Chapter 2 Structure of the Atmosphere

2.1. What is the thermal structure of the atmosphere?
What is the and chemical composition of the atmosphere
Why is the atmosphere layered?
What causes air pressure?
What are 3 units of air pressure at sea level?

Air is well mixed throughout the atmosphere, the atmosphere itself is not physically uniform but has significant variations in temperature and pressure with altitude, which define a number of atmospheric layers

Layers of the atmosphere

Exosphere (outside the atmosphere)
Thermosphere (80 to 640km).
Mesosphere (50 to 80km) and
Stratosphere Including the ozone layer(16 to 50 km),
Troposphere (0 to 16 km,

Surface of the Earth

The boundaries between these four layers are defined by abrupt changes in temperature, and include respectively the tropopause, stratopause and mesopause. In the troposphere and mesosphere, temperature generally falls with increasing altitude due to a decrease in air density. Temperature increases with altitude in the stratosphere due to ozone collection of energy and in the thermosphere due to faster moving molecules.

In addition to temperature, other criteria can be used to define different layers in the atmosphere. The ionosphere, for example, which occupies the same region of the atmosphere as the thermosphere, is defined by the presence of ions, a physico-chemical criterion. The region beyond the ionosphere is known as the exosphere. The ionosphere and the exosphere together make up the upper atmosphere (or thermosphere). The magnetosphere is the region above the Earth's surface in which charged particles are affected by the Earth's magnetic field. Another well-known layer of the atmosphere is the ozone layer, occupying much of the stratosphere. This layer is defined by its chemical composition - where ozone is especially abundant.

There are a number of atmospheric gases which make up air. The main gases are nitrogen, about 78%, and oxygen, about 21%. Water vapor can range from 0-4%. The remaining 1% of the atmospheric gases is made up of trace gases, e.g. the noble gas Argon (0.6%). Hydrogen is also present in trace quantities in the atmosphere, but because it is so light, over time much of it has escaped Earth's gravitational pull to space. The remaining trace gases include the gases, carbon dioxide, methane, nitrous oxide, and ozone, so-called greenhouse gases because they are involved in the Earth natural greenhouse effect which keeps the planet warmer than it would be without an atmosphere.

2.2. How has the composition of the atmosphere changed over geologic time?
What has been the affect?

Earth's earliest atmosphere (H and He similar to other planets) was swept away by solar wind since these gases were so light. Volcanoes spewed water vapor, CO_2, methane and nitrogen gases. As earth crust cooled, water condensed forming rain and filling the oceans. The CO_2 dissolved into the water (chemical buffering) leaving mostly N_2 in the air. One small source of O_2 was the breakup of H_2O by UV light. The major source was life forms (cyanobacteria) broke up CO_2 into C and O_2, keeping the carbon and releasing the oxygen (a waste product). Carbon now cycles through the biogeochemical spheres. The living organisms on the planet, mostly microorganisms, created and currently maintain the mix of gases in the atmosphere and keep the constantly changing atmosphere in balance. The Gaia Hypothesis states that the living organisms keep the entire planet system in balance, including all the biogeochemical cycles.

**2.3. How is the atmosphere currently changing?
What human activities are contributing to this?
What are aerosols?**

Human civilization is currently increasing the following substances in the atmosphere which are mostly "aerosols": carbon dioxide (from combustion), methane gas (cows), acid particles (sulfur and nitrogen oxides from combustion), dust particles (fires), chemical pollutants (CFCs from refrigeration and air conditioning units and other synthetics from chemical processes)

**2.4. What is the greenhouse effect and what makes it happen?
How does incoming radiation from the sun differ from outgoing radiation from the earth?**

Greenhouse gases like water vapor, carbon dioxide, methane and nitrous oxide trap the infrared radiation released by the Earth's surface. The atmosphere acts like the glass in a greenhouse, allowing much of the shortwave solar radiation to travel through unimpeded, but trapping a lot of the long wave heat energy trying to escape back to space. This process makes the temperature rise in the atmosphere just as it does in the greenhouse. This is the Earth's natural greenhouse effect and keeps the Earth 33°C warmer than it would be without an atmosphere, at an average 15°C. In contrast, the moon, which has no atmosphere, has an average surface temperature of -18°C.

