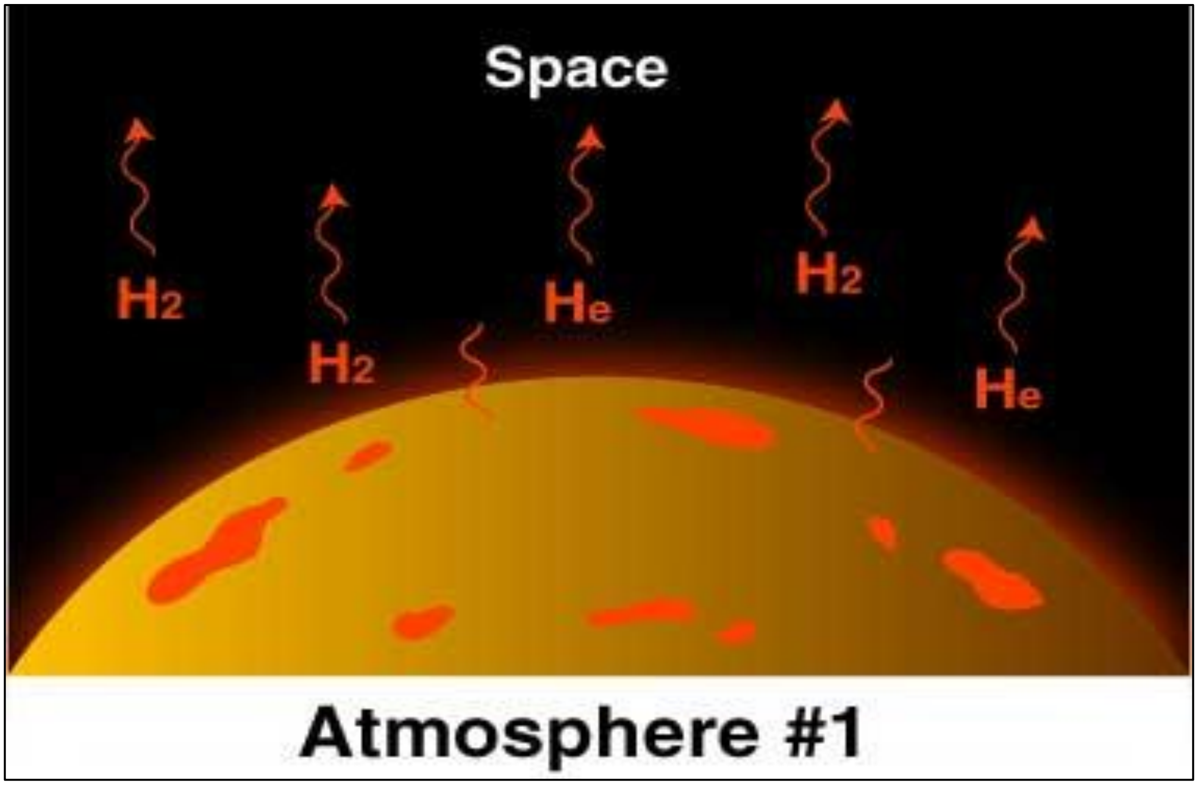
High in the atmosphere, some oxygen (O_2) molecules absorbed energy from the Sun's ultraviolet (UV) rays and split to form single oxygen atoms. These atoms combining with remaining oxygen (O_2) to form ozone (O_3) molecules, which are very effective at absorbing UV rays. The thin layer of ozone that surrounds Earth acts as a shield, protecting the planet from irradiation by UV light.

The amount of ozone required to shield Earth from biologically lethal UV radiation, wavelengths from 200 to 300 nanometers (nm), is believed to have been in existence

600 million years ago. At this time, the oxygen level was approximately 10% of its present atmospheric concentration. Prior to this period, life was restricted to the ocean. The presence of ozone enabled organisms to develop and live on the land. Ozone played a significant role in the evolution of life on Earth, and allows life as we presently know it to exist.

