Composition & Vertical Structure of the Atmosphere

June 7th, 2021

What is the Atmosphere?

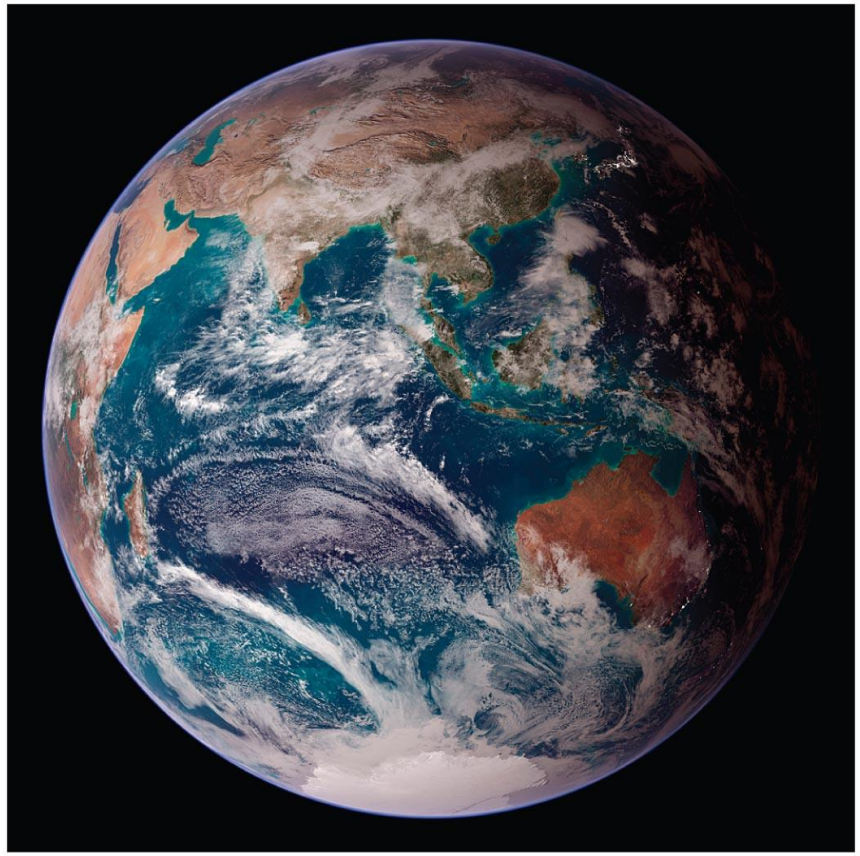
Atmosphere: a mixture of gases, liquids and solids that are held close to the earth's surface due to gravity

Synonym: **Air**

Particles are mainly microscopic and are held in suspension

Pure air is tasteless, and is invisible because the gases are colorless

Most solid particles in the atmosphere are (often) impurities



Size of Earth's Atmosphere

The atmosphere completely surrounds the earth and can be thought of as a vast ocean of air with Earth at its bottom

Held to the earth by **gravitational attraction** and therefore accompanies our planet in all its celestial motions

Although the atmosphere extends outward to more than 10,000 kilometers, more than 50 percent of its mass is concentrated within ~600 meters of Earth's surface, and more than 98 percent within 26 kilometers of the surface

The atmosphere also extends downward into caves, rock, and soil, as well as being dissolved into water and in the bloodstreams of living organisms.

