Chapter 23

IS GLOBAL WARMING HAPPENING, AND ARE WE PART OF THE PROBLEM?

Case Study – Global Warming and the Polar Bears of Hudson Bay

● This case study illustrates one of the consequences of global warming, namely changes in the condition of polar bears in the western Hudson Bay region where biologists have documented a decline in bear population, lower body weights, and birth rates, and have linked these changes to the earlier breakup of sea ice. The early breakup of sea ice is a consequence of global warming. The question is whether this is due to a climate anomaly or whether this is the beginning of a trend.

23.1 IS THE TEMPERATURE RISING?

● Yes. In the past 100 yr global average temperature has risen about 0.6 C.
● Historic trends are obtained using the geological record. This includes use of ice core data (where we obtain paleo-CO_2 trapped in bubbles), pollen diagrams (from which we reconstruct the history of vegetation), and deposits of ocean Foraminifera (where we can reconstruct temperature based on measurements of oxygen isotopes), to name a few.

23.3 WHAT CAUSES CLIMATE CHANGE?

● Earth's temperature is determined by four main factors: 1) the amount of incoming solar radiation, 2) albedo, 3) atmospheric absorption of IR radiation and 4) evaporation and condensation of water vapor (which affects 2 and 3).
● Ice core data and other evidence show that Earth's temperature has varied over time (Fig. 23.3). Bubbles trapped in ice also show changes in atmospheric CO_2 concentrations.
● Earth's climate changes because of variation in its energy budget.
● The amount of energy reflected by the earth is the albedo. White surfaces (e.g. snow cover) increase albedo as do increases in cloud cover and dust, dark surfaces decrease albedo. The temperature is very sensitive to small changes in albedo.
● Variation in the sun's energy (incoming radiation) may be another cause
● Milankovich cycles are another explanation, i.e., a wobble in the Earth's orbit changes the distance between Earth and Sun on an approximately 100,000 year cycle.
● There are some data to indicate that massive releases of methane from methane hydrates (which would increase IR absorption in the atmosphere) at the bottom of the ocean might have had impacts on past climate.

23.3 THE ATMOPSHERE

● If you could shrink the earth down to the size of an apple, the atmosphere would be about the size of the peel. Ninety percent of the weight of the atmosphere lies within the first 12 km above the surface, and consists of nitrogen (78%), oxygen (21%) argon (0.9%), CO_2 (0.03%) and some traces of others such as ozone and methane. This layer of

atmosphere is known as the **troposphere**, and this is where most of the weather occurs (cloud formation and precipitation). Above the troposphere lies the **stratosphere**, which is where a very important layer of ozone occurs (between 25-30 km aloft).
● Important atmospheric properties include temperature, pressure (force per unit area), and water vapor content. An atmosphere of pressure is equivalent to 10^5 N/m^2. Vapor content varies from about 1-4%, depending on temperature. At saturation, the relative humidity is 100%.
● There are prevailing wind patterns on a global scale that emerge when you compute average wind speed and direction (see Fig. 23.8). Regions of divergence at the surface and high pressure at 30^o N and S, and a region of westerly flow, convergence, and rising air at the equator can be seen. These patterns explain a great deal about the macroscale climate (e.g. the distribution of deserts) and biogeography of the earth.
& Processes that remove materials from the atmosphere include **sedimentation**, **rainout**, **oxidation**, and **photodissociation**.

23.4 CLIMATE

● Climate is the characteristic or average state of the atmosphere for a given region and it refers to the long-term average, while weather refers to the current state of the atmosphere of short deviations from the mean climate. Microclimate is a term that refers to the micro-scale, such as the atmosphere around a leaf or the climate within the boundaries of an urban area. The latter differs from the surrounding natural climate in several ways: urban areas are warmer, less humid, dustier, foggier, and have 5-10% more precipitation.
● Climate change is a natural feature of earth. There was a major warm period between 1100 and 1300 AD when the Vikings colonized Iceland, Greenland and N. America, for example. This gave way to what is known as the little Ice Age, little because it was brief. The cause(s) of natural climate change are not well understood, but factors such as variation in CO_2 concentration and variations in the earth's orbit around the sun (**Milankovitch cycles**) are certainly involved. Climate has changed rapidly in the last 20 years. The 1990s was the warmest decade in the past 142 years.