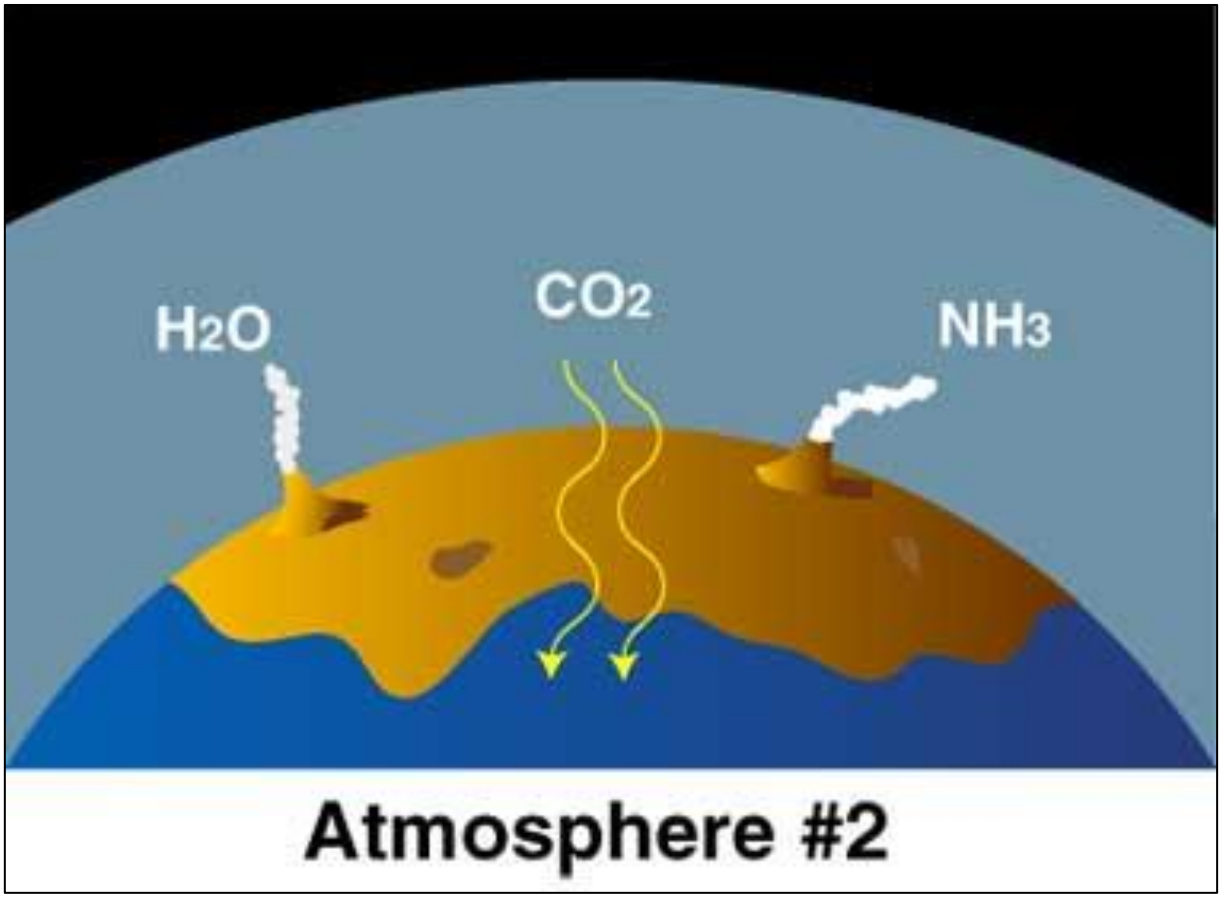
1-1 The First atmosphere:

The first of earth's atmosphere, formed when the planet was still very young, was primarily hydrogen and helium (He). This atmosphere is about 4.57 billion years old, and was short-lived. Heat from the molten crust and solar wind dissipated this layer. Hydrogen and helium are not heavy enough to make up a stable atmosphere unless the planet is very massive. These elements are more likely to gain escape velocity during random thermal fluctuations. This is part of reason why hydrogen and helium are very rare in earth's atmosphere's atmosphere today.



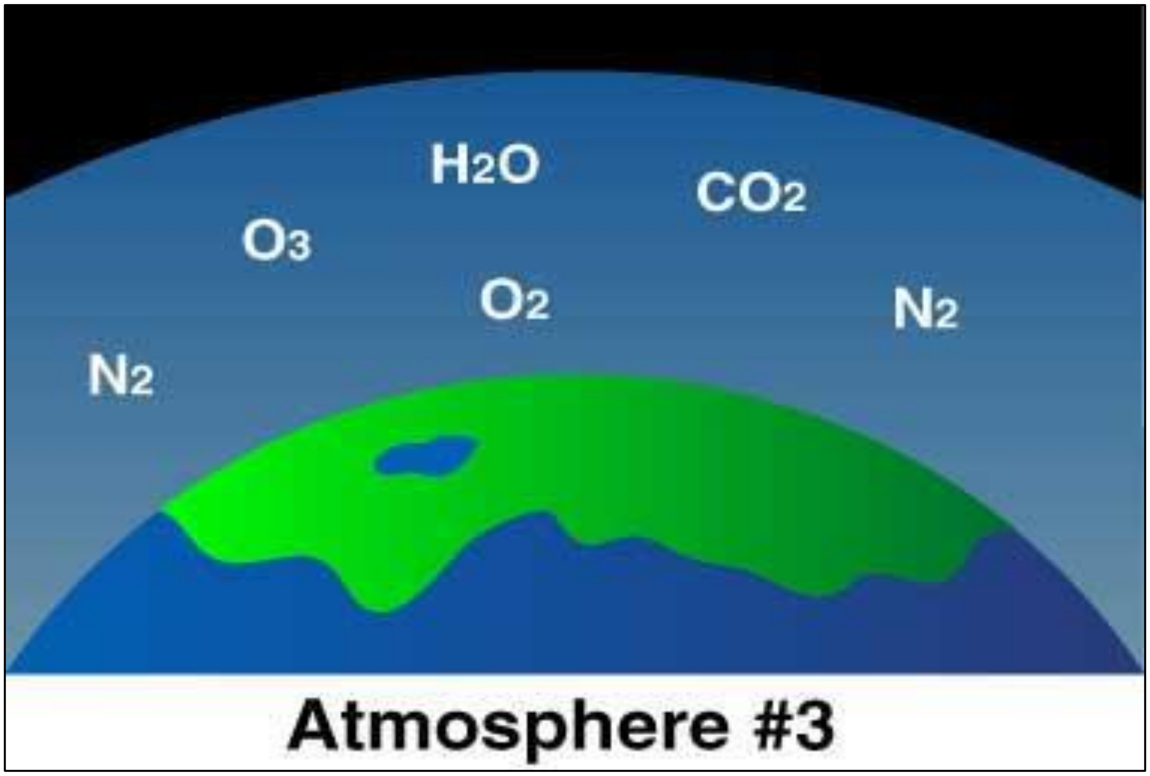
1-2 The Secondary Atmosphere:

