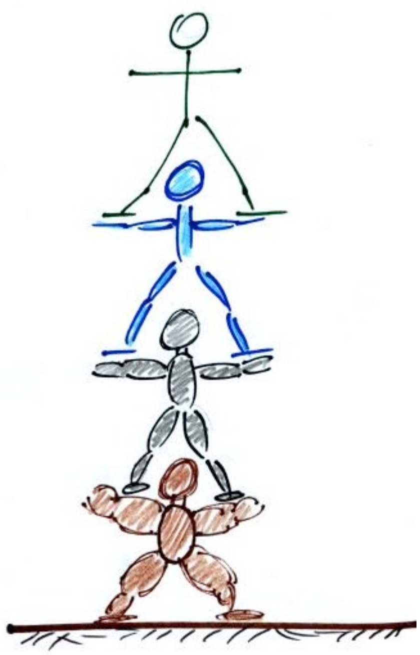
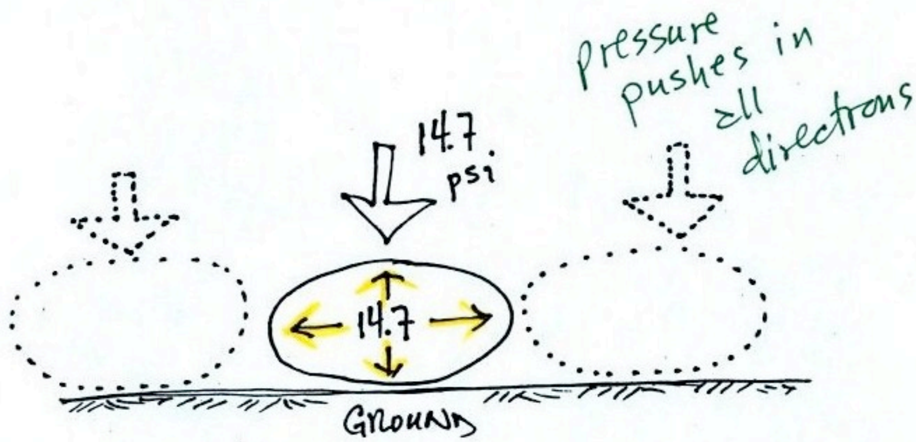
Module 2: Lecture 5

Pressure at any level in the atmosphere is determined by the weight of the air above it. We used a pile of bricks (each brick represents a layer of air) to help visualize and understand why pressure decreases with increasing altitude.

A pile of bricks can lead to the belief that air pressure exerts force in just a downward direction. A better representation might be a "people pyramid." If the bottom person in the stack above were standing on a scale, the scale would measure the total weight of all the people in the pile. That is analogous to sea level pressure being determined by the weight of the all the air above. The bottom person in the picture above must be strong and be able to push upward with enough force to support the people above. That is equivalent to the bottom layer of the atmosphere having enough pressure, <u>pressure that points up, down, and sideways</u>, to support the weight of the air above.

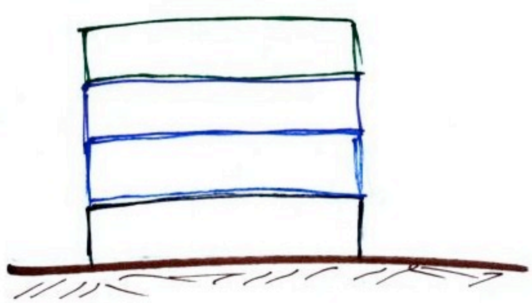


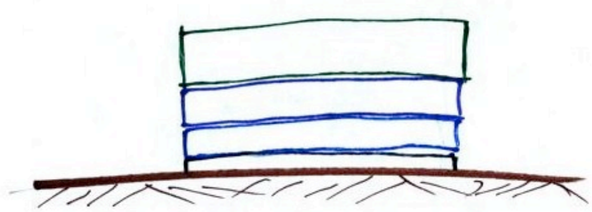
Air pressure is a force that pushes downward, upward, and sideways. If you fill a balloon with air and then push downward on it, you can feel the air in the balloon pushing back (pushing upward). You would see the air in the balloon pushing sideways as well. Another example is the tire air pressure on your automobile. The air in the tires pushes down on the road **<u>and pushes upward</u>** with enough force to keep the 2000 pound vehicle off the road.



