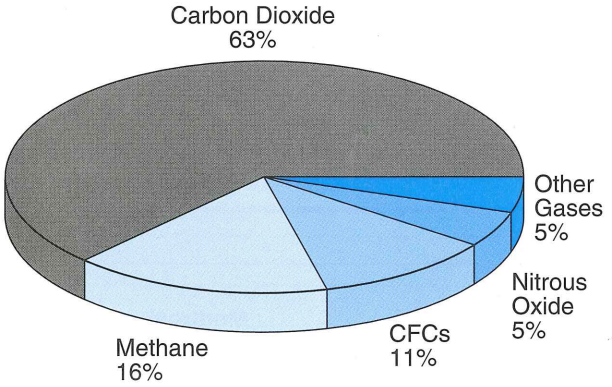
Global warming (the greenhouse effect)

The earth's atmosphere has played the role of a greenhouse for 5 billion years. The **greenhouse effect** is caused by various atmospheric gases, carbon dioxide (CO_2) being the most important. (See Figure 6.12.) Others include methane, nitrous oxide, ozone, and chlorofluorocarbons (CFCs). All these gases do not affect incoming short-wave radiation from the sun, but they trap some of the long-wave heat that radiates from the ground. Any increase in them, might be expected to raise the average temperature of the atmosphere.

This warming trend has been underway for some time. (See Figure 6.13.) The average temperature of the globe has increased by half a degree in the past century. But the rate appears likely to increase. The Food and Agriculture Organization (FAO) has predicted a 1°C increase in average global temperatures by 2010 and a 4.5°C increase by 2050.

Figure 6.12 The greenhouse gases



Scientists anticipate a rise in global temperatures of about one degree celsius by the year 2025. The major green-house gases contributing to this warming are expected to be carbon dioxide, methane, and CFCs.

From Environment Canada.

The increase in greenhouse gases

The main reason for this expected warming is our increasing production of greenhouse gases. CO_2 is the main problem, as it rises with the burning of fossil fuels and of the rain forests. Some reductions in fossil-fuel burning took place during the early 1980s as a result of the economic recession, but the burning of rain forests increased. Fossil fuel use will likely increase again, and the output of CO_2 will rise.

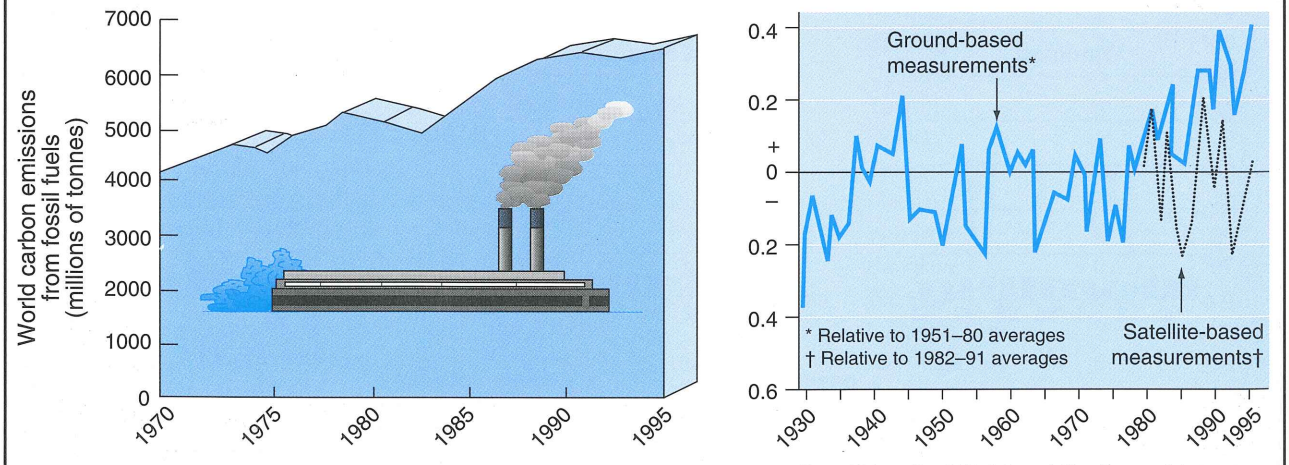
Methane is a powerful greenhouse gas becoming more significant in the atmosphere. It is produced in the stomachs of cattle, at the bottom of rice fields, by rotting garbage, and by burning fossil fuels. No decline in the upward trend can be detected. However, the use of CFCs has declined since the early 1970s when their use in aerosol cans was reduced. CFCs contribute to the greenhouse effect and are a threat to the ozone layer.

