GLOBAL WARMING

▼DAVID E. NEWTON▼

CONTEMPORARY WORLD ISSUES

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A Reference Handbook

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For Jim Greenhaw:
Some people are special because they compose great symphonies, write great sonnets, or create great paintings. Others are special just because of who they are.
Thanks for being who you are.

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Preface

THE WORLD SEEMS TO BE CONFRONTED with a new "Impending Environmental Disaster" every few years. Over the past two or three decades, impending environmental disasters have included nuclear holocaust accompanied by nuclear winter, devastation caused by acid rain, depletion of the ozone layer, massive famines in various parts of Africa, decimation of the world's tropical rain forests, and contamination of vast parts of the oceans by oil spills.

In 1988, yet another impending environmental disaster appeared on the horizon: global warming. Aroused to some extent by the unusually hot summer of that year, scientists, government officials, journalists, and ordinary citizens suddenly became aware of a potential global catastrophe, a change in the Earth's climate that could rival anything seen in thousands of years.

The culprit behind this scenario was a flood of carbon dioxide and other gases released by human activities. Many scientists feared that the addition of these gases to those already present in the atmosphere might drastically increase an already well-known warming phenomenon, the greenhouse effect. They predicted an increase in sea levels that might inundate coastal cities, changes in regional climates that could significantly alter agricultural patterns around the world, and a variety of other changes in the natural world and in human societies.

As is often the case with impending environmental disasters, stories in the media often featured the most extreme predictions about global warming. Prompt and drastic action was sometimes demanded to prevent the worst consequences of climate change.

The science of global warming, however, is more complex than the average citizen was led to believe. The evidence for significant, long-term changes in the Earth's annual average temperature was not particularly strong. Computer models relating concentrations of carbon dioxide and other gases to temperature trends were not well developed.

Projections about environmental effects that might be expected as a result of temperature changes in the atmosphere were subject to serious questions.

All in all, responsible scientists differed in their opinion on whether global warming had begun and, if so, what effects it ultimately might have. Those differences of opinion have created difficult choices for government officials. The kinds of changes needed to curtail global warming are likely to be very expensive. In view of the questions surrounding global warming and in view of the weak nature of the world's economy, policy makers have wondered what actions are justified in dealing with this latest impending environmental disaster. That question is not likely to be answered soon.

The purpose of this book is to provide sufficient background information about global warming to allow concerned citizens to contribute to the decisions that will ultimately be made. The first three chapters of the book provide a historical account of the global warming debate with some biographical sketches of important figures involved in that history.

Chapter 4 offers a collection of facts and opinions about this debate. Chapters 5–7 provide resources for those who wish to pursue the study of global warming in more detail, a list of organizations interested in the issue, and print and nonprint references on the topic. A glossary of terms used in the study of global warming and its effects rounds out the book.

David Newton is a free-lance writer with more than 450 commercial publications to his credit, including about 50 books. His most recent titles include *Gun Control, James Watson and Francis Crick: Discovery of the Double Helix and Beyond, Population: Too Many People?, AIDS Issues: A Handbook,* and *Cities at War: Tokyo.* Dr. Newton formerly taught junior and senior high school science and mathematics in Grand Rapids, Michigan, and chemistry, teacher education courses, and human sexuality at Salem (Massachusetts) State College. He is currently Adjunct Professor in the College of Professional Studies at the University of San Francisco. In his spare time, he is a volunteer for the San Francisco SPCA and for Open Hand, an organization that provides meals for HIV positive men and women.

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Changes in the Earth's Climate

PLANET EARTH IS CONSTANTLY CHANGING. Sometimes change is abrupt and dramatic, as during an earthquake or volcanic eruption. But in most cases, change comes about very slowly over hundreds or thousands of years, and humans are hardly aware of it.

Such is the case with climatic change. Suppose you could be transported back 200 years in time. The weather conditions you would find in the 1790s would be much the same as those you experience today. In terms of climate change, 200 years is but the blink of an eye.

Yet, many scientists are convinced that our climate is changing. They point to statistics that show the Earth very slowly has been getting warmer, especially over the past 150 years. For many people, those statistics are bad news. As the Earth becomes warmer, it is likely to undergo some important changes, they say. Ocean levels will rise. Coastal cities will be flooded. Productive farmlands will become deserts. These threats are serious enough, these people warn, that actions will have to be taken soon to prevent widespread disaster.

Other people disagree. Some do not think data on weather patterns are clear. We just do not have enough information, they say, to predict long-term trends. Others agree that a warming trend has occurred, but they disagree about the cause of the trend, its possible effects, or what to do about it.

The problem of global warming presents a profound challenge to the world. Nations must make decisions on an issue about which serious disagreements exist among scientists. If we wait too long to take action, it may be too late to stop the warming trend. Horrible disasters could result. But if we move too quickly and there turns out to be no real problem, huge amounts of money could be wasted.