**2.5. What is global warming?
How is global warming related to the greenhouse effect?
What is the expected outcome of global warming?
What is the cause of global warming?
What can we do about it?**

The average temperature of the earth has risen over the last 100 years by 0.6C. Local average temperatures have increased in some locations by much more. All the glaciers of the earth are melting, even in Antarctica. During the last 200 years mankind has been releasing extra quantities of greenhouse gases which are trapping more heat in the atmosphere. Over the same time period the climate of the Earth has warmed, and many scientists now accept that there is a direct link between the man-made enhancement of the greenhouse effect and global warming.

The increase in global temperature has also been linked to the natural cycle through geologic time which has included many ice ages. The evidence shows that global and regional climates have changed dramatically at times. During the past two million years, for example, ice ages alternated with periods of relative warmth on a roughly 100,000-year cycle. Researchers believe these events were triggered by slow changes in the tilt of the Earth's axis, along with changes in the Earth's distance from the Sun. During the past 1,000 years, however, the climate appears to have been fairly stable. Two exceptions to this stability, known as the Medieval Warm Period and the Little Ice Age, occurred between the 9th and 14th centuries and the late 16th to early 19th centuries respectively. Those two periods, along with short-term fluctuations in climate on the scale of decades or years, provide boundaries for what could be considered the natural range of climate variability during the past millennium.

The current increase in temperature is increasing faster than it should due to this cycle, hence the linkage to human activity. Some scientists (mostly funded by oil money) resist this current thinking and continue to say the global warming effect is a part of the natural cycle and is not caused by human activity. Correlations exists, they admit, but not causation.

The policy of the Bush administration was that increased carbon dioxide in the atmosphere and global warming may not be bad things and that our economy will benefit from the greater growth of plants and greater agricultural exports. We will adjust and adapt better than other countries and be more competitive in the future, so what is there to worry about?

The increase in temperature is expected to increase over the next 100 years with some computer models indicating an average increase of 1 to 10°C with 4°C being most quoted. The warmer temperatures are expected to raise sea level by expanding ocean water, melting mountain glaciers, and melting parts of the Greenland Ice Sheet. Most of the United States is expected to warm, although sulfates may limit warming in some areas. Scientists currently are unable to determine which parts of the United States will become wetter or drier, but there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils.

Greenhouse gases include any gas in the atmosphere that is capable, as a result of its particular molecular structure, of absorbing infrared radiation or heat. They are called greenhouse gases because they behave like glass in a greenhouse gas, allowing sunlight to pass through but trapping the heat formed and preventing it from escaping, thereby causing a rise in temperature. Natural greenhouse gases include water vapor or moisture, carbon dioxide, methane, nitrous oxide and even ozone, which is more commonly associated with the ozone layer and ultraviolet radiation. The amounts of all these gases in the atmosphere are now being increased as a result of man-made processes, such as fossil fuel burning and deforestation. The atmospheric concentration of carbon dioxide, for example, has increased by 30% since the 18th century, whilst levels of methane have more than doubled. Water vapor, whilst not directly released by man-made processes in substantial quantities, may be increasing as a result of climate feedback effects.

In addition to the man-made increase of naturally occurring greenhouse gases, mankind has released some completely new chemicals into the atmosphere, including the CFCs or chlorofluorocarbons. Although these have now been banned in an attempt to save the ozone layer, they will remain in the atmosphere for at least another 50 years. Although their abundance in the atmosphere is very low, molecule for molecule they can be thousands of times better at absorbing heat than carbon dioxide, and consequently contribute significantly to the enhanced greenhouse effect. Furthermore, their replacements, the HCFCs (hydrochlorofluorocarbons) and HFCs (hydrofluorocarbons), whilst being relatively harmless to the ozone layer, are equally potent greenhouse gases, and at present their phase-out dates are
not due for another 20 to 30 years.

