Atmosphere

The atmosphere is a critical system that helps to regulate Earth's climate and distribute heat around the globe. Earth's atmosphere is also a important system for life on our planet. Together with the oceans, the atmosphere shapes Earth's climate and weather patterns and makes some regions more habitable than others. But Earth's climate is not static.

The atmosphere is a complex system in which physical and chemical reactions are constantly taking place. Many atmospheric processes take place in a state of dynamic balance—for example, there is an average balance between the heat input to, and output from, the atmosphere.

This condition is to a leaky bucket sitting under a faucet: when the tap is turned on and water flows into the bucket, the water level will rise toward a steady state where inflow from the tap equals outflow through the leaks.

Similarly, Earth's climate system maintains a dynamic balance between solar energy entering and radiant energy leaving the atmosphere. Levels of oxygen in the atmosphere are regulated by a dynamic balance in the natural carbon cycle between processes that emit oxygen through photosynthesis and others that consume oxygen, such as respiration. The strength of atmospheric circulation is also controlled by a dynamic balance.

Today human actions are altering key dynamic balances in the atmosphere. Most importantly, humans are increasing greenhouse gas levels in the troposphere, which raises Earth's surface temperature by increasing the amount of heat radiated from the atmosphere back to the ground.

The earth’s atmosphere is a thin, gaseous envelope comprised mostly of nitrogen (N_2) and oxygen (O_2), with small amounts of other gases, such as water vapor (H_2O) and carbon dioxide (CO_2). Almost 99% of the atmosphere lies within a mere 30 km of the earth’s surface.

Nitrogen (N_2) occupies about 78 percent and oxygen (O_2) about 21 percent of the total volume.

At the surface, there is a balance between destruction (output) and production (input) of these gases. For example, nitrogen is removed from the atmosphere primarily by biological processes that involve soil bacteria.

Nitrogen is returned to the atmosphere mainly through the decaying of plant and animal matter. Oxygen, on the other hand, is removed from the atmosphere when organic matter decays and when oxygen combines with other substances, producing oxides. It is also taken from the atmosphere during breathing, as the lungs take in oxygen and release carbon dioxide. The addition of oxygen to the atmosphere occurs during photosynthesis, as plants, in the presence of sunlight, combine carbon dioxide and water to produce sugar and oxygen.

The concentration of the invisible gas water vapor, however, varies greatly from place to place, and from time to time. Close to the surface in warm, steamy, tropical locations, water vapor may account for up to 4 percent of the atmospheric gases, whereas in colder arctic areas, its concentration may dwindle to a mere fraction of a percent. Water vapor molecules are, of course, invisible.

Q) How water vapor become visible? They become visible only when they transform into larger liquid or solid particles, such as cloud droplets and ice crystals. The changing of water vapor into liquid water is called condensation, whereas the process of liquid water becoming water vapor is called evaporation.

Water vapor is an extremely important gas in our atmosphere. Not only does it form into both liquid and solid cloud particles that grow in size and fall to earth as precipitation, but it also releases large amounts of heat called latent heat—when it changes from vapor into liquid water or ice.

Carbon dioxide (CO_2), a natural component of the atmosphere, occupies a small (but important) percent of a volume of air, about 0.037 percent. Carbon dioxide enters the atmosphere mainly from the decay of vegetation, but it also comes from volcanic eruptions, the exhalations of animal life, from the burning of fossil fuels (such as coal, oil, and natural gas), and from deforestation.

The removal of CO_2 from the atmosphere takes place during *photosynthesis,* as plants consume CO_2 to produce green matter. The CO_2 is then stored in roots, branches, and leaves. The oceans act as a huge reservoir for CO_2, as phytoplankton (tiny drifting plants) in surface water fix CO_2 into organic tissues.

Atmospheric concentration of CO_2 has risen more than 15 percent since 1958,

Carbon dioxide is another important greenhouse gas because, like water vapor, it traps a portion of the earth's outgoing energy.