Water related sediments have been found dating from as early as 3.8 billion years ago. About 3.4 billion years ago, nitrogen was the major part of the then stable “second atmosphere”. An influence of life has to be taken into account rather soon in history of the atmosphere, since hints of early life forms are to be found as early as 3.5 billion years ago. During this period, the rocks gave off large quantities of gases including nitrogen, ammonia, carbon monoxide and water vapor as well-a mixture similar to that given off by volcanoes and fumaroles today. Like modern volcanic gases, the primeval atmosphere is thought to have contained only the slightest trace of oxygen, so it would have been poisonous to almost all modern life forms.



1-3 The Third Atmosphere:

This time span was the Phanerozoic Eon (time when abundant animal life existed and time when diverse hard-shelled animals first appeared), during which oxygen-breathing metazoan life forms began to appear. By 3.5 billion years ago, life had emerged, in the form of "Archaea". Archaea are a major group of single celled organisms without nuclei. About 2.7 billion years ago, they were joined by microbes called cyanobacteria. Cyanobacteria were the first oxygen producing phototropic organism and slowly began to suck in carbon dioxide from the atmosphere and release oxygen.



- **The Present Composition of Atmosphere**

  Air is the name given to the atmosphere used in breathing and photosynthesis. Dry air contains roughly (by volume) :
  78.09% nitrogen,
  20.95% oxygen,
  0.93% argon,

0.039% carbon-di-oxide, and small amounts of other gases like neon, helium, ozone and hydrogen.

Air also contains a variable amount of water vapor, which makes up 4% of the atmosphere by volume and 3% by weight. Many natural substances may be present in tiny amounts in an unfiltered air sample, including dust, pollen, salt, smoke and spores, sea spray and volcanic ash. Various industrial pollutants such as chlorine, fluorine, and elemental mercury and sulfur compounds may also be present. The composition of the atmosphere is relatively constant up to 50 km above the earth’s surface, with the exception of ozone and water vapor.

Table 1-1: Evolution of the Earth's atmosphere.

Name of Stage	**Duration of Stage (Billions of Years Ago)**	**Main Constituents of the Atmosphere**	**Dominant Processes and Features**
Early Atmosphere	4.4 to 4.0	H_2O, hydrogen cyanide (HCN), ammonia (NH_3), methane (CH_4), sulfur, iodine, bromine, chlorine, argon	Lighter gases like hydrogen and helium escaped to space. All water was held in the atmosphere as vapor because of high temperatures.
Secondary Atmosphere	4.0 to 3.3	At 4.0 billion H_2O, CO_2, and nitrogen (N) dominant. Cooling of the atmosphere causes precipitation and the development of the oceans. By 3.0 billion CO2, H2O, N2 dominant. O2 begins to accumulate.	Continued release of gases from the lithosphere. Water vapor clouds common in the lower atmosphere. Chemosynthetic bacteria appear on the Earth sometime between 3.9 and 3.5 billion years ago. Life begins to modify the atmosphere.
Living Atmosphere	3.3 to Present	N_2 - 78%, O_2 - 21%, Argon - 0.9%, CO_2 - 0.036%	Development, evolution and growth of life increases the quantity of oxygen in the atmosphere from <1% to 21%. 500 million years ago concentration of atmospheric oxygen levels off. Humans begin modifying the concentrations of some gases in the atmosphere beginning around the year 1700.

Table 1-2: Approximate origin time of the major plant and animal groups.

Organism Group	Time of Origin
Marine Invertebrates	570 Million Years Ago
Fish	505 Million Years Ago
Land Plants	438 Million Years Ago
Amphibians	408 Million Years Ago
Reptiles	320 Million Years Ago
Mammals	208 Million Years Ago
Flowering Plants (Angiosperms)	140 Million Years Ago

2. CLASSIFICATION OF THE ATMOSPHERE (Atmospheric Structure)

Various regions of the Earth's atmosphere are named according to a number of different classification schemes. These classification schemes are based on temperature, composition, gravitation and ionization. Different regions are suffixed by -sphere whereas the division between regions is suffixed by -pause where the prefix is the region below or -base where the prefix is the region above.