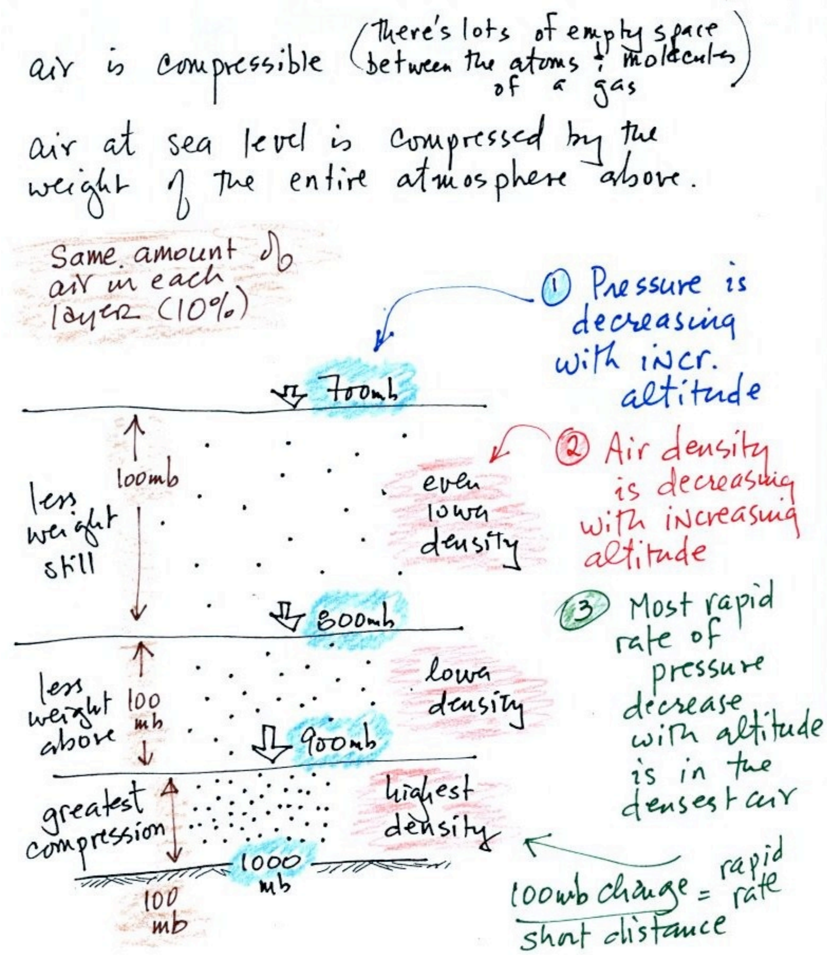
The air layer at the ground is compressed by the weight of the whole atmosphere above. The air layer isn't completely flattened. Air pushes upward with enough force that it is just able to support the weight of the air above. [The air also pushes sideways with the same force but there are air parcels alongside that push back.]

Because air is compressible, a pile of mattresses may be a more realistic representation of how the air density decreases with increasing altitude. The mattress at the bottom of the pile feels the weight of all the mattresses above and is the most compressed. The mattresses higher up are not compressed as much because there is less weight remaining above.





The same is true with layers of air in the atmosphere. Here is the same idea applied to the atmosphere.



Here are the main ideas conveyed in this figure.

1.   Pressure decreases with increasing altitude. 1000 mb of pressure at the bottom decreases to 700 mb of pressure at the top of the picture.