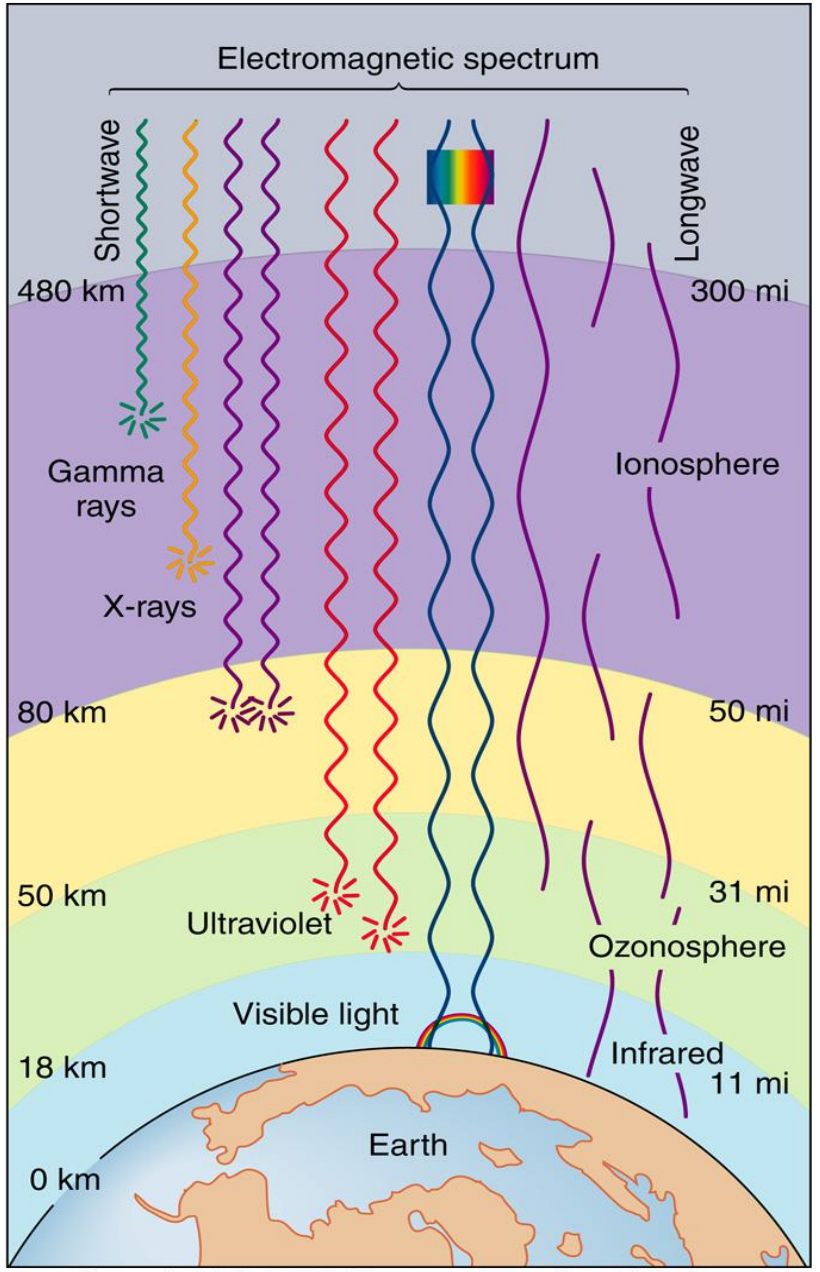
Importance of the Atmosphere

Atmosphere makes life possible on earth by supplying oxygen that animals need and carbon dioxide that plants need

Helps to maintain water supply – essential for all living things

Insulates Earth's surface against temperature extremes and thus provides a livable environment over most of the planet

Shields the earth from much of the Sun's ultraviolet radiation – would otherwise be fatal to most life forms



Composition of the Atmosphere

Three main components:

1. Permanent Gases:

- *Nitrogen, Oxygen and Argon*

2. Variable Gases:

- *Water Vapor*
- *Carbon Dioxide*
- *Ozone*

3. Particulates (Aerosols)

TABLE 3-1 Principal Gases of Earth's Atmosphere

	Percent of Volume of Dry Air	Concentration in Parts per Million Parts of Air
Permanent gases		
Nitrogen (N_2)	78.084	
Oxygen (O_2)	20.946	
Argon (Ar)	0.934	
Neon (Ne)	0.00182	18.2
Helium (He)	0.00052	5.2
Krypton (Kr)	0.00011	1.1
Hydrogen (H_2)	0.00005	0.5
Variable gases		
Water vapor (H_2O)	0–4	
Carbon dioxide (CO_2)	0.039	390
Carbon Monoxide (CO)		<100
Methane (CH_4)	0.000178	1.78
Ozone (O_3)		<2
Sulfur dioxide (SO_2)		<1
Nitrogen dioxide (NO_2)		<0.2