2-1 Temperature classification or (THERMAL STRUCTURE)

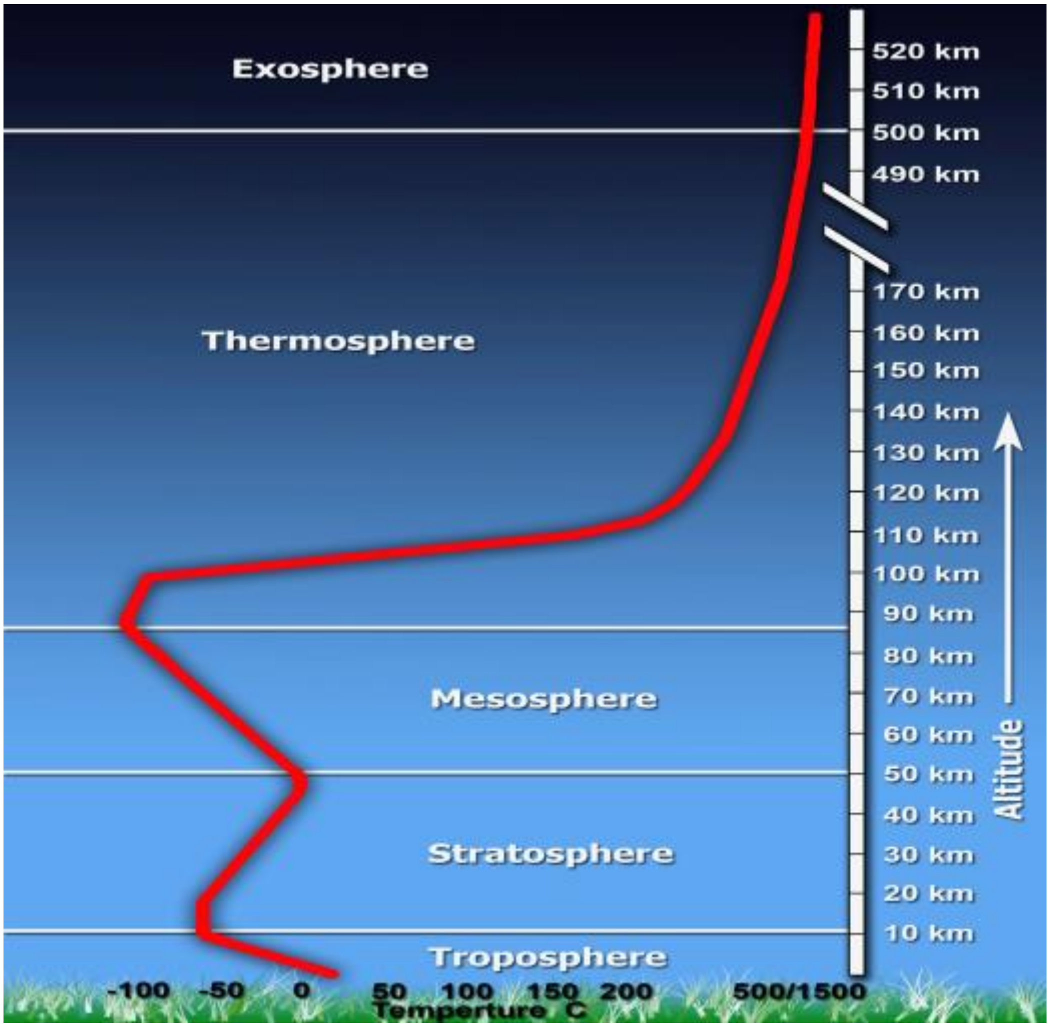
In the temperature classification, atmospheric layers are characterized by variations in temperature resulting primarily from the absorption of solar radiation; visible light at the surface, near ultraviolet radiation in the middle atmosphere, and far ultraviolet radiation in the upper atmosphere.

2-1-1 Troposphere

The troposphere is the atmospheric layer closest to the planet and contains the largest percentage (around 80%) of the mass of the total atmosphere. Temperature and water vapor content in the troposphere decrease rapidly with altitude. Water vapor plays a major role in regulating air temperature because it absorbs solar energy and thermal radiation from the planet's surface. The troposphere contains 99 % of the water vapor in the atmosphere. Water vapor concentrations vary with latitude. They are greatest above the tropics, where they may be as high as 3 %, and decrease toward the polar regions.

All weather phenomena occur within the troposphere, although turbulence may extend into the lower portion of the stratosphere. Troposphere means "region of mixing" and is so named because of vigorous convective air currents within the layer.

The upper boundary of the layer, known as the tropopause, ranges in height from (8 km) near the poles up to (18 km) above the equator. Its height also varies with the seasons; highest in the summer and lowest in the winter.



2-1-2 Stratosphere

The stratosphere is the second major strata of air in the atmosphere. It extends above the tropopause to an altitude of about (50 km) above the planet's surface. The air temperature in the stratosphere remains relatively constant up to an altitude of (25 km). Then it increases gradually to up to the stratopause. Because the air temperature in the stratosphere increases with altitude, it does not cause convection and has a stabilizing effect on atmospheric conditions in the region. Ozone plays the major role in regulating the thermal regime of the stratosphere, as water vapor content within the layer is very low. Temperature increases with ozone concentration. Solar energy is converted to kinetic energy when ozone molecules absorb ultraviolet radiation, resulting in heating of the stratosphere.

The ozone layer is centered at an altitude between (15-25 km). Approximately 90 % of the ozone in the atmosphere resides in the stratosphere. Ozone concentration in the this region is about 10 parts per million by volume (ppmv) as compared to approximately 0.04 ppmv in the troposphere. Ozone absorbs the bulk of solar ultraviolet radiation in wavelengths from 290 nm - 320 nm (UV-B radiation). These wavelengths are harmful to life because they can be absorbed by the nucleic acid in cells. Increased penetration of ultraviolet radiation to the planet's surface would damage plant life and have harmful environmental consequences. Appreciably large amounts of solar ultraviolet radiation would result in a host of biological effects, such as a dramatic increase in cancers.