Levels of **methane** have been rising over the past century, increasing recently by about one half of one percent per year. Most methane appears to derive from the breakdown of plant material by certain bacteria in rice paddies, wet oxygen-poor soil, the biological activity of termites, and biochemical reactions in the stomachs of cows.

Levels of nitrous oxide have been rising annually at the rate of about one-quarter of a percent. Nitrous oxide forms in the soil through a chemical process involving bacteria and certain microbes. Ultraviolet light from the sun destroys it.

Chlorofluorocarbons represent a group of greenhouse gases that, up until recently, had been increasing in concentration. At one time, they were the most widely used propellants in spray cans.

Today, however, they are mainly used as refrigerants, as propellants for the blowing of plastic-foam insulation, and as solvents for cleaning electronic microcircuits. they have an important effect on our atmosphere as they not only have the potential for raising global temperatures, they also play a part in destroying the gas ozone in the stratosphere.

At the surface, **ozone** (O3) is the primary ingredient of *photochemical smog,* which irritates the eyes and throat and damages vegetation. But the majority of atmospheric ozone (about 97 percent) is found in the upper atmosphere—in the stratosphere where it is formed naturally, as oxygen atoms combine with oxygen molecules.

Vertical Structure of the Atmosphere (AIR PRESSURE AND AIR DENSITY)

Air molecules (as well as everything else) are held near the earth by gravity. The air near the surface is compressed, air density normally decreases rapidly at first, then more slowly as we move farther away from the surface.

The amount of force exerted over an area of surface is called atmospheric pressure or, simply, air pressure. Atmospheric pressure always decreases with increasing height.

Unit for air pressure found on surface weather maps is the millibar (mb), although the hectopascal* (hPa) is gradually replacing the millibar as the preferred unit of pressure on surface maps. Another unit of pressure is inches of mercury (Hg), With a sea-level pressure near 1000 mb

2nd class

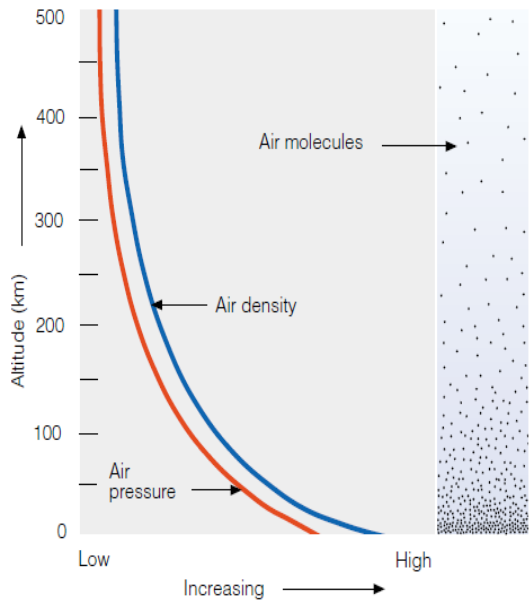


FIGURE 1.5
Both air pressure and air density decrease with increasing altitude.

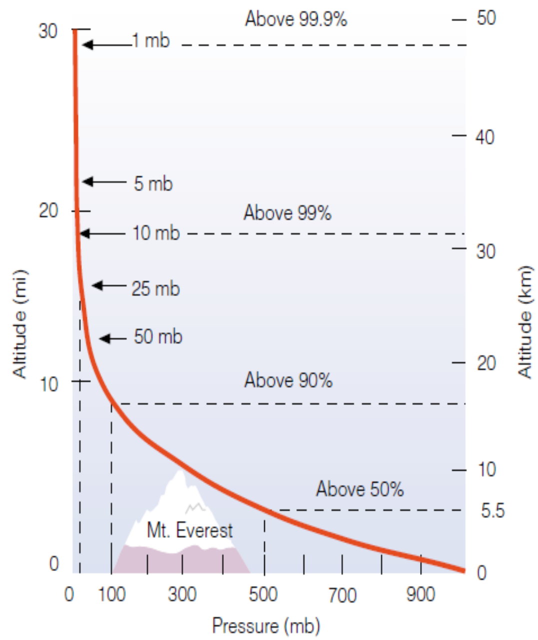


FIGURE 1.6
Atmospheric pressure decreases rapidly with height. Climbing to an altitude of only 5.5 km, where the pressure is 500 mb, would put you above one-half of the atmosphere's molecules.