Nitrogen

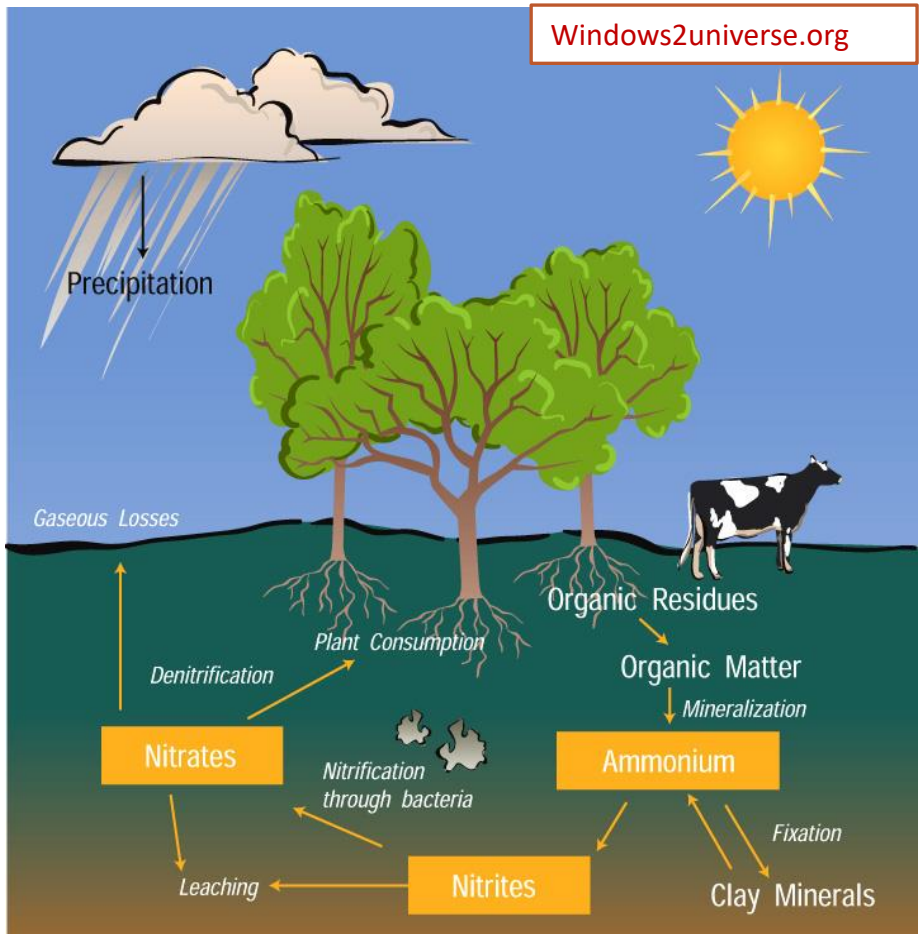
colorless, tasteless and prevent for quick burn

These are the two most abundant components of the atmosphere

N = 78 % and O = 21 %

Nitrogen is added to the atmosphere by decay and burning of organic matter, volcanic eruptions, and chemical breakdown of certain rocks

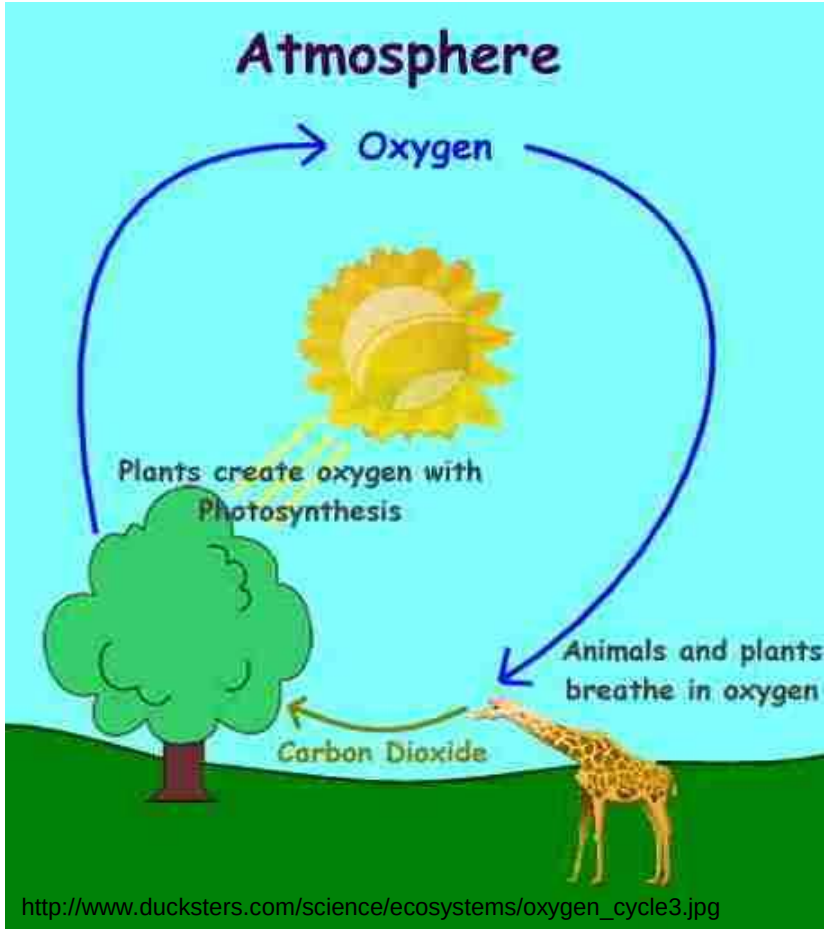
Nitrogen is removed by certain biological process (growing trees) washed away in rain and snow



Oxygen

Oxygen is produced by vegetation and is removed by a variety of organic and inorganic processes

Oxygen and Nitrogen quantities tends to be constant



Other permanent gases

Argon makes up about 1 %

Nitrogen, Oxygen, and Argon, have little effect on weather and climate.