2-1-3 Mesosphere

The mesosphere a layer extending from approximately (50 to 85 km) above the surface, is characterized by decreasing temperatures. The coldest temperatures in Earth's atmosphere occur at the top of this layer, the mesopause, especially in the summer near the pole. The mesosphere has sometimes jocularly been referred to as the "ignorosphere" because it had been probably the least studied of the atmospheric layers. The stratosphere and mesosphere together are sometimes referred to as the middle atmosphere.

2-1-4 Thermosphere

The thermosphere is located above the mesosphere. The temperature in the thermosphere generally increases with altitude reaching (600-2000 K) depending on solar activity. This increase in temperature is due to the absorption of intense solar radiation by the limited amount of remaining molecular oxygen. At this extreme altitude gas molecules are widely separated. Above (100 km) from Earth's surface the chemical composition of air becomes strongly dependent on altitude and the atmosphere becomes enriched with lighter gases (atomic oxygen, helium and hydrogen). Also at (100 km) altitude, Earth's atmosphere becomes too thin to support aircraft and vehicles need to travel at orbital velocities to stay aloft. This demarcation between aeronautics and astronautics is known as the Karman Line. Above about (160 km) altitude the major atmospheric component becomes atomic oxygen. At very high altitudes, the residual gases begin to stratify according to molecular mass, because of gravitational separation.

2-1-5 Exosphere

The exosphere is the most distant atmospheric region from Earth's surface. In the exosphere, an upward travelling molecule can escape to space (if it is moving fast enough) or be pulled back to Earth by gravity (if it isn't) with little probability of colliding with another molecule. The altitude of its lower boundary, known as the thermopause or exobase, ranges from about (250-500 km) depending on solar activity. The upper boundary can be defined theoretically by the altitude (about 193,000 km, half the distance to the Moon) at which the influence of solar radiation pressure on atomic hydrogen velocities exceeds that of the Earth's gravitational pull. The exosphere observable from space as the geocorona is seen to extend to at least 97,000 km from the surface of the Earth. The exosphere is a transitional zone between Earth's atmosphere and interplanetary space.

2-2 Ions classification or (MAGNETO-ELECTRONIC STRUCTURE)

The upper atmosphere is also divided into regions based on the behavior and number of free electrons and other charged particles.

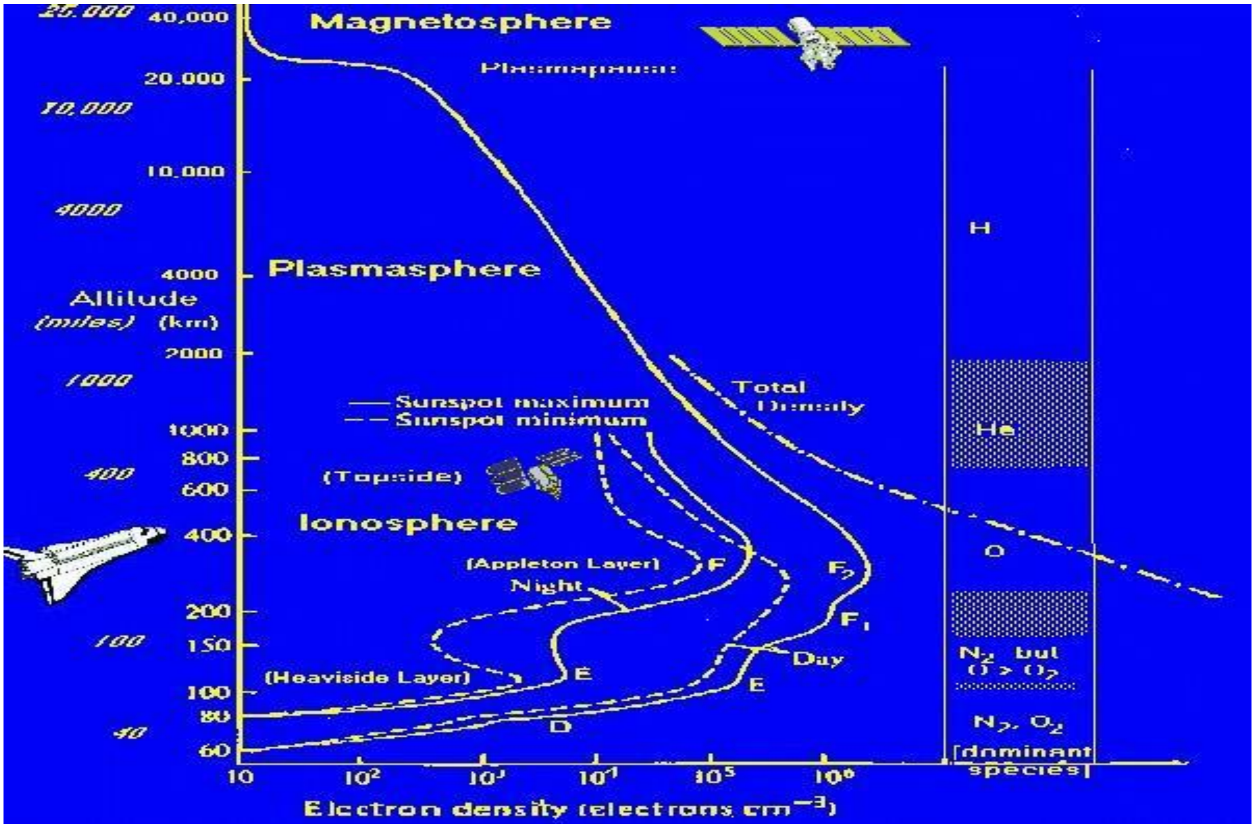
2-2-1 Ionosphere

The ionosphere is defined by atmospheric effects on radiowave propagation as a result of the presence and variation in concentration of free electrons in the atmosphere.