The effects of global warming

A rise in sea level A rise of 4.5 °C in the average global temperature by the year 2050 would melt large amounts of ice in the Arctic and Antarctic. This extra water, lower atmospheric pressure, and ocean warming would create a rise in **mean sea level** of between 20 to 150 cm. Scientists estimate that sea level could rise by over 4 m by the end of the twenty-first century.

Low-lying coastal areas would be seriously affected by an increase in sea level. If the average sea level rose

Figure 6.13 Increasing CO_2 and global temperature trends



From *University of Virginia* and *The Economist.*

by 1 m, additional storm surges would threaten all land below 5 m. The effects of the loss of land below 5 m could be disastrous. Many of the world's major cities are at sea level, including all seaports.

Assuming the predictions of a rising sea level are correct, several parts of the world would be affected. The Mississippi delta would be flooded and the city of New Orleans threatened. Other deltas, where upstream dams have trapped most of the river silt, would erode and become estuaries. Erosion has already occurred in the Nile delta. Cities like Venice would face enormous costs to stay above water. In the Netherlands, which is one of the countries that would be most seriously affected by a higher sea level, the cost of building more dikes and pumps has been estimated at $6 billion (US) over the next century. A Western country may be able to afford such an expense, but developing countries may not have the resources to protect low-lying coastlines. In Bangladesh and Indonesia much of the recent migration of people has been to just such low-lying coastal areas. Floods in the Bay of Bengal regularly cause widespread loss of life. It is a situation that is likely to get worse.

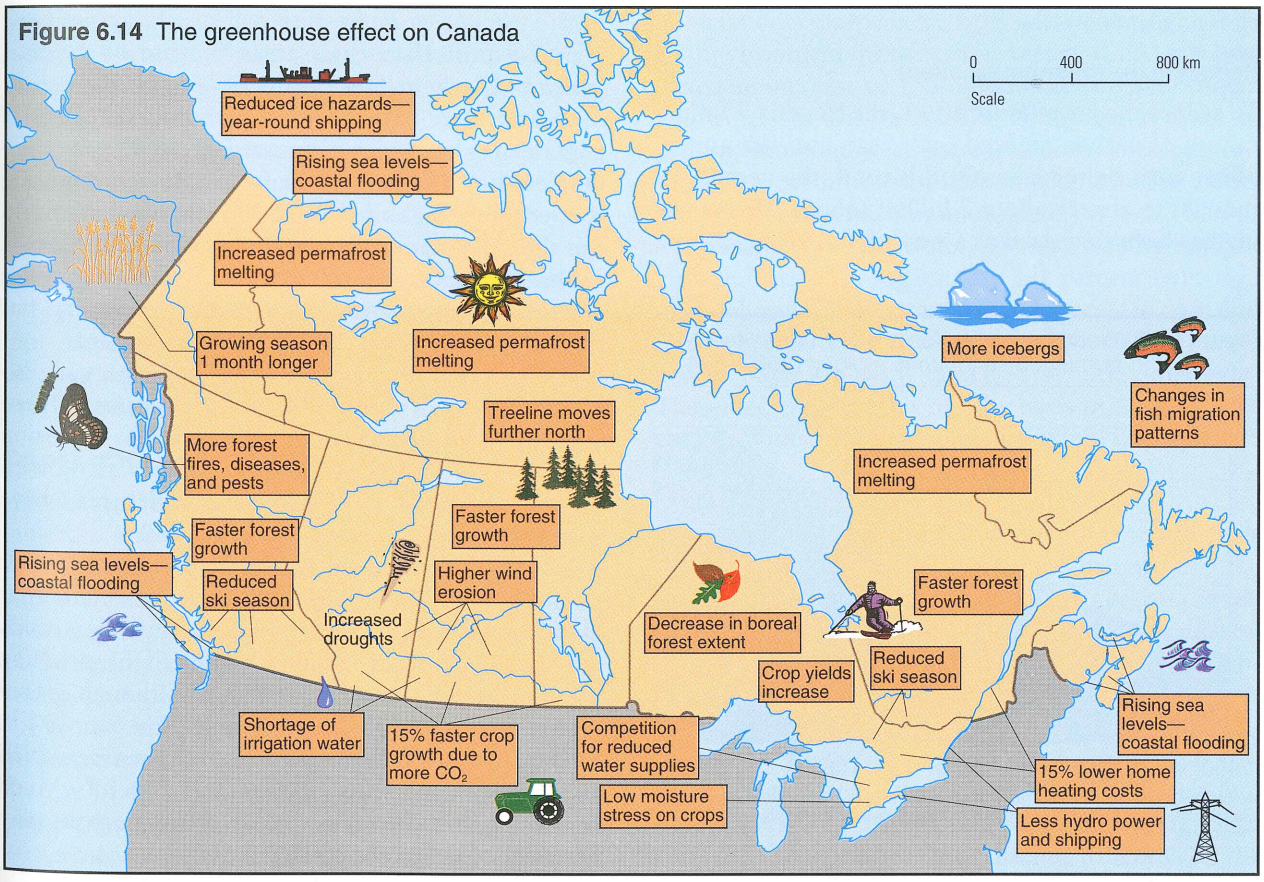
On a worldwide basis, no less than 5 000 000 km^2 of low-lying coastal land could be affected. While this is only 3 percent of the world's land area, it accounts for 33 percent of the world's cropland.