The trace gases: **neon, helium, krypton, and hydrogen all have little effect on weather and climate**

Variable gases

Several of these occur in sparse but highly variable quantities in the atmosphere, but:

- **Significantly influence weather and climate**
- **Critical ones are: Water vapor, Carbon dioxide, Ozone**

Variable gases….

1. **Water vapor**

Water in the form of a gas – invisible (*Visible forms of water in the atmosphere are clouds and precipitation – water in it's liquid or solid form*)

Water vapor is most abundant in air overlying warm, moist surface areas such as tropical oceans, where water volume may amount to as much as 4 % of total volume

Over deserts and in polar regions – water vapor around 1 %

But, the total amount of water vapor in Earth's atmosphere is nearly constant, **so it is variable in location and not in time**.

Water vapor is the source of clouds and precipitation

Variable gases….

2. Carbon Dioxide

The other gas (along with water vapor) that significantly influences climate by absorbing infrared radiation and thereby helping to warm the lower atmosphere – greenhouse gas

Distributed fairly uniformly in the lower levels of the atmosphere

Concentration has been increasing steadily for the last century or so because of the **burning of fossil fuels**

The proportion has increased at a rate of 0.0002 (2 parts per million per year)

1970 = 280 ppm; 2009 around 390 ppm; 2013 ~ 400 ppm

Most scientist believe this increasing CO_2 is producing significant but still unpredictable global climatic changes due to radiative forcing

Variable gases….

3. Ozone

Minor but vital gas – made up of three oxygen atoms (O_3) instead of the more common two oxygen atoms (O_2).

Ozone is concentrated in the stratosphere (area sometimes called the ozone layer) between 15 and 48 km (9 to 30 miles) above the Earth's surface

O_3 is an excellent absorber of ultraviolet solar radiation; filtering out enough to protect life forms from potential deadly effects

Ozone is the stratosphere has a completely different impact

90% stratosphere; 10% troposphere

Other variables gases

Carbon monoxide, sulphur dioxide, nitrogen oxides, and various hydrocarbons are increasingly being introduced into the atmosphere by emission from factories and automobiles

All of these are hazardous to life and may have possible influences on climate

Methane, introduced into the atmosphere both naturally and through human activity, absorbs certain wavelengths of radiation and so plays a role in regulating the temperature of the atmosphere

- See band saturation in later class

Particulates (Aerosols)

Large non-gaseous particles in the atmosphere; liquid water and ice, which forms clouds, rain, snow, sleet, and hail.

Dust particles large enough to be visible, and are sometimes kept aloft in the atmosphere in sufficient quantities to cloud the sky; are too heavy to remain long in the air

Solid and liquid particles are collectively called **Particulates or Aerosols**

Particulates (Aerosols)

Sources are both

- Natural: **volcanic ash, windblown soil and pollen grains, meteor debris, smoke from wildfires and salt spray from breaking waves**
- Human: **industrial and automotive emissions and smoke and soot from fires of human origin**

Affect weather and climate in two ways:

- **Hygroscopic: they absorb water and water vapor condenses around them – making them a condensation nuclei. This is a critical step in cloud formation**
- **Either absorb or reflect sunlight: decreasing the amount of solar energy that reaches Earth's surface**

Vertical Structure of the Atmosphere

The vertical structure of the Atmosphere can be viewed from four perspectives: temperature, pressure, composition and function.

