ESA21
Environmental Science Activities for the 21st Century

The Atmosphere

Introduction

Atmosphere Connections

Each day, Earth's 6.3 billion people interact with the atmosphere in many ways. Jet pilots, for example, fly through the atmosphere and must be intimately familiar with weather patterns. Satellite TV stations send signals through the atmosphere that bounce off satellites and then back through the atmosphere to satellite dishes scattered far and wide. Many of these interactions are invisible and involve gases, heat, or energy waves. The most basic of these interactions is, of course, breathing. In fact, right now as you read these words, you are inhaling oxygen (O_2) and exhaling carbon dioxide (CO_2). We humans need a steady supply of "clean" air.

The process by which humans inhale O_2 and exhale CO_2 is known as respiration. This exchange of gases is the respiratory system's means of getting oxygen to the blood. Without air, a person will die faster than if they were deprived of any other human need, such as food, water, cable television, and the Internet. Most of us can only hold our breath for about a minute. After 30 seconds, it begins to get uncomfortable. After 3 to 5 minutes, hypoxia, or oxygen deprivation sets in, brain cells begin to die and you're on your way to being dead. Note: This is not part of your lab assignment.

Besides breathing, how else does your body interact with the atmosphere? Maybe you've never asked yourself this question before, but there are many other ways that your body and the atmosphere interact. Have you ever sneezed? Sneezing is a reflex response to the presence of atmospheric particulates, such as pollen or dust, in your nose. We also sneeze when we are sick with a cold. Sneezing sprays the atmosphere around you with microscopic bacteria and fluid at a speed close to the fastest baseball pitchers, about 100 miles per hour.

What other bodily functions interact with the atmosphere? How about burping or "passing" gas, that releases nitrogen, oxygen, carbon dioxide, hydrogen, and methane into the atmosphere as a result of the process of digestion. In addition, we all have our own unique body odor caused by the mixing of perspiration and bacteria that those close to use can usually smell.

Have you ever made a sound? Sound travels through the atmosphere in waves called, not surprisingly, sound waves. What do you think of when you heard the word "waves"? Most of us probably think of waves in the ocean. If you're a sports fan, you might think of how crowds in stadiums sometime make a "human" wave. Waves are made up of both crests, which are the top of the wave, and troughs, which are the bottom. The distance from one crest to the next is called wavelength.

There are many types of waves that pass through the atmosphere. Your eyes see light, which travels

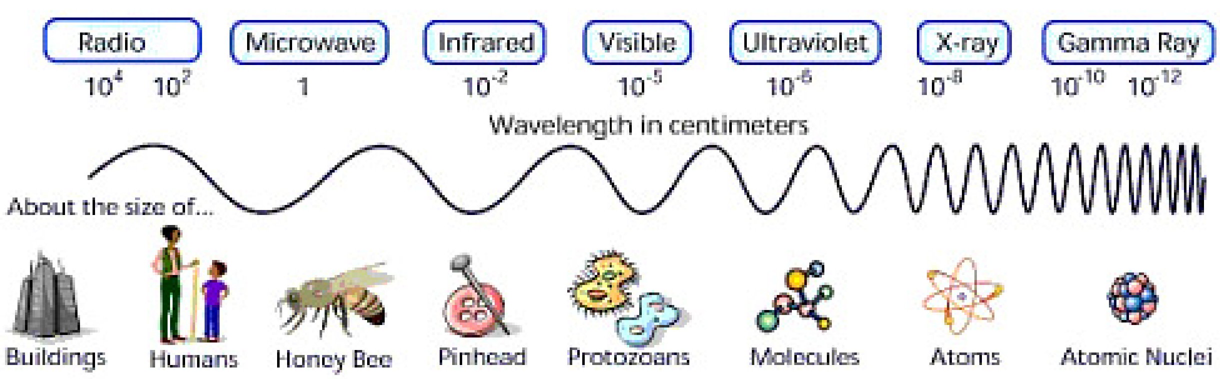

Fig. 1: Electromagnetic spectrum (*Source: NASA*)

through the atmosphere in waves. If you've ever been sunburned or gotten a tan, it was ultraviolet waves that cause the temporary changes in your skin color. So you see there are many ways that your body interacts with the atmosphere and most of them are invisible. Figure 1 depicts the wavelengths of various forms of energy ranging from radio waves, which are quite large, to X-rays and gamma rays, which are infinitesimal.