Effects on plants Carbon dioxide is essential for plant growth. Some plants, including most of the world's food crops, have a more marked response to CO_2 than others. Scientists at the FAO predict, however, that corn, millet, and sorghum may suffer from competition from weeds. Temperature increases could also cause problems for rice, wheat, and potatoes.

More CO_2 has the effect of increasing carbohydrate growth rather than protein levels in crops. Crops may therefore require more nitrogen fertilizer in an environment rich in CO_2. The manufacturing of nitrate fertilizers uses a great deal of energy, which in turn creates pollution.

Effects on farming belts Global warming would have other adverse effects. The warming trends are expected to be much greater in higher latitudes than toward the equator. Crop belts in temperate regions could be significantly warmed, but they may also dry out as evaporation increases. Warmer temperatures

Figure 6.14 The greenhouse effect on Canada



could increase the rate of crop growth but would also lead to the much faster growth of insects and pests. The FAO predicts increased problems from ticks, tsetse flies, and mosquitoes.

Existing agricultural belts would have to make costly adjustments. The United Nations Environment Program (UNEP) calculates that wheat production in the southern Canadian Prairies could decline by 25 percent as a result of drier conditions. On the other hand, warming temperatures could move the farm belts over 200 km northward, increasing production in Canada's northern Prairies and in Russia. Figure 6.14 on page 81 shows some ways in which Canada could be changed by the greenhouse effect.

A shift in climatic belts could also affect forestry, particularly in Canada. Trees in Canada take about 80 to 100 years to mature. In that space of time the climatic belts could move north by 200 or 300 km. Trees are selected for the climatic conditions in which they are planted. Because of possible changes in climate, trees may have to mature in conditions not so well suited to them.

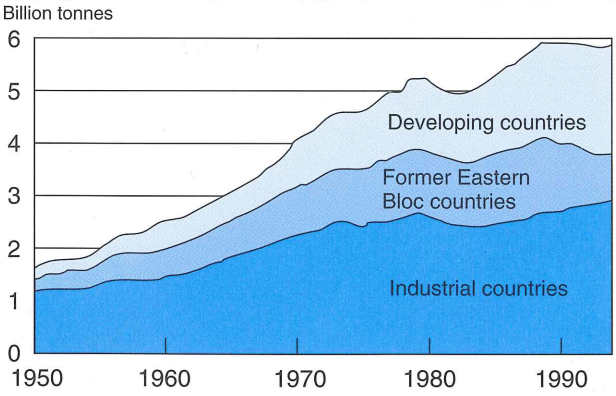
In the world as a whole, UNEP calculates that deserts and grasslands would expand at the expense of forests. Forest fires would increase. River flow patterns would be altered, making some existing hydroelectric plants useless.