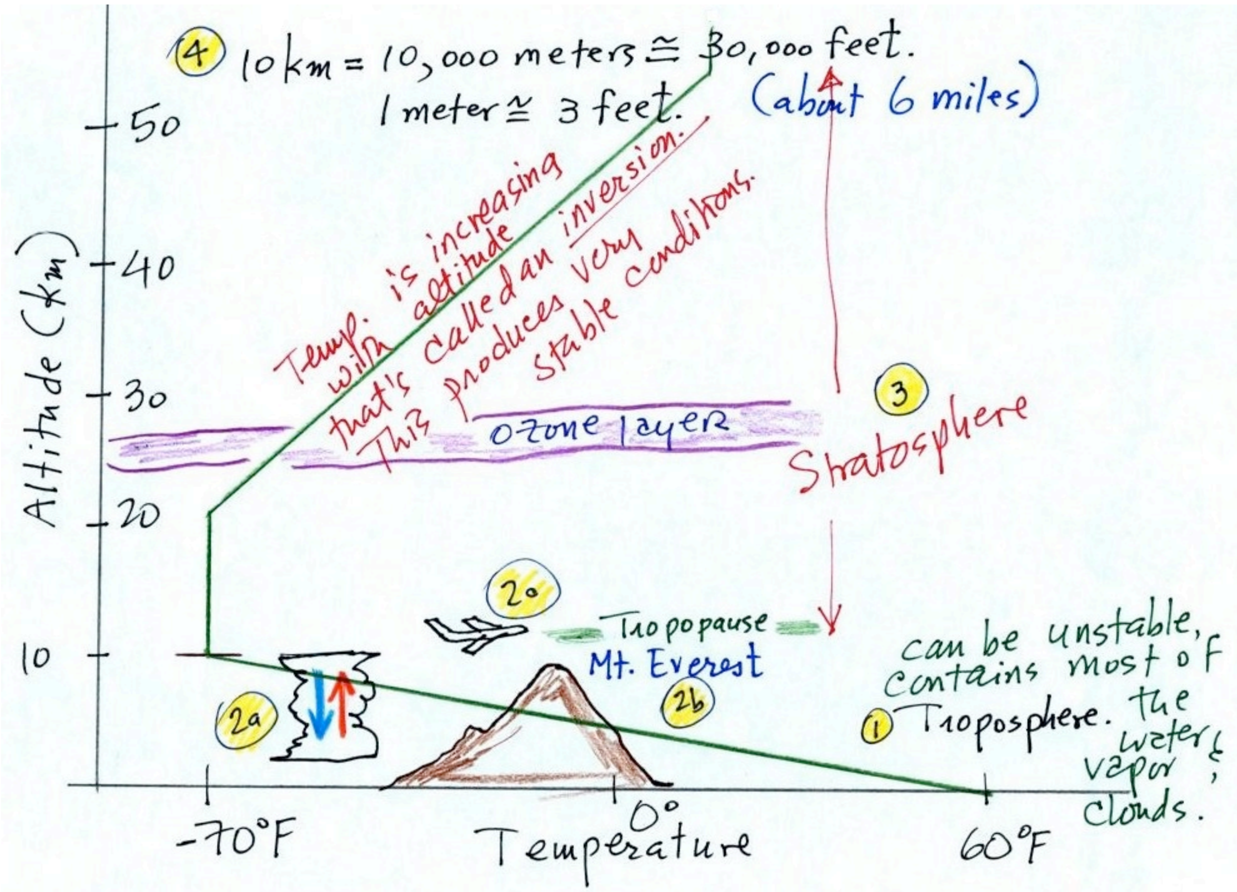
2. Each layer of air contains the same amount (mass) of air. You can tell because the decrease in pressure as you move upward through each layer is the same (100 mb). Each layer contains 10% of the air in the atmosphere and has the same weight.

3. The densest air is found in the bottom layer. Each layer has the same amount of air (same mass) but the bottom layer is compressed the most so it has the smallest volume. The same mass in a small volume leads to a high density. The top layer has the same amount of air but about twice the volume. It therefore has a lower density.

4. You again notice something that we covered earlier: the pressure decreases most rapidly with

increasing altitude in the dense bottom air layer. At 800 mb where the air is less dense, it takes almost twice the altitude for the pressure to decrease from 800 mb to 700 mb.

So far we have looked at how pressure and air density change with increasing altitude. In the last part of this lecture we will have a quick look at how air temperature changes with altitude. The two lowest layers are shown in the figure below. There are additional layers (the mesosphere and the thermosphere) above 50 km but we will not worry about them.



The following describes each numbered point on the above figure.

Point 1. We live in the **troposphere**, where the temperature usually decreases with increasing altitude. On average, the troposphere is found between at altitude of 0 to10 kilometers (km). The troposphere is usually a little higher in the tropics and lower at polar latitudes. The troposphere contains most of the water vapor in the atmosphere (the water vapor comes from evaporation of ocean water) and it is where most of the clouds and weather occurs. The troposphere can be stable or unstable. (The prefix "tropo" means to turn over and refers to the fact that air can move up and down in the troposphere).