23.5 VARIATIONS IN OCEAN CURRENTS MAY AFFECT CLIMATE

● Variation in the ocean circulation known popularly as the ocean conveyor belt, which delivers warm water to the North Atlantic is thought to have a great effect on latitudinal gradients in atmospheric temperature. As the earth warms and polar ice melts, the density of the Artic water decreases (fresh water is less dense than saline water). This freshening of the Arctic may prevent warm surface currents that flow north from the equator from sinking. This would stop the circulation and the delivery of warm water to the arctic, plunging the Earth into an ice age.

● El Niňo or a change in upwelling off the Peru coast brings high rates of precipitation and flooding to Peru and droughts and fires are commonly observed in Australia and Indonesia. El Niňo is strongly linked to the atmosphere, because the upwelling is produced by westerly winds across the Pacific.

23.6 WHAT IS THE GREENHOUSE EFFECT?

● incoming shortwave radiation that is absorbed (about 70% of total incoming) is all radiated back to space as long-wave radiation (except for the 1-2% captured by plants). Some of the outgoing long-wave radiation warms our atmosphere as it is absorbed by various gases, much like glass in a greenhouse retains heat, hence the term greenhouse effect. A **greenhouse gas** (or GHG) is anyone of the gases that absorb long-wave radiation or IR. Most natural greenhouse warming is due to water vapor in the air (about 85%) and small particles (12%). GHGs include CO_2, CH_4, CFCs, N_2O, and some others**.**

23.7 GREENHOUSE GASES ARE INCREASING AND WE MAY BE PART OF THE REASON

● The **anthropogenic** sources of greenhouse gases (CO_2, methane, CFCs, nitrous oxide) are increasing as a consequence of industrialization and population growth. Per unit molecule, the greenhouse gases differ in their ability to absorb IR, but no anthropogenic source comes close in importance to CO_2 because of the massive quantities of CO_2 being released by fossil fuel combustion. Anthropogenic sources of methane include farm animals (ruminants), rice paddies, and destruction of forests (termites). The CO_2 is primarily from fossil fuel combustion and secondarily from deforestation (fire and decomposition). The major sources of NOx are fossil fuel combustion and agriculture (fertilizers). See Table 22.1 for the relative contributions of anthropogenic greenhouse gases to global warming. The term **forcing** is used a lot in the climate change literature, e.g. anthropogenic forcing or methane forcing, meaning caused by people or caused by methane.

A CLOSER LOOK 23.1: Monitoring of Atmospheric CO_2

● Air samples collected near the summit of Mauna Loa, HI since 1958 have documented a steady increase in atmospheric CO_2 concentration from about 315 ppm to about 375 ppm today (see Fig. 23.16). The saw-tooth pattern in the data (Fig. 23.16) is the result of metabolic processes in the northern hemisphere. The CO_2 concentration falls during the summer, when net ecosystem production and net photosynthesis are positive, and the concentration rises in the winter when respiration exceeds assimilation. Note, the northern and southern hemisphere seasons are opposite, as are their seasonal metabolic patterns, but the CO_2 northern and southern hemisphere air mix with one another only very slowly, giving rise to distinct northern and southern hemisphere CO_2 patterns. Mauna Loa was selected as a monitoring site because it is far from a major anthropogenic CO_2 source and the variability that comes with it, and it is reasonably high above sea level to represent a well-mixed sample of average air. The Mauna Loa CO2 record is arguably the most famous data set in the world and is a fine example of the importance of long-term monitoring of environmental trends.

23.8 WOULD IT BE SO SERIOUS IF EARTH WARMED UP A BIT?

● Mathematical models are used to simulate climate. Climate models of the atmosphere are referred to as GCMs (global circulation models). Generally these models run on super computers. The Japanese Earth Simulator is currently the fastest. The models are predicting a rise in temperature of 1.4 to 5.8 C from 1990 to 2100 and a rise in sea level of 20 cm to 2 m. Such changes would have significant impacts.