Atmospheric Composition

The "air" you are breathing is actually a mixture of gases. This mixture of gases is known as the atmosphere. The word "atmosphere", by the way, comes from the Latin "atmosphaera", which was cobbled together from the from Greek word "atmos", meaning "vapor", and the Latin word "sphaera" translated as sphere. Quite literally then, the atmosphere is the "vapor-sphere".

This gaseous composition of the atmosphere is usually expressed by percentage volume, that is, each gas's relative part of the total mixture. For example, 78% of the atmosphere is made of the gas nitrogen (N_2), 21% is composed of oxygen (O_2), and .9% is made up of argon (Ar). These three gases together make up 99.9% of the atmosphere. Other "vapors" or gases that make up the atmosphere include water vapor (H_20), Carbon Dioxide (CO_2), Neon (Ne), Helium (He), Methane (CH_4), Krypton (Kr), and Hydrogen (H_2). These gases, along with many others, are referred to as "trace" gases, in that there are small traces of them in the atmosphere. The concentration of gases in the atmosphere is measured in parts per thousand (ppt), parts per million (ppm) and parts per billion (ppb).

The atmosphere also contains solid material in addition to the gases above. This solid material is very small, between .1 and 25 thousandths of a millimeter, or micrometer and is known as particulates. To give you some idea how small particulates are, a single grain of table salt is about 100 micrometers in size, and so we are talking about a mass of material that is 1/1000 to ¼ the size of a grain of table salt. In addition to gases and solids, liquids also exist in the atmosphere. The most common one of these is water, good old H_20. Water exists in the atmosphere as clouds, rain, and fog, all of which are visible and, therefore, familiar. The table below shows the composition of the atmosphere and the cumulative volume of each compound.

Full Name	Formula	% Volume	# Of Parts	Unit	Variable?	Cumulative Volume
Nitrogen	N2	78.1%	78 parts per	Hundred		78.10%
Oxygen	O2	20.9%	21 parts per	Hundred		99.00%
Argon	Ar	0.934%	9 parts per	Thousand		99.93%
Water Vapor	H20	0.04%	400 parts per	million	variable	99.97%
Carbon Dioxide	CO2	0.0369%	370 parts per	million		99.99%
Neon	Ne	0.00182%	18 parts per	Million		100.00%
Helium	He	0.000524%	5 parts per	Million		100.00%
Methane	CH4	0.0001842%	2 parts per	Million		100.00%
Krypton	Kr	0.000114%	1 part per	Million		100.00%
Hydrogen	H2	0.0001%	1 part per	million	variable	100.00%
Nitrous Oxide	N20	0.0000315%	315 parts per	billion		100.00%
Carbon Monoxide	CO	0.00002%	200 parts per	billion	variable	100.00%
Xenon	Xe	0.0000087%	87 parts per	billion		100.00%
Ozone	O3	0.000005%	34 parts per	billion	variable	100.00%
Sulphur Dioxide	SO2	0.000002%	20 parts per	billion	variable	100.00%
Ammonia	NH3	0.000002%	20 parts per	billion	variable	100.00%
Formaldehyde	CH20	0.000001%	10 parts per	billion	variable	100.00%
Nitrogen Dioxide	NO2	0.0000003%	3 parts per	billion	variable	100.00%
Nitric Oxide	NO	0.0000003%	3 parts per	billion	variable	100.00%
Hydrogen Sulfide	H2S	0.0000002%	2 parts per	billion	variable	100.00%
Hydrochloric Acid	HCl	0.00000015%	2 parts per	billion	variable	100.00%
Nitric Acid	HNO3	0.0000001%	1 part per	billion	variable	100.00%