D-region is about (60 - 90 km) in altitude but disappears at night.

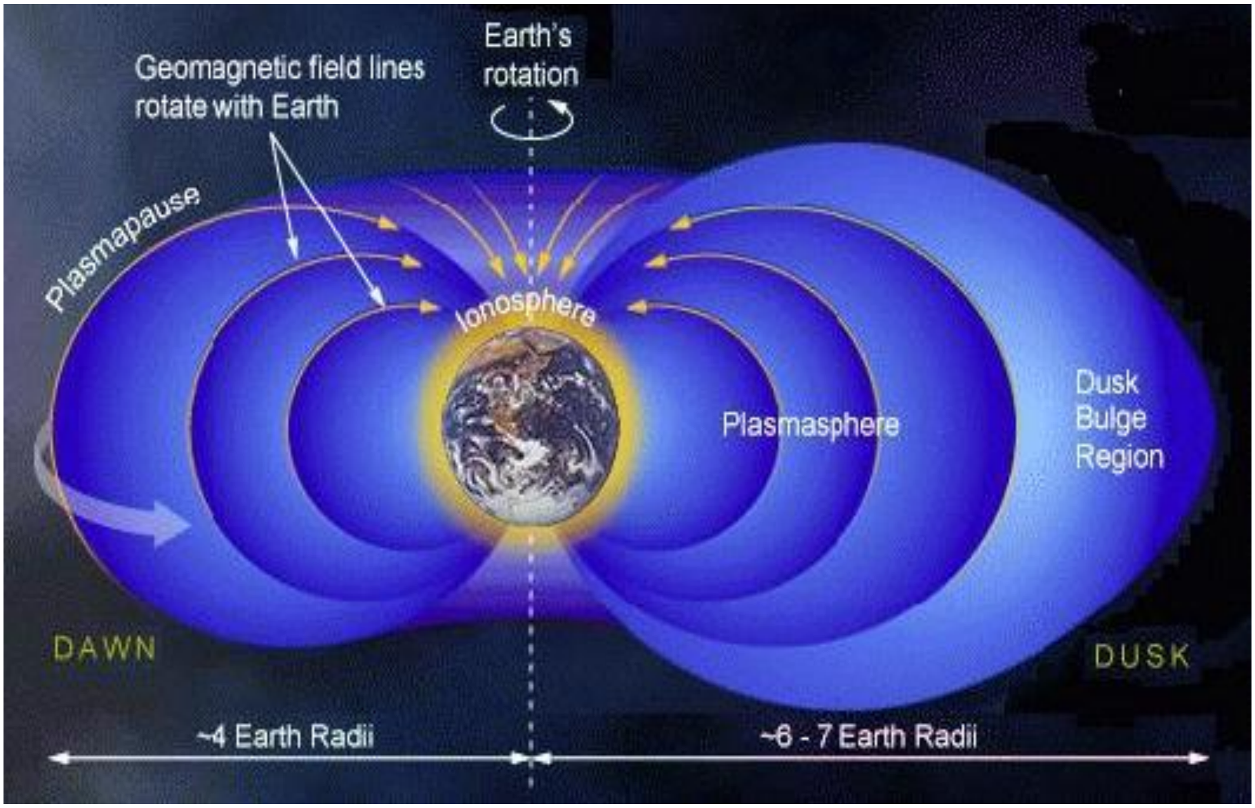
E-region is about (90 - 140 km) in altitude.