A. *Thermal Layers or Temperature*: There are five key thermal layers in the atmosphere:

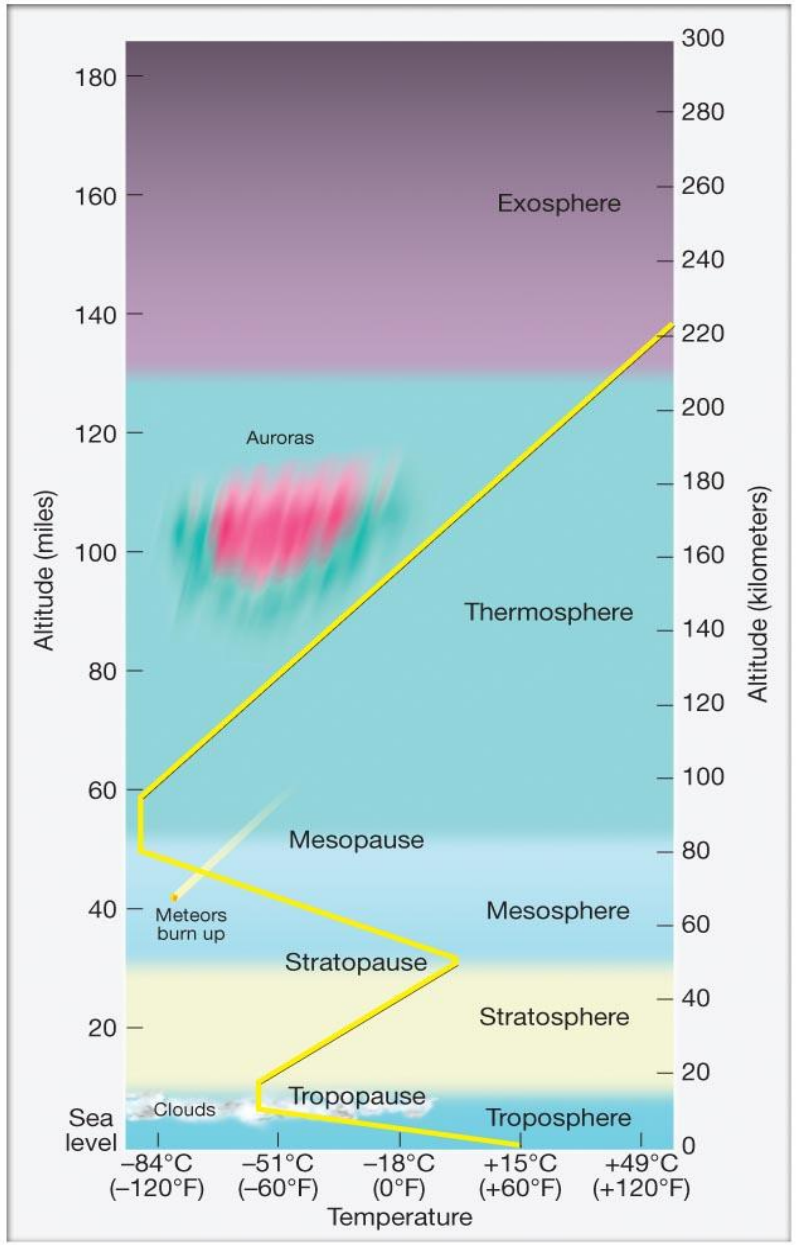
   a) Troposphere
   b) Stratosphere
   c) Mesosphere
   d) Thermosphere
   e) Exosphere

Most weather phenomena occur in lower atmosphere or Troposphere, so this is the area we are most concerned about in this class.

Note:

"**-sphere**" is used when talking about the entire layer;

"**-pause**" is used when referring to just the upper portion of a layer or the boundary between two layers



Thermal Layers: ***Lower layers***

Troposphere

- the lowest thermal layer of the atmosphere; temperature decreases with height.
- Derived from the Greek word *tropos* ("turn") and imply an overturning of air in this zone as a result of vertical mixing and turbulence.
- The depth of the troposphere varies in both time and space; deepest over Tropical regions and shallowest over the poles, deeper in summer that in winter.
- On average, the top of the troposphere (including the tropopause) is about 18 kilometers (11 miles) above sea level at the equator and about 8 kilometers (5 miles) above sea level at the poles.

Thermal Layers: ***Lower layers***

absorb the UV radiaion

Stratosphere—atmospheric layer directly above troposphere, where temperature **increases** with height.

a) In comparison to the turbulent troposphere, the stratosphere could be considered stagnant.

b) **Stratopause—top of the stratosphere, elevation about 48 kilometers (30 miles),** where maximum temperature is reached.

c) 90 % of Ozone found here

Thermal Layers: *Upper layers*

Mesosphere—atmospheric layer above the stratopause, where temperature again decreases with height as it did in the troposphere.

Mesopause—transition zone at the top of the mesosphere.