Reducing the greenhouse effect

To reduce the greenhouse effect, the roughly 7 billion tonnes of carbon emitted each year into the atmosphere must be reduced. Of this total, the oceans are thought to absorb about 2 billion tonnes. Tree planting has been suggested as a way of absorbing carbon, but very large areas would have to be reforested and current deforestation would have to be reduced or eliminated in many parts of the world. These solutions would require major changes in policy by many countries.

In June 1988 an international conference of climate experts was held in Toronto to discuss the greenhouse effect. They recommended that world carbon dioxide emissions be cut by 20 percent by 2005. To date, however, few countries have adopted this goal. The problem is, as Figure 6.15 shows, that developing countries may use increasing amounts of fossil fuels as they industrialize.

Figure 6.15 World carbon emissions from fossil fuel burning, by economic region, 1950–1994



Adapted from Worldwatch Paper #130, *Climate of Hope: New Strategies for Stabilizing the World's Atmosphere*, by permission of Worldwatch Institute.

The scientific uncertainty

It will take time before we can say with certainty that the earth is warming up because of the increase in greenhouse gases. However, the decade of the 1980s included six of the hottest years of the twentieth century. Measurements of the amount of CO_2 and methane in the atmosphere continue to show steady increases, and these trends indicate that future warming is likely.

Those who discount the greenhouse theory claim that a run of warm, dry years is normal and that we may have similar runs of below average temperatures in the future. An interesting point is that cities have warmed more than rural areas because of the heat generated in them. Since many of our climate recording stations are in or near cities, the warming of our climate may have been overstated. It also appears that temperature readings taken from satellites covering the whole earth, and not just the inhabited areas, do not show a warming trend (see Figure 6.13). There is much disagreement in the scientific community about whether or by how much the earth is warming, but there is no doubt that the debate is heating up!

Variations in the amount of volcanic dust can also create changes in temperature at least as great as those caused by changes in greenhouse gases. The explosion at Mount St. Helens in the United States along with erupting volcanoes in Chile and Mexico may have reduced solar radiation in the early 1980s.

Increased cloudiness can also be expected to result from the greenhouse effect. Some experts claim that clouds could reduce the expected warming by as much as half. The clouds would screen more of the incoming solar radiation. Others claim that, although global warming would melt more polar ice, the increase in freshwater would, in turn, lead to more sea ice, which could also counteract the warming trend. Much research needs to be done on the role the oceans play in climatic change on a global scale.

A United Nations conference on climatic change was held in Geneva in 1996. The Intergovernmental Panel on Climatic Change (IPCC) reported that the evidence supporting the human impact on climatic change was becoming stronger. Emissions of CO_2 had risen by 4 percent in developed nations since 1990. As a result, several governments, including the US, demanded stronger action to curb greenhouse gases. Also at the conference, the World Health Organization (WHO) stated that global warming could cause millions of additional deaths as tropical diseases spread to new areas. Malaria, for example, could affect 50 to 80 million extra people, with dengue fever, river blindness, and Lyme disease also spreading.

Many scientists feel that the greenhouse effect is only one factor in a complex series of climatic equations. Some insist that soil erosion or chemicals in the environment present a more immediate threat to our planet than the warming of the atmosphere. But should we risk waiting until the greenhouse effect is proven one way or the other? By then action to prevent its effects will be too late.

The threat to the ozone layer

Ozone is a tiny component of the earth's atmosphere, but it plays a crucial role in filtering out ultraviolet radiation, which in large doses would destroy life on this planet. The so-called **ozone layer** is a band of the stratosphere about 25 km above the earth. Ozone is present in higher than normal quantities in this layer, although it still accounts for only 1 molecule in 100 000. Scientists observed that a "hole" in the protective shield of ozone developed over Antarctica in the mid-1970s. Ice crystals in the upper atmosphere over Antarctica are thought to speed up the destruction of ozone. Since then Canadian scientists have detected a thinning of ozone over the Arctic and even over Toronto.