Weather and Climate

The term *weather* refers to conditions in the Earth's atmosphere over time, such as a day or a week. Is it raining? How hot is it? From what direction and how fast is the wind blowing? Factors such as these are the weather conditions.

Climate refers to weather patterns over a longer time, usually no less than 30 years. The weather this summer might be unusually hot. Or the region you live in may have had a drought that lasted for six years. But neither of these events tells us anything about climate change. Weather patterns change from year to year and decade to decade, and these fluctuations are normal. But they do not necessarily indicate long-term climatic trends. Only when consistent patterns can be traced over many decades is it possible to say that the climate has begun to change.

All of the factors that make up weather and climate—precipitation, temperature change, air movements—take place in the Earth's atmosphere. To understand weather and climate, therefore, it is first necessary to learn about the Earth's atmosphere.

Earth's Evolving Atmosphere

Primitive Earth's atmosphere was very different from what it is today. It was, in fact, more like the atmospheres found on Saturn, Jupiter, Uranus, and Neptune. Methane, ammonia, hydrogen, carbon dioxide, and carbon monoxide were probably the most common gases in the primitive atmosphere. Virtually no modern-day life form could survive in such an atmosphere.

At some point, however, changes began to occur. Simple life forms began to appear. These life forms had the ability to metabolize carbon dioxide, water, and other substances, releasing oxygen gas in the process. As green plants began to appear, the conversion of carbon dioxide to oxygen by photosynthesis took place more rapidly. Over time, the concentration of oxygen in the atmosphere increased, and the amounts of methane, ammonia, carbon dioxide, and other primitive atmosphere gases were reduced.

The percentage of oxygen in the atmosphere rose from zero at the time of Earth's creation, to about 0.4 percent 800 million years ago, to about 4 percent 580 million years ago, to its present level, 21 percent, about 50 million years ago. Today, the concentration of primitive atmosphere gases is very low. Methane makes up only 1.5×10^{-4} (15/100,000) percent of the atmosphere; ammonia, 1×10^{-6} (1/1,000,000) percent; hydrogen, 5×10^{-5} (5/100,000) percent; carbon monoxide, 1.2×10^{-5} (12/1,000,000) percent; and carbon dioxide, about 0.0353 (353/10,000) percent.

In some ways, the most important relationship among atmospheric gases involves oxygen and carbon dioxide. The consumption of one of these gases usually results in the production of the other. For example, when plants grow, they take carbon dioxide out of the air and use it to produce starch, cellulose, and other carbohydrates—the process called photosynthesis. Oxygen gas is released as a by-product of this reaction:

$$\text{carbon dioxide} \xrightarrow{\text{is converted to}} \text{oxygen}$$

When plants die and decay, this process is reversed. Plant material reacts with oxygen in the air (it "oxidizes") to produce carbon dioxide. Combustion (burning) and respiration by animals involves a similar process:

$$\text{oxygen} \xrightarrow{\text{is converted to}} \text{carbon dioxide}$$

The reactions involving oxygen and carbon dioxide reached equilibrium in the atmosphere many millions of years ago. The term *equilibrium* means that the rate at which oxygen and carbon dioxide are used up in these reactions is the same as the rate at which they are being produced. The concentration of each gas has remained nearly constant, therefore, for millions of years.

The Structure and Composition of the Atmosphere

As a matter of convenience, scientists usually divide the Earth's atmosphere into four major regions. The region closest to Earth, the *troposphere,* extends to a height of 10 to 16 kilometers (6–10 miles) above the Earth's surface. Beyond the troposphere are the *stratosphere* (16–50 kilometers or 10–30 miles), the *mesosphere* (50–85 kilometers or 30–50 miles), and the *thermosphere* (beyond 85 kilometers or 50 miles).

The part of the atmosphere of greatest interest to humans is the troposphere, because that is the region in which nearly all weather takes place. About 95 percent of all gases found in the atmosphere are found in the troposphere. Nitrogen, oxygen, and argon—the most abundant gases—make up 78 percent, 21 percent, and 0.9 percent, respectively, of the troposphere. Carbon dioxide, neon, helium, methane, and krypton are the next most common gases in the troposphere.

Tropospheric gases have a number of important functions. As mentioned earlier, for example, plants need carbon dioxide and animals need oxygen to survive. But gases in the atmosphere also play critical roles in the way the Earth gains and loses energy.

By far the most important source of energy for the Earth is the sun. Each minute, 1.12×10^{19} calories of solar energy reach the Earth's atmosphere. That energy arrives in the form of Xrays, gamma rays, visible light, ultraviolet radiation, infrared radiation, and other forms of solar radiation.