Methyl Chloride	CH3Cl	0.00000006%	600 parts per	trillion		100.00%
Freon-12	CF2Cl2	0.0000000544%	546 parts per	trillion		100.00%
Carbonyl Sulfide	COS	0.00000005%	500 parts per	trillion		100.00%
Freon-11	CFCl3F	0.0000000263%	263 parts per	trillion		100.00%
Carbon Tetrachloride	CCl4	0.000000098%	97 parts per	trillion		100.00%
Freon-113	C2F3Cl3	0.000000082%	82 parts per	trillion		100.00%
Methyl Chloroform	CH3CCl3	0.000000056%	47 parts per	trillion		100.00%
HCFC-22	CHClF2	0.0000001525%	153 parts per	trillion		100.00%
HFC-23	CHF3	0.0000000011%	23 parts per	trillion		100.00%
Sulphur Hexaflouride	SF6	0.000000004%	5 parts per	trillion		100.00%
Perfluoroethane	C2F6	0.000000004%	4 parts per	trillion		100.00%
Triflouromethyl Sulphur Pentaflouride	SF5CF3	0.00000000012%	.12 parts per	trillion		100.00%
Sources						
1. McGraw-Hill Encyclopedia of Science and Technology, 1987, McGraw-Hill, Inc.						
2. Carbon Dioxide Information Analysis Center						

Layers of the Atmosphere

So we see that the atmosphere contains gases, suspended liquids, and solids that entirely surround the earth. The earth's gravity pulls these gases, liquids, and solids toward the surface. Not surprisingly, there are more gases closer to the surface and fewer as you move away. Therefore, the earth's atmosphere is denser at the surface and gradually thins as altitude increases.

The atmosphere begins at sea level, (and in some places on land that are just below sea level) and extends outward some 6,000 miles (10,000 km) into space. From the surface to an altitude of 50 miles (80 km) the chemical composition is of the atmosphere is highly uniform. Due to this uniformity, this section of atmosphere is known as the homosphere. The homosphere, or lower atmosphere, is divided into various layers. The troposphere is the layer closest to the surface and it extends outward an average of 11 miles (18 km), though it is thicker at the equator and thinner at the poles. Beyond the troposphere is the stratosphere, which extends from 11 to around 30 miles from the surface. The mesosphere starts at around 30 miles and extends outward to 50 miles from the surface.

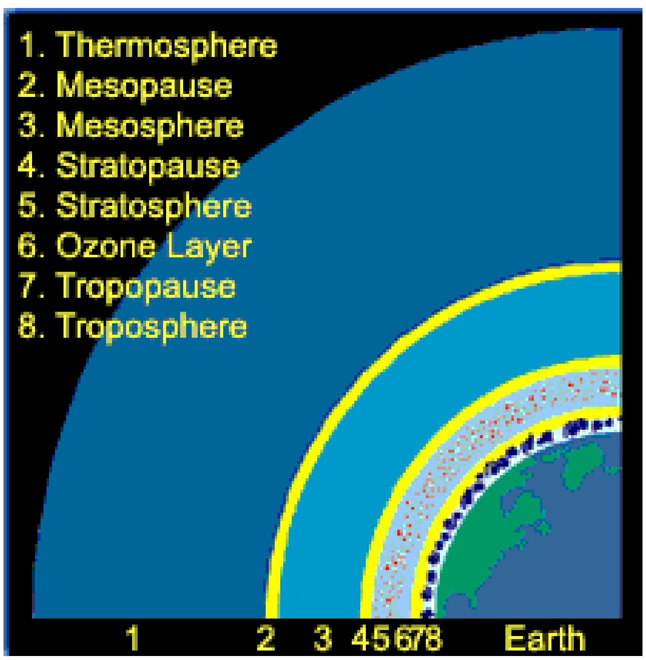

Fig. 2: Layers of the atmosphere *(NASA)*

Above 50 miles, the chemical composition of the atmosphere changes with altitude. This layer is known as the upper atmosphere or heterosphere. This upper layer is also known as the thermosphere and it extends outward several thousand miles with no real boundary between the upper atmosphere and space.

