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The government of Tuvalu is developing plans for moving all 9,300 of its citizens to other countries. Tuvalu is an island nation north of Fiji in the South Pacific. It consists of nine small islands and atolls, none of which is more than five meters (about 16 feet) above sea level. As the world's average annual temperature continues to rise, glaciers are expected to melt and the ocean's level is expected to rise. By some estimates, Tuvalu will be completely inundated by the year 2100, essentially washing away a nation that is the smallest in size only after the Vatican City.

Global warming is one of the most important environmental issues facing the world in the 21st century, but it is hardly a new story. In 1827, French mathematician Jean-Baptiste Fourier (1768–1830) hypothesized a process by which solar energy is captured by the Earth's atmosphere, thus raising the planet's temperature. Fourier suggested the name greenhouse effect for the process as an analogy to the way glass windows make possible the warming that takes place inside a greenhouse.

Fourier offered no mechanism by which warming occurred, a deficiency in his theory amended in the early 1860s by English physicist John Tyndall (1820–1893). Tyndall suggested that carbon dioxide and water molecules in the atmosphere capture infrared radiation reflected off the Earth's surface, thus warming the atmosphere. However, Tyndall's idea was essentially qualitative, and it was not until the early 1900s that a complete and quantitative explanation of the planet's "heat budget" was provided by the Swedish chemist Svante Arrhenius (1859–1927). Arrhenius derived a set of mathematical equations that showed, along with a number of other details, how much energy was received by the Earth's atmosphere, how much was absorbed by the Earth's surface, how much was reflected back into the atmosphere, and how much was captured by carbon dioxide and water molecules in the atmosphere. Fourier, Tyndall, and Arrhenius all understood that their research was relevant to a general explanation as to how the Earth's climate had undergone dramatic changes over its long history.

Those changes to the Earth's climate have been extreme, ranging from periods during which the planet was plunged into long cold spells (sometimes referred to as "ice ages"), fluctuating with periods of much warmer global temperatures (often called "interglacial" periods). As a result, we know that there have been periods in the Earth's history when the African Sahara—now a desert—and the continent of Greenland—now a massive sheet of glacial ice—were both lush, green landscapes.

The fact that Fourier, Tyndall, and Arrhenius' global warming theories did not explain these cataclysmic temperature changes indicated that much larger forces must be at work. Serbian engineer Milutin Milankovitch (1879–1958) first explained those forces in detail in the 1920s. Milankovitch showed how changes in the Earth's position in space in comparison to the Sun could account for the very large climatic changes that produced the ice ages and the interglacial periods. Until fairly recently in Earth's

history, Milankovitch's grand astronomic factors appeared to sufficiently explain changes that take place in Earth's climate. But with the rise of the Industrial Revolution, a new factor appeared to change that equation. Beginning in the late eighteenth century, humans began to burn larger and larger quantities of fossil fuels—coal, oil, and natural gas—a process that releases carbon dioxide and water vapor to the atmosphere. For the first time in Earth's history, human activity had the potential for modifying natural processes such as the greenhouse effect to an extent that could be observed and measured.

Many government officials, politicians, environmentalists, and ordinary citizens around the world have now become convinced of the severity of the global warming problem. A number of organizations and campaigns have been formed to deal with the problem. On an international scale, the most significant action has been a conference held in Kyoto, Japan, in 1997 to consider possible actions to delay or reduce the effects of global warming. At that conference, several countries signed the Kyoto Protocol, an agreement calling for a reduction in the amount of carbon dioxide released to the atmosphere by most developed nations. That agreement has been ratified by more than 180 nations, with Australia and the United States as the most notable exceptions. It came into effect on November 18, 2004, when Russia ratified the protocol, reaching the requirement that nations producing 61.6% of all carbon dioxide emissions ratify the protocol.

A number of nations have already adopted policies and practices to bring them into agreement with the protocol. Thus far, however, the United States has decided not to act on the protocol or to make significant efforts to reduce carbon dioxide emissions. Both the executive and legislative branches of the U.S. government claim that the economic damage caused by programs for the reduction of carbon dioxide emissions would be too serious to implement. Probably the first important research to confirm this fact was initiated in 1957 by American chemist Charles Keeling (1928–2005). Keeling established monitoring stations on Mauna Loa in Hawaii and at the South Pole to measure the concentration of carbon dioxide in the atmosphere. Keeling's research over the next half century has produced some of the most definitive factual information available about anthropogenic effects on climate. It shows that the concentration of carbon dioxide in the atmosphere has increased gradually from 315 parts per million since his research began to more than 380 parts per million in the early 2000s.

Keeling's fundamental discovery set the stage for the current debate over global warming. Most scientists today would probably agree that increases in the concentration of carbon dioxide in the atmosphere results in an increase in the Earth's average annual temperature. Warmer temperatures, in turn, are likely to have a host of effects on the Earth's physical and biological environment. These effects may include accelerated melting of the Earth's ice caps, a rise in ocean levels worldwide, an increase in the number and intensity of violent storms, and significant changes in weather patterns in most parts of the world.

As with many scientific issues, there is no unanimous agreement on this scenario. Some authorities may agree with part of that chain of events (for example, more carbon dioxide produces warmer temperatures), but are uncertain about other parts (for example, a greater number of violent storms). The consensus of experts in the field, however, is probably that anthropogenic carbon dioxide is likely to produce significant climatic changes over the next century or more, with additional consequences that are now only poorly understood.

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Further Reading

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