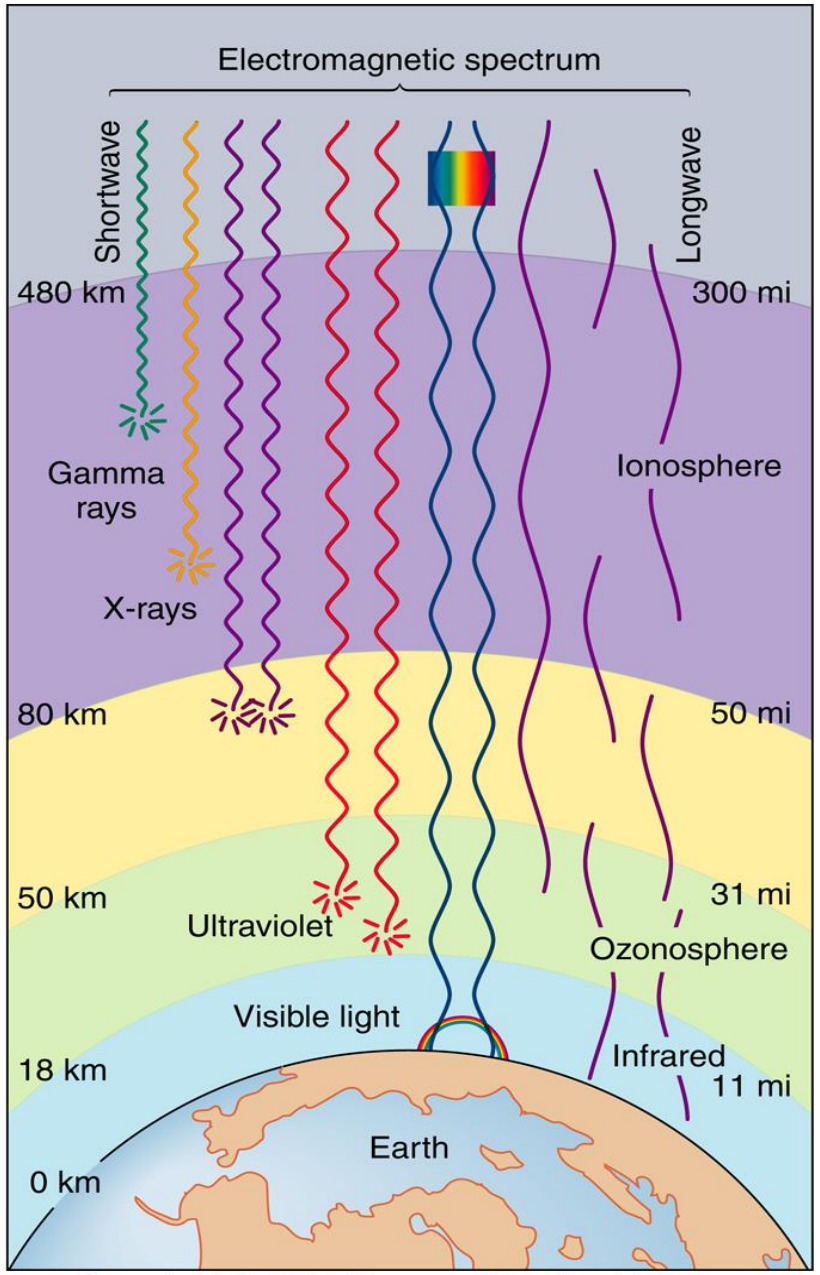
Thermosphere—the highest recognized thermal layer in the atmosphere, above the mesopause, where temperature remains relatively uniform for several kilometers and then increases continually with height.

Exosphere—the highest zone of Earth's atmosphere.

Temperature Patterns in the Atmosphere

A. Temperature alternately decreases and increases from one layer to the next.

B. The warm zones of the thermal layers each have their own specific source of heat.
   - In the troposphere, it's the visible portion of sunlight.
   - In the stratosphere and thermosphere, the Sun's ultraviolet rays serve as the heat source (the warm zone of the stratosphere is near the top of the ozone layer, which absorbs UV rays).