Solar radiation reaching the Earth's atmosphere experiences a number of different fates. About 40 percent of the radiation is reflected back into outer space by dust and clouds in the atmosphere. Ten to twenty percent of solar radiation reaching the atmosphere is absorbed by gas molecules in the atmosphere. For example, a form of oxygen known as *ozone* captures ultraviolet light in the stratosphere. Most gases capture at least some form of solar radiation. This capture of solar radiation by atmospheric gases increases the amount of heat stored in the atmosphere.

The remaining 40 to 50 percent of solar energy passes through the atmosphere and reaches the Earth's surface. About one-third of this radiation is reflected back into the atmosphere off snow, water, rocks, soil, and other materials on the Earth's surface. The other two-thirds are absorbed by these materials. This absorbed solar energy is given off as heat waves (infrared radiation) back to the atmosphere.

Much of the infrared radiation returned to the atmosphere escapes back into space, but not all of it. Carbon dioxide, water, and certain other gases in the troposphere capture and hold some of the radiation. These gases retain some of the solar energy that otherwise would have escaped back into outer space, raising the temperature of the atmosphere.

Carbon dioxide and other tropospheric gases act like the glass windows in a greenhouse. Visible light is able to pass through the glass windows on its way into the greenhouse. When objects inside the greenhouse absorb visible light, they become warm and reradiate heat (infrared radiation). Because infrared radiation cannot pass through glass, however, the greenhouse becomes warmer. Due to its similarity to heating in a greenhouse, the capture of infrared radiation by tropospheric gases is sometimes called the *greenhouse effect.* Atmospheric gases such as carbon dioxide that capture heat are sometimes referred to as *greenhouse gases.*

The greenhouse effect is critical to the survival of life as we know it on Earth. Without the capture of heat by carbon dioxide and other greenhouse gases, the Earth's surface temperature would be about 35° C (63° F) lower. At that temperature, water would not exist in the liquid state. Lakes, ponds, rivers, streams, and most of the oceans would be frozen solid.

The amount of solar radiation reaching the Earth's atmosphere changes over time. Scientists have long known, for example, that the number of sunspots on the sun increases and decreases in an 11-year cycle. There is some evidence that weather patterns on Earth tend to follow that cycle. No explanation has been found for this pattern, however.

In the longer term, the amount of solar radiation received by the Earth changes because of natural variations in the Earth's orbit around the sun. For example, the planet's angular orientation toward the sun varies between 22° and 24.5° every 41,000 years. This variation means the Earth will receive greater or lesser amounts of solar energy during the 41,000-year cycle. The ice ages and other glacial periods appear to be the result of changes such as these, rather than major changes in the Earth's atmosphere.

The Study of Ancient Climates

Scientists know that the Earth's climate has changed significantly during the planet's history. At one time, the world was warm enough to permit the growth of abundant vegetation as far north as the island of Greenland. In fact, the island got its name because of the lush forests that once grew there. Now, of course, Greenland is almost totally covered with thick layers of snow and ice.

The best-known climatic changes are the ice ages and the interglacial periods that occurred between them. The Earth apparently has experienced seven major ice ages in its history. Each ice age, in turn, has consisted of alternate periods of warming and cooling. The most recent ice age began about 125,000 years ago and has been marked by five major cycles of cooling and warming.

Attempts to understand the ice ages go back at least 100 years. Over time, it has become apparent to scientists that a combination of astronomical factors account for most of the long-term changes in the Earth's climate. These factors include changes in the planet's angular tilt, its axial precession (a "wobble" that occurs in the planet's orientation to the sun on a 23,000-year cycle), and a 100,000-year variation in the shape of the planet's orbit around the sun. The Serbian engineer Milutin Milankovitch worked out a mathematical theory that shows how these factors interact to produce major changes in the Earth's climate.

The effort to explain climatic variations continues today. Scientists operate on the assumption that the more they know about natural climate change, the better they will be able to understand changes brought about by human activities. Today, researchers realize that, in addition to astronomical factors, a complex interaction of conditions on the planet affects climate change. The concentration of atmospheric gases, cloud cover, and the oceans are probably the most important of these conditions. An example of current research in this area is the work of Columbia University geologist Wallace Broecker.

Broecker has studied a period of Earth history known as the Younger Dryas. The Younger Dryas began about 11,000 years ago, at a time when the Earth was gradually warming, recovering from the most recent ice age. In less than a century, the warming pattern changed dramatically in one part of the planet, the region adjacent to the North Atlantic. In that region, temperatures dropped as much as 6° C (11° F) in about 50 years. Canada, Iceland, Great Britain, and Northern Europe became much colder, and ice formed in the North Atlantic, apparently disrupting normal circulation patterns in the Atlantic Ocean. During the 1980s, Broecker developed a theory that explains how a change in the flow of glacial meltwater from the Arctic ice sheet caused the Younger Dryas. In so doing, he showed how the movement of sea currents and climate are closely related (Lippsett n.d.).

Broecker was interested not only in learning more about the Younger Dryas but also in finding out what that period had to teach us about current climate change. He concluded that an