Though the atmosphere extends outward several thousand miles, one half of the gas molecules that comprise the atmosphere are located within the first 3.5 miles (5.6 km), or 18,840 feet. Fully 90% of the molecules are within the first 10 miles (16 kilometers), or 52,580 feet, and some 97% of gas molecules are packed within the first 18 miles (30 km). Gravity keeps the atmosphere very close to the earth's surface. Also, since most human activities take place from sea level to around 10,000 feet or 2 miles, conditions in the layer of the lower atmosphere closest to the surface, the troposphere, are what affects us day to day. The troposphere, #8 in the diagram, extends outward to about 11 miles, and contains about 90% of the molecules in the atmosphere.

Natural Changes in the Atmosphere

The troposphere is an extremely dynamic and ever changing system. Every day, the light, clouds, and heat energy in the troposphere go through a million variations. These changes affect daily life in thousands of subtle and direct ways and, for generations, humans have been fascinated by the troposphere's daily changes, which are known as weather. We all have a sense of what weather is. On some days it is rainy, and some days sunny. Some days are hot and some are cold. Sometimes the wind blows with intense ferocity.

Daily changes in the troposphere are known as weather. Long term, average conditions are referred to as climate. Weather is more extreme than climate, meaning that daily ranges of temperature, precipitation, pressure, and wind are greater than the long-term extremes of climate. Since climate refers to long-term average conditions, it is more moderate.

One way to look at the relationship between weather and climate is to take a look at your checking account. The monthly balance for twelve months of a year would represent climate and the daily inflows and outflows of funds, weather. Your daily balances might vary a great deal from day to day while your monthly balances, which are an average of your daily balances, would be more consistent. In the same way, weather changes much more rapidly than climate and you know this from your own experience. One day it might be warm and close to 60 degrees and the next day, cold and in the mid-forties. Climate also changes, but on a much longer time scale. Later in this section on atmosphere we'll look more closely at climate change.

Student Name:

Professor Name:

The Weather – Activity Sheet

The objective of this exercise is to have you observe atmospheric conditions as well as develop your understanding of major atmospheric concepts. For this exercise, you are asked to observe and record weather conditions for four days. In addition, you are asked to answer questions about your observations, as well as respond to a series of questions on general atmospheric characteristics. In the second part of the exercise, you are asked to perform a number of calculations relating to atmospheric conditions and characteristics.

Part One - Weather Observation

Please read the exercise completely before you begin. Also, printing this exercise before you begin will help you in carrying out the exercise.

1. Keep a log of atmospheric conditions for 4 days and record the following information. Find out information from any one of the following sources such as local newspapers, television news, or the Weather Channel.

	Day One	Day Two	Day Three	Day Four
Date				
Location				
High Temperature (˚F)				
Low Temperature (˚F)				
High/Low Difference				
Air Pressure (AP)				
AP Rising or Falling?				
Wind Direction				
Wind Speed (mph)				
Time of Sunrise				
Time of Sunset				
Length of Daylight				

Answer the following questions with regards to the atmospheric observations you made and then complete the temperature conversions below.

Question 1 - What is the overall four-day temperature trend?

Question 2 - What is the overall four-day pressure trend?

Question 3 - Was the wind direction consistent over the four-day period? If not, what pattern did you observe?

Question 4 - Was the wind speed consistent over the four-day period? If not, what pattern did you observe?

Question 5 - What pattern did you observe with regards to the amount of daylight over the four-day period? Are the days getting shorter or longer?

Part Two - Temperature Conversion

Temperature can be measured in different scales. In the U.S. we use the measure temperature in degrees Fahrenheit (F). Most other countries and many scientists use the Celsius (C) scale. In the Celsius scale, water boils at 100˚C and freezes at 0˚C. The formulas for converting from one temperature scale to the other are as follows:

˚F = (9/5 x ˚C) + 32 and ˚C = (5/9) x (˚F – 32)

Complete the following calculations and place your answer in the center column below:

15 degrees Fahrenheit		degrees Celsius
75 degrees Fahrenheit		degrees Celsius
32 degrees Fahrenheit		degrees Celsius
31 degrees Celsius		degrees Fahrenheit
13 degrees Celsius		degrees Fahrenheit
0 degrees Celsius		degrees Fahrenheit