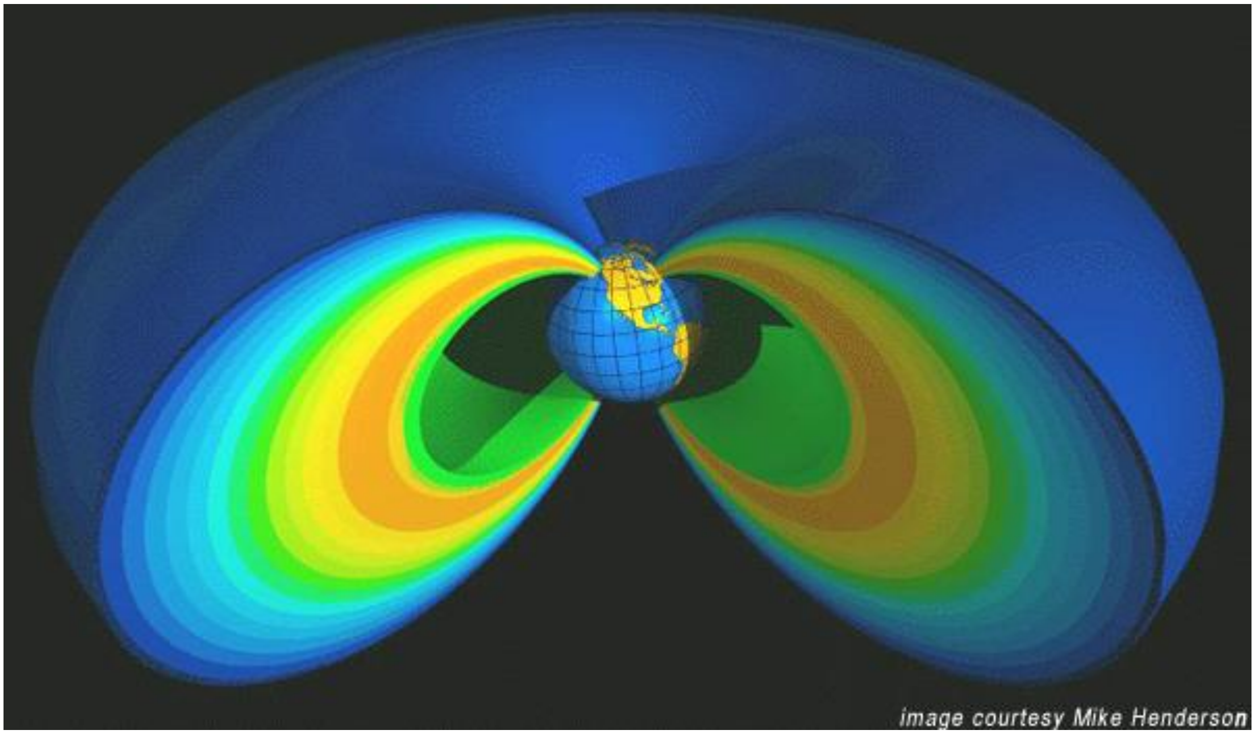
F-region is above (140 km) in altitude. During the day it has two regions known as the F1-region from about (140 to 180 km) altitude and the F2-region in which the concentration of electrons peaks in the altitude range of (around 250 to 500 km). Most recent map of the Height of Maximum (hmF2). The ionosphere above the peak electron concentration is usually referred to as the Topside Ionosphere.



2-2-2 Plasmasphere

The plasmasphere is not really spherical but a doughnut-shaped region (a torus) with the hole aligned with Earth's magnetic axis. [In this case the use of the suffix -sphere is more in the figurative sense of a "sphere of influence".] The Earth's plasmasphere is made of just that, a plasma, the fourth state of matter. This plasma is composed mostly of hydrogen ions (protons) and electrons. It has a very sharp edge called the plasmapause. The outer edge of this doughnut over the equator is usually (19,000-32,000 km) above the surface. The plasmasphere is essentially an extension of the ionosphere. Inside of the plasmapause, geomagnetic field lines rotate with the Earth. The inner edge of the plasmasphere is taken as the altitude at which protons replace oxygen as the dominant species in the ionospheric plasma which usually occurs at about (1000 km) altitude. The plasmasphere can also be considered to be a structure within the magnetosphere.