Causes of the depletion of the ozone layer

Ozone is a rare form of oxygen, with three atoms per molecule instead of the usual two. If all the atmospheric ozone lay directly on the earth's surface, it would create a layer only 3 mm thick. Sunlight produces ozone by the process $O_2 + O \rightarrow O_3$. Ozone is easily destroyed by a number of gases, including several that are produced by industry.

Chlorine and nitric acid in the atmosphere are the greatest threats to ozone. A single chlorine atom can destroy 10 000 molecules of ozone. Much of the chlorine comes from CFCs (chlorofluorocarbons). About 40 percent of CFCs come from aerosol cans, although their use for this purpose is now banned in North America. CFCs are also used in refrigerators and as foam-blowing agents. Other gases that deplete ozone include bromine, halon 1301 (a fire extinguishing agent), and carbon dioxide.

Although these explanations of ozone depletion are widely accepted, not everyone agrees with them. Another theory is that the peak of the sunspot cycle in 1979 and 1980 caused a temporary decline in ozone levels. This theory claims that an increase in solar energy increases the nitrogen dioxide in the upper atmosphere. This in turn can lead to an increase in the compounds that cause a decline in ozone.

As with many other environmental problems, there is a time lag between the activities that release damaging gases into the atmosphere and the actual depletion of the ozone. This time lag may be twenty or thirty years. Even if all the damaging chemicals were banned right away, the ozone layer would continue to deteriorate for many years. This fact underlines the need for prompt action.

The effects of a decrease in the ozone layer

There are three main effects of a reduction in the layer of protective ozone. It is estimated that a 1 percent depletion of ozone would lead to a 4 percent increase in melanoma skin cancer from ultraviolet light. The US Environmental Protection Agency (EPA) has predicted an increase of 153 million cases of skin cancer worldwide by the year 2075 if nothing is done to protect the ozone layer. Increased ultraviolet light can also cause eye problems, both in people and in cattle, and can damage the immune system.

An increase in ultraviolet light may also harm plant growth. Estimates suggest that a 1 percent reduction of ozone would lead to a similar reduction in crop and timber yields. Fish stocks could also decline, since marine algae are easily damaged by ultraviolet light. These micro-organisms are the basis of aquatic food chains. Without them, marine life could not exist.

Protecting the ozone layer

Many scientists share the concern for the ozone layer and they have been pressuring politicians to take action. A twenty-four nation treaty to control the use of most CFCs and other ozone-depleting gases, known as the **Montréal Protocol**, was signed in September 1987. These nations pledged to reduce their 1986 total output of ozone-depleting gases by 50 percent by 1999. In June 1990 the Canadian government announced its intention to stop all CFC production by 1997. At a 1992 international conference in Copenhagen, agreement was reached to accelerate the

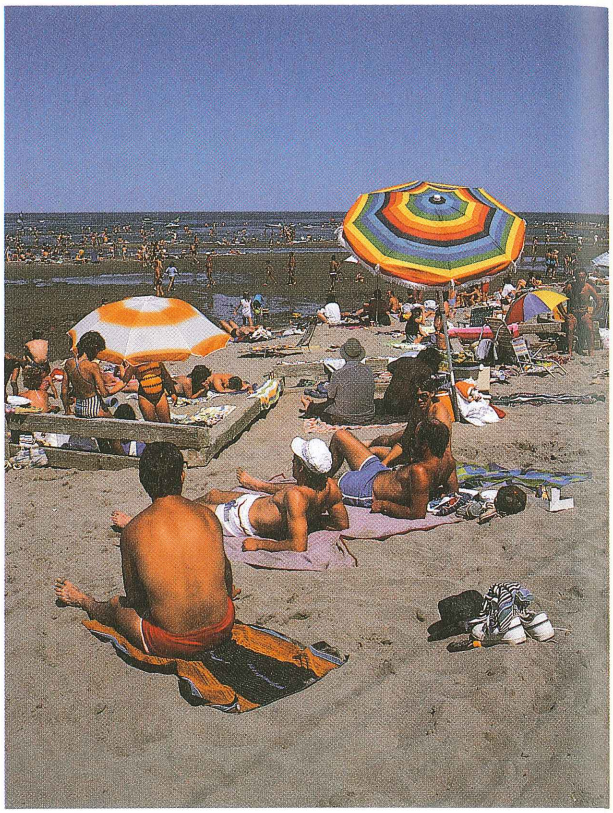
phasing out of ozone depleting substances by 1996.