The Structure of the Atmosphere

The atmosphere is composed of nitrogen, oxygen, argon, water vapor, and a number of trace gases. This composition has remained relatively constant throughout much of Earth's history.

Chemical reactions maintain the ratios of major constituents of the atmosphere to each other. For example, oxygen is released into the atmosphere by photosynthesis and consumed by respiration.

The concentration of oxygen in the atmosphere is maintained by a balance between these two processes: Photosynthesis:

$CO_2 + H_2O + light \rightarrow CH_2O" + O_2$

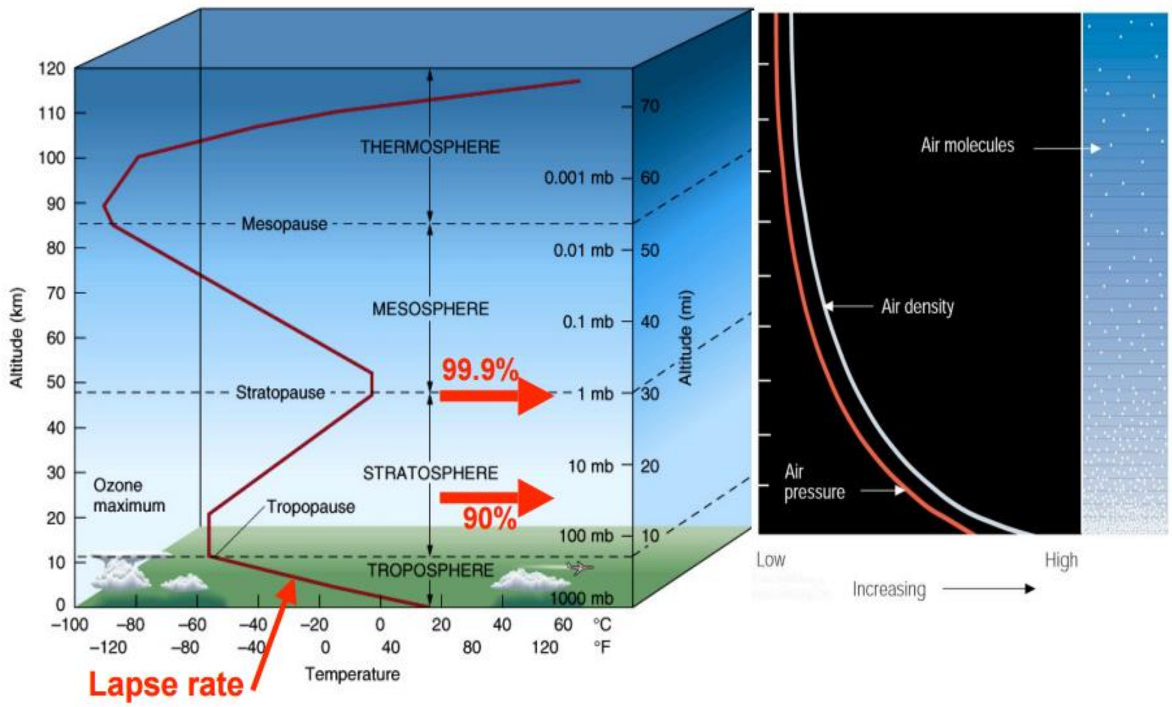
Respiration: $CH_2O + O_2 \rightarrow CO_2 + H_2O + energy$

2nd Lecture

Meteorology

2nd class

Earth's atmosphere extends more than 560 kilometers (348 miles) above the planet's surface and is divided into four layers, each of which has distinct thermal, chemical, and physical properties (Fig).