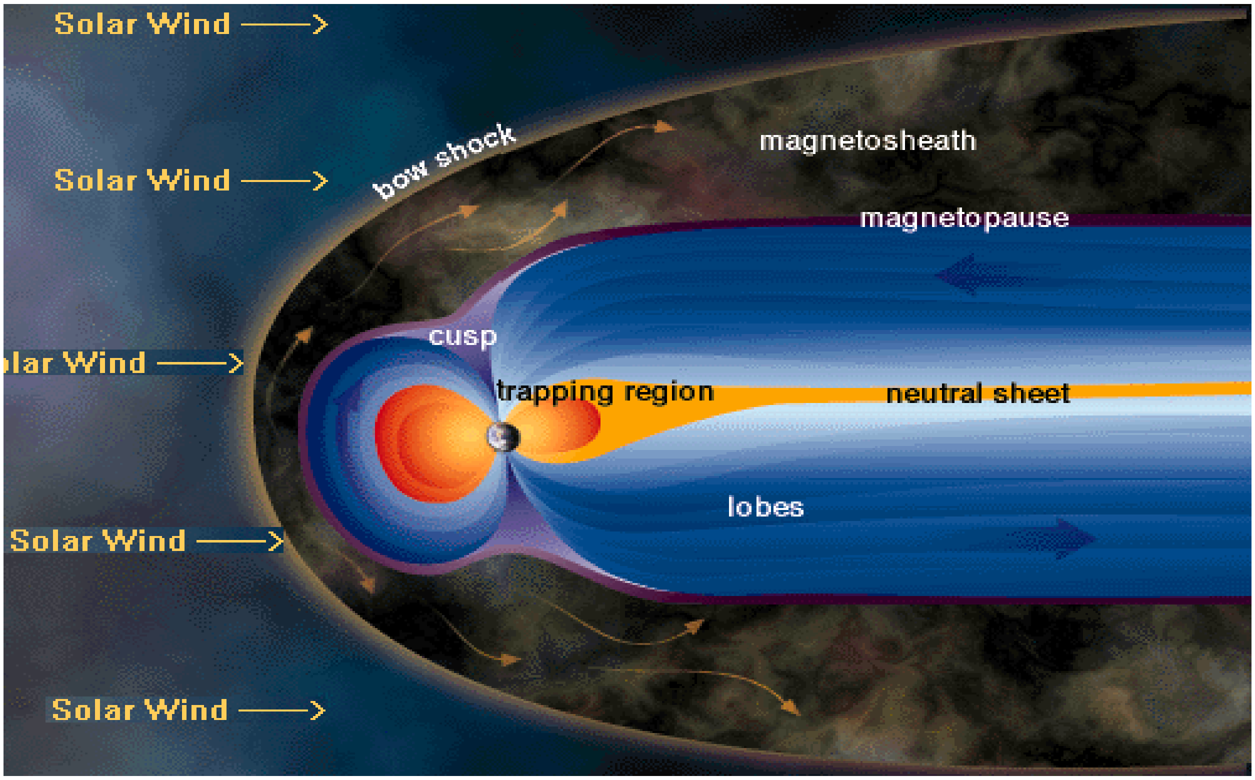




2-2-3 Magnetosphere

Outside the plasmapause, magnetic field lines are unable to corotate because they are influenced strongly by electric fields of solar wind origin. The magnetosphere is a cavity (also not spherical) in which the Earth's magnetic field is constrained by the solar wind and interplanetary magnetic field (IMF). The outer boundary of the magnetosphere is called the magnetopause. The magnetosphere is shaped like an elongated teardrop (like a Christmas Tree ornament) with the tail pointing away from the Sun. The magnetopause is typically located at (about 56,000 km) above the Earth's surface on the day side and stretches into a long tail, the magnetotail, a few million km long (about 1000 Earth radii), well past the orbit of the Moon (at around 60 Earth radii), on the night side of the Earth. However, the Moon itself is usually not within the magnetosphere except for a couple of days around the Full Moon.

Beyond the magnetopause are the magnetosheath and bow shock which are regions in the solar wind disturbed by the presence of Earth and its magnetic field.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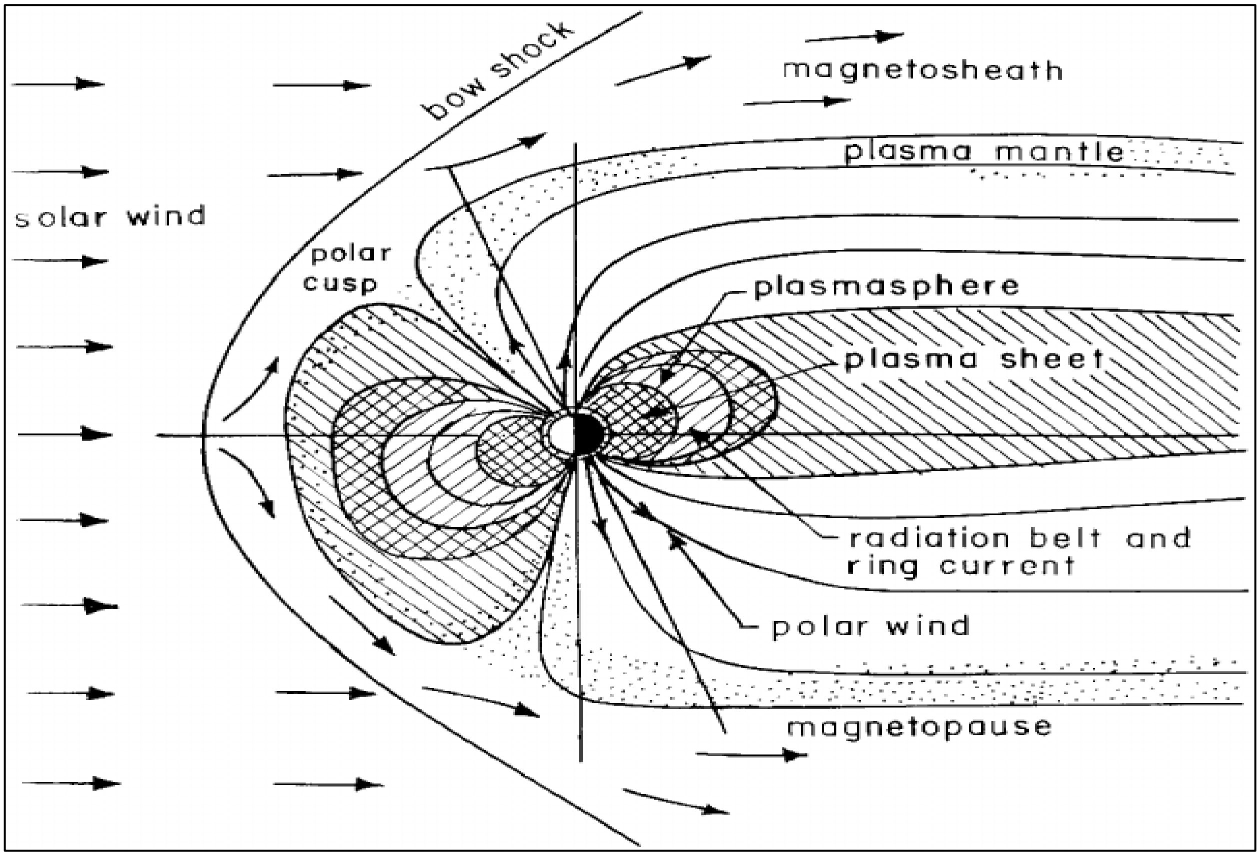
bow shock
magnetosheath
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solar wind
polar cusp
plasmasphere
plasma sheet
radiation belt and ring current
polar wind
magnetopause