2.6. Where is the ozone layer? How and why is it changing? What will happen if the ozone hole grows? What can we do about it?

The ozone layer is not really a layer at all, but has become known as such because most ozone particles are scattered between 19 and 30 kilometers (12 to 30 miles) up in the Earth's atmosphere, in a region called the stratosphere. The concentration of ozone in the ozone layer is usually under 10 parts ozone per million. Without the ozone layer, a lot of ultraviolet (UV) radiation from the Sun would not be stopped reaching the Earth's surface, causing untold damage to most living species. In the 1970s, scientists discovered that chlorofluorocarbons (CFCs) could destroy ozone in the stratosphere.

Ozone is created in the stratosphere when UV radiation from the Sun strikes molecules of oxygen (O_2) and causes the two oxygen atoms to split apart. If a freed atom bumps into another O**2**, it joins up, forming ozone (O_3). This process is known as photolysis. Ozone is also naturally broken down in the stratosphere by sunlight and by a chemical reaction with various compounds containing nitrogen, hydrogen and chlorine. These chemicals all occur naturally in the atmosphere in very small amounts.

In an unpolluted atmosphere there is a balance between the amount of
ozone being produced and the amount of ozone being destroyed. As a result, the total concentration of ozone in the stratosphere remains relatively constant. At different temperatures and pressures (i.e. varying altitudes within the stratosphere), there are different formation and destruction rates. Thus, the amount of ozone within the stratosphere varies according to altitude. Ozone concentrations are highest between 19 and 23 km.

Most of the ozone in the stratosphere is formed over the equator where the level of sunshine striking the Earth is greatest. It is transported by winds towards higher latitudes. Consequently, the amount of stratospheric
ozone above a location on the Earth varies naturally with latitude, season, and from day-to-day. Under normal circumstances highest ozone values are found over the Canadian Arctic and Siberia, whilst the lowest values are found around the equator. The ozone layer over Canada is normally thicker in winter and early spring, varying naturally by about 25% between January and July. Weather conditions can also cause considerable daily variations.

Loss of ozone high up in the atmosphere occurs when there is more ozone being destroyed by CFCs than there is being created naturally. Scientists believed that ozone levels were quite stable until the late 1970s. Since then, a general decline in ozone levels has been seen. However, every year during September and October (the Southern Hemisphere spring), ozone loss is much greater over Antarctica, where an ozone hole forms.

The hole forms because the air above Antarctica is cut off from the rest of the world by a natural circulation of wind called the Polar Vortex. This prevents mixing in the atmosphere and so any ozone depletion is concentrated here. In addition, the very cold temperatures in the air high above Antarctica speed up the destruction of ozone. In summer (December and January), the ozone hole repairs itself, but forms again the following spring.

Where is the ozone hole?
What can we do to stop the the destruction of the ozone layer?

Recently, an ozone hole has been seen forming above the Arctic during the Northern Hemisphere springtime. Fortunately, this ozone hole is not as big as the one that forms over Antarctica, but more people live in the Northern Hemisphere who could be affected by it.

Following the Montreal Protocol most ozone depleting chemicals (ODCs) have or are being phased out of use in most target applications such as aerosols, refrigeration and air conditioning. However, consumer products bought prior to international agreements may still be in use in our homes and offices and cannot easily be replaced. Large appliances, such as refrigerators, have long lifetimes and early replacement would entail great cost. Proper care and maintenance of equipment to ensure that the CFCs they contain are never released to the atmosphere should be applied. Remember that a single CFC molecule can destroy 100,000 ozone molecules.

In addition, if purchasing fire extinguishers try to avoid any that contain halons, which have bromine in them. Purchase carbon dioxide, water, or dry chemical extinguishers instead. Finally, although foam packaging is CFC-free, some products contain HCFCs (hydrochlorofluorcarbons), which while far less damaging to the ozone layer, could contribute substantially to global warming. Avoid those that do. Use and re-use non-disposable packaging.