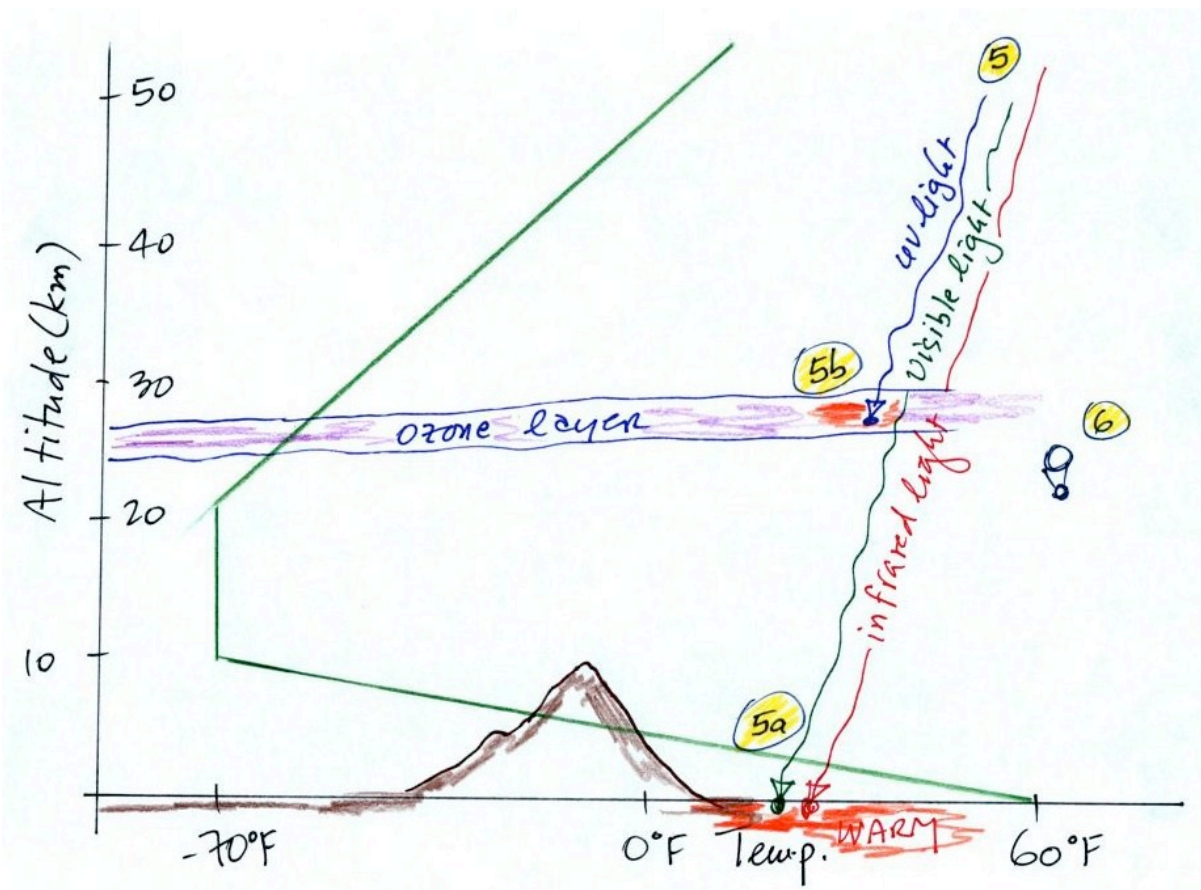
2a. The thunderstorm shown in the figure indicates unstable conditions, which means that strong vertical air motions are occurring. When the thunderstorm reaches the top of the troposphere, it runs into the bottom edge of the stratosphere which is a very stable layer. The air cannot continue to rise into the stratosphere so the cloud flattens out and forms an anvil (the flat top of the thunderstorm). The flat anvil top is something that you can often see during the monsoon season.

2b. The summit of Mt. Everest is a little over 29,000 feet tall and is close to the top of the troposphere.

2c. The cruising altitude in a passenger jet is usually between 30,000 and 40,000, near or just above the top of the troposphere, and at the bottom of the stratosphere.

3. Temperature remains constant between 10 and 20 km and then increases with increasing altitude between 20 and 50 km. These two sections form the stratosphere. The stratosphere is a very stable air layer. Increasing temperature with increasing altitude is called an inversion, which is the reason the stratosphere is so stable.

4. A kilometer is one thousand meters. Since 1 meter is <u>about</u> 3 feet, 10 km is <u>about</u> 30,000 feet. There are 5280 feet in a mile so this is <u>about</u> 6 miles (<u>about</u> is usually close enough in this class).



The following describes each numbered point on the above figure.

5. Sunlight is a mixture of ultraviolet (7%), visible (44%), and infrared light (49%). We can see the visible light.

5a. On average about 50% of the sunlight arriving at the top of the atmosphere passes through the atmosphere and is absorbed by the ground (20% is absorbed by gases in the air, 30% is reflected back into space). This warms the ground. The air in contact with the ground is warmer than air just above. As you get further and further from the warm ground, the air is colder and colder. This explains why air temperature decreases with increasing altitude in the troposphere.

5b. How do you explain increasing temperature with increasing altitude in the stratosphere? The ozone layer is found in the stratosphere (peak concentrations are found near 25 km altitude). Absorption of ultraviolet light by ozone warms the air in the stratosphere and explains why the temperature increases with altitude. The air in the stratosphere is much less dense (thinner) than in the troposphere so it takes less ultraviolet energy to warm this thin air as compared to denser air close to the ground.

6. This is a manned balloon; Auguste Piccard and Paul Kipfer are inside. In 1926 they made the first trip into the stratosphere. It really was quite a daring trip at the time, and they almost did not survive it.