Look closely at Fig. and notice that air temperature normally decreases from the earth’s surface up to an altitude of about 11 km. This decrease in air temperature with increasing height is due primarily to the fact that sunlight warms the earth’s surface, and the surface, in turn, warms the air above it.

The rate at which the air temperature decreases with height is called the temperature **lapse rate**. **lapse rate** in this region of the lower atmosphere is about 6.5 degrees Celsius (°C) for every 1000 meters (m).

The region of the atmosphere from the surface up to about 11 km contains all of the weather we are familiar with on earth. This region of circulating air extending upward from the earth's surface to where the air stops becoming colder with height is called the troposphere just above 11 km the air temperature normally stops decreasing with height.

Here, the lapse rate is zero. This region, where the air temperature remains constant with height, is referred to as an isothermal (equal temperature) zone. The bottom of this zone marks the top of the **troposphere** and the beginning of another layer, the **stratosphere**. The boundary separating the troposphere from the **stratosphere** is called the **tropopause**.

The next atmospheric layer, the **stratosphere**, extends upward from the tropopause to 50 kilometers. In the stratosphere temperatures increase with altitude because of absorption of sunlight by stratospheric ozone. (About 90 percent of the ozone in the atmosphere is found in the stratosphere.) The stratosphere contains only a small amount of water vapor (only about one percent of total atmospheric water vapor) due to the "cold trap" and the tropopause, and vertical air motion in this layer is very slow. The **stratopause**,

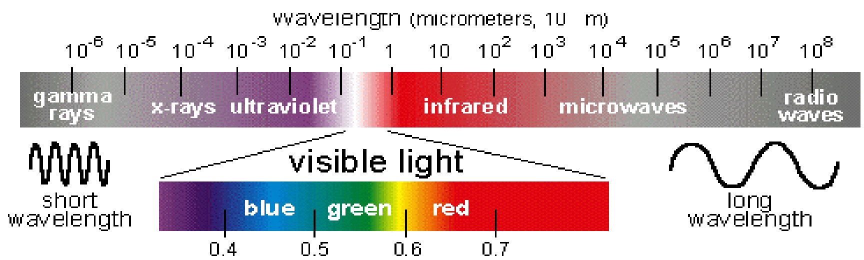
where temperatures peak at about -3°C, marks the top of the **stratosphere**. In the third atmospheric layer, the **mesosphere**, temperatures once again fall with increasing altitude, to a low of about -93°C at an altitude of 85 kilometers. Mesopause: the coldest region on Earth.

Above this level, in the **thermosphere**, temperatures again warm with altitude, rising higher than 1700°C.

Here, oxygen molecules (O_2) absorb energetic solar rays, warming the air. **THE IONOSPHERE** The **ionosphere** is not really a layer, but rather an electrified region within the upper atmosphere where fairly large concentrations of ions and free electrons exist.

The atmosphere exerts pressure at the surface equal to the weight of the overlying air. Figure also shows that atmospheric pressure declines exponentially with altitude—a fact familiar to everyone who has felt pressure changes in their ears while flying in an airplane or climbed a mountain and struggled to breathe at high levels.

Solar Radiation and the Atmosphere



- Solar radiation occurs in a range of wavelengths represented by the electromagnetic spectrum.

- Incoming short- and intermediate-wavelength radiation may be absorbed by gases in the atmosphere, reflected back into space from the atmosphere or Earth's surface, or absorbed by Earth's surface.

- Incoming and outgoing long-wavelength radiation is absorbed by water vapor, carbon dioxide, and other gases in the atmosphere.

- The greenhouse effect occurs when long wavelength radiation is absorbed in the troposphere. The interaction of solar radiation and the atmosphere provides the habitable planet we live on and contributes to the future potential for global warming. In addition, solar radiation supplies the energy necessary for cloud formation, precipitation, and local weather conditions.