23.9 WHAT WILL BE THE EFFECTS OF RISING SEA LEVEL?

● By 2030 we expect CO_2 concentrations will have doubled from the pre-industrial levels, resulting in a 1-2 ^oC warming on average (see Fig. 22.21), with greater warming at the poles (polar amplification). Consequently, we expect semiarid areas will become dryer, other areas wetter (see Fig. 23.18); the global distribution of biomes will change (they are changing now); agricultural production will decrease in some areas, increase in others; the geographic distribution of tropical diseases will expand; sea level will rise; the biogeography of plants and animals will change and extinctions will rise. These effects will cause great disruptions to human populations regionally as they cope with crop failures, new diseases, and changing coastlines.
● Sea level is now 120 m higher than at the end of the last ice age. Further increases of 1 m or more would seriously threaten coastal cities around the world and island nations. Just the cost of protecting or moving cities threatened by sea level rise will be enormous (see Fig. 23.19). Various models predict a change in sea level of between 20 cm and 2 m in the next century.

23.10 HOW WILL GLOBAL WARMING AFFECT THE WORLD'S CLIMATE?

● The intensity and frequency of storms is expected to increase because the latitudinal temperature gradient will increase.
● Agriculture will be affected by changes in patterns of precipitation. The best agricultural areas in the future may not be in N. America due to drought.
● Water shortages may develop as water tables decline
● There will be ecological consequences to species as their ranges change and in some cases (e.g. polar bear, Kirtland's warblers) they will lose habitat to the point of extinction.
● There will be public health consequences as tropical diseases spread into the temperate zone.

23.11 CAN WE DO ANYTHING TO SLOW THE TEMPERATURE RISE?

● Peak CO2 emissions will likely occur within the next 50-100 years (Fig. 23.25). There will be a lag in climate response of 100s-1000s of years. Think about that.
● We could reduce our production and release of GHGs.
● We could find ways to sequester (store) GHGs.
● We could take actions to increase albedo, such as injecting sulfur oxides into the upper atmosphere. This amounts to a global scale experiment with unknown consequences, as is adding enormous quantities of CO2.

23.12 WHAT HAS BEEN DONE SO FAR TO MITIGATE GLOBAL WARMING?

● The first steps to control CO2 emissions were takein in 1988 at a conference in Toronto. Scientists recommended at 20% reduction by 2005. A second step was taken in 1992 at the Earth Summit in Rio de Janeior where a general blueprint for reducing global emission was suggested.
● In December 1997, legally binding emission limits were discussed in Kyoto, Japan, but specific aspects of the agreement divided the delegates. The U.S. eventually agreed to cut

emissions to about 7% below 1990 levels. However, that was far less than the reductions suggested by scientists, who recommended reductions of 60 to 80% below 1990 levels. In fact, after the conference, it was realized that emissions of carbon dioxide in 2010 would likely be about 30% higher than the 1990 emissions.
● The U.S. Congress has been slow to act, and the United States, in the Hague meetings of late 2000, refused to honor reductions in emissions of CO2 that were agreed to at Kyoto in 1997.

23.13 CAN WE DO ANYTHING TO ALLEVIATE THE EFFECTS OF GLOBAL WARMING?

● Move some species at risk to new habitats.
● We could establish new nature preserves.
● establish wildlife corridors
● Think globally, act locally

Critical Thinking Issue

● Should the precautionary principle be applied to global warming? Is there sufficient scientific evidence to justify taking action? Does the cost justify the gains?

Web Resources

http://www.epa.gov/climatechange/index.html This is the EPA's climate change site.

http://climate.gsfc.nasa.gov/ NASA's climate-related site.

http://cdiac.esd.ornl.gov/pns/pns_main.html This is the entry to ORNL's comprehensive collection of climate change-related data, including the most up-to-date statistics from Mauna Loa and elsewhere.

http://www.ucmp.berkeley.edu/fosrec/Wetmore.html In case you were wondering what is a foram?

http://www.es.jamstec.go.jp/esc/eng Home page of the Japanese Earth Simulator

http://www.eia.doe.gov/oiaf/1605/ggrpt/ An annual inventory of anthropgenic greenhouse gas emissions in the United States

http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html The NOAA ENSO site with animations and updates on the current state of the Pacific.

http://www.fe.doe.gov/programs/sequestration/ This is DOE's carbon sequestration site.

http://www.museum.state.il.us/exhibits/ice_ages/ This exhibit answers basic questions about the Ice Ages, which are "intervals of time when large areas of the surface of the globe are covered with ice sheets (large continental glaciers)." Includes a video clip depicting the retreat of glaciers in North America. From the Illinois State Museum.