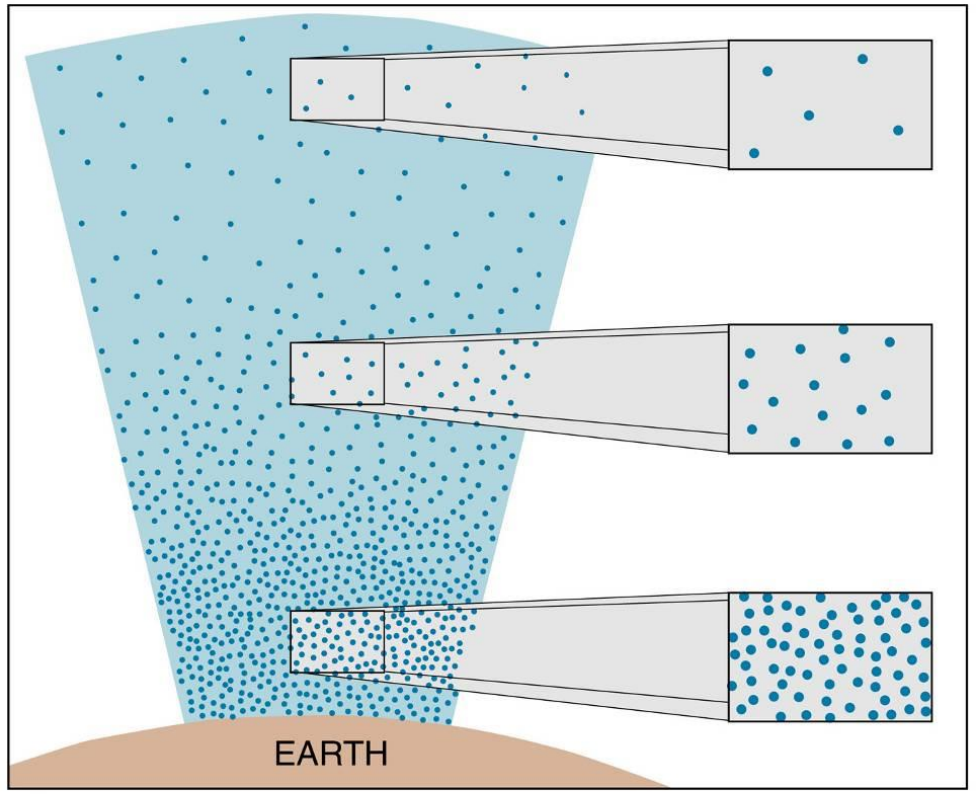


Pressure

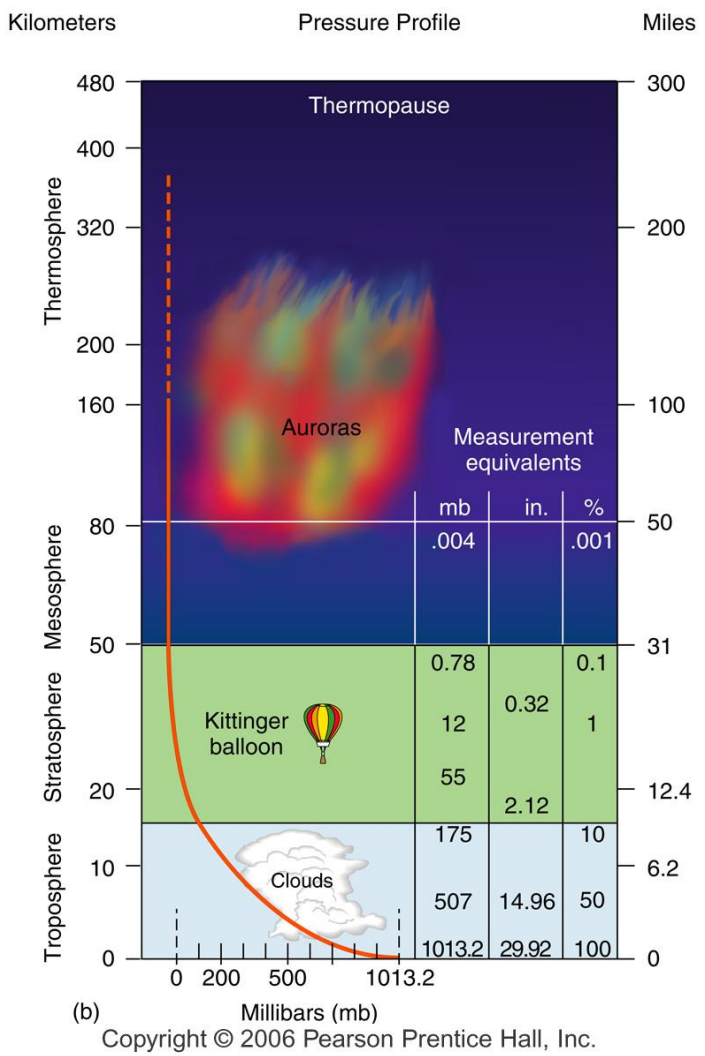
Atmospheric pressure is basically the weight of overlying air.