Chemical companies are researching new products to replace the CFCs, which were once thought to be safe inert gases. DuPont (Canada) has built a factory in Ontario to produce a new product called HCFC-123. This eliminates 98 percent of the threat to the ozone, but at a cost several times higher than that of CFCs. The replacement of CFCs worldwide has been estimated to cost at least $6 billion (US).

The international agreements described above may be having some success. While reports of increases in the "ozone hole" continue in many parts of the world, measurements of CFCs in the atmosphere seemed to have levelled off in 1996 and may be beginning to decline. If so, there could be an improvement in the overall ozone layer by 2010. A threat to future progress in reducing CFCs, however, is the expected increase in the number of refrigerators in the developing world, especially in China. The resulting increase in the use of CFCs there could more than offset the decline in industrialized countries.

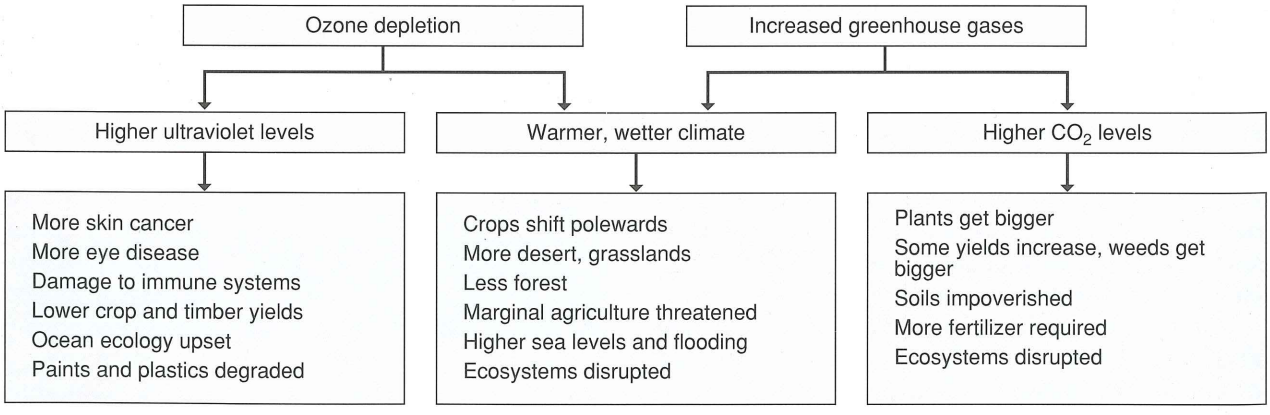
Natural events such as volcanic eruptions can affect the atmosphere, including the ozone layer, in several ways. For example, the El Chichon eruption in Mexico in 1983 sent a large volume of sulphur into the atmosphere in the form of a stratospheric cloud. This led to an increase in acid rain and a decrease in solar radiation reaching the earth. Scientists say the eruption caused the cold winters of 1984 and 1985. The stratospheric clouds created by the El Chichon eruption also led to a sharp decrease in ozone levels, since the destruction of ozone is made easier by the existence of stratospheric clouds.

We have seen that the combined effects of greenhouse gases and ozone depletion present major problems to society. The landscape may be changed, particularly by the rise in sea level. Plant life may be altered, and both humans and animals can be affected. These problems are summarized in Figure 6.16. Overcoming these hazards will be enormously expensive.



Although it is well known that sunbathing may increase the chances of skin cancer, many people choose to ignore the risk.

Figure 6.16 Social effects of damaging the atmosphere



From "Changing the Atmosphere," the United Nations Environment Program.