Thus, air pressure is normally highest at sea level and rapidly decreases with altitude.

Air pressure decreases with increasing altitude but not at a constant rate



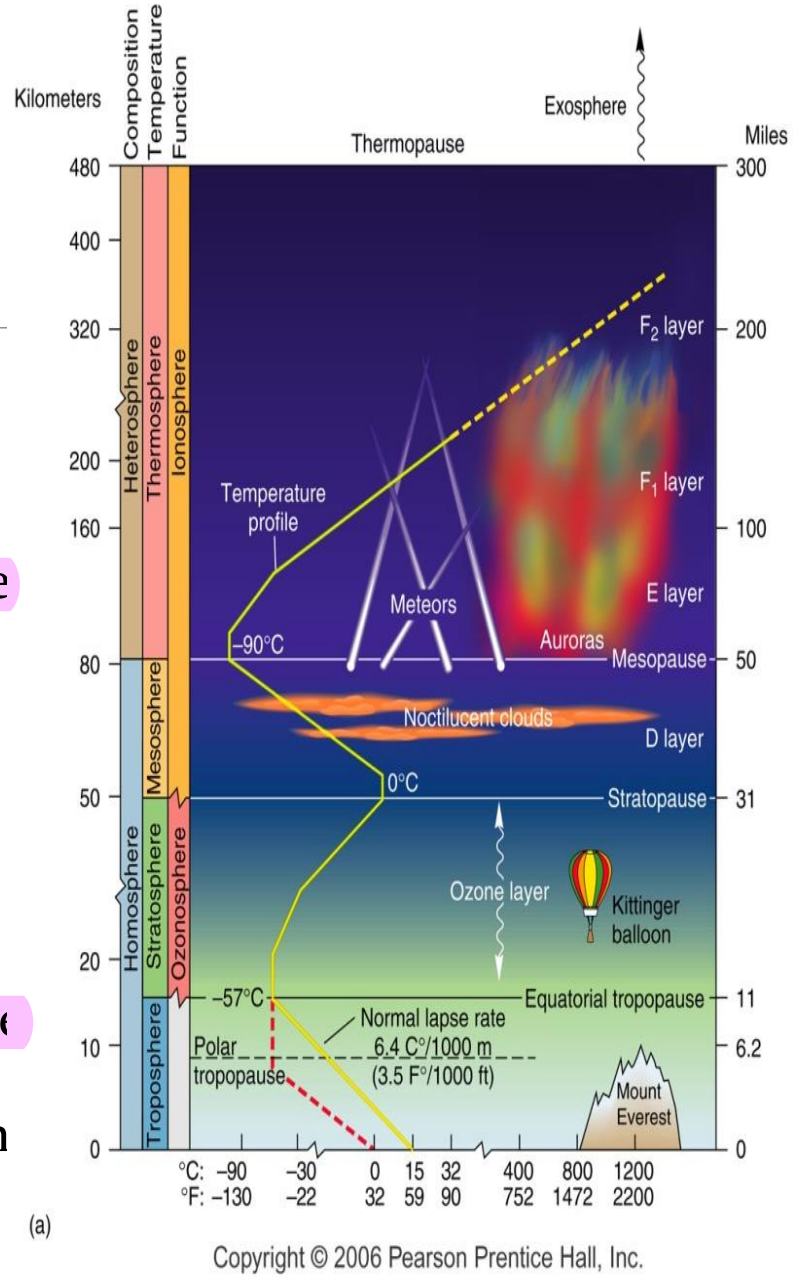
(a)



Composition and Function

Composition: arrangement of the gases

1. Homosphere:
   I. Principal gases of atmosphere have a uniform vertical distribution in the lowest 80 kilometers (50 miles) of the atmosphere.
   II. **Zone of homogeneous composition of the gases of the atmosphere; in both troposphere and stratosphere.**
2. Heterosphere:
   I. **Zone of heterogeneous composition; begins in mesosphere and continues through exosphere** where gases tend to be layered according to their molecular masses rather than having the homogenous composition of the homosphere
   II. **Nitrogen>Oxygen (atomic)>Helium>Hydrogen.**



Composition and Function

Function:

1. Ozonosphere—ozone layer; the zone of relatively rich concentration of ozone in the atmosphere, between about 15 to 48 kilometers (9 to 30 miles) high, that absorbs ultraviolet radiation.

2. Ionosphere—deep layer of ions, electrically charged molecules and atoms, in mesosphere (middle and upper parts) and thermosphere (lower part) that aids in long distance communication by reflecting radio waves back to Earth.