

AGRICULTURAL TERRACES have been constructed for some 2,000 years. Those on the opposite page are in Guizhou Province, China.

HOW DID HUMANS FIRST ALTER

GLOBAL CLIMATE?

A bold new hypothesis suggests that our ancestors' farming practices kicked off global warming thousands of years before we started burning coal and driving cars

By William F. Ruddiman

The scientific consensus

that human actions first began to have a warming effect on the earth's climate within the past century has become part of the public perception as well. With the advent of coal-burning factories and power plants, industrial societies began releasing carbon dioxide (CO₂) and other greenhouse gases into the air. Later, motor vehicles added to such emissions. In this scenario, those of us who have lived during the industrial era are responsible not only for the gas buildup in the atmosphere but also for at least part of the accompanying global warming trend. Now, though, it seems our ancient agrarian ancestors may have begun adding these gases to the atmosphere many millennia ago, thereby altering the earth's climate long before anyone thought.

New evidence suggests that concentrations of CO₂ started rising about 8,000 years ago, even though natural trends indicate they should have been dropping. Some 3,000 years later the same thing happened to methane, another heat-trapping gas. The consequences of these surprising rises have been profound. Without them, current temperatures in northern parts of North America and Europe would be cooler by three to four degrees Celsius—enough to make agriculture difficult. In addition, an incipient ice age—marked by the appearance of small ice caps—would probably have begun several thousand years ago in parts of northeastern Canada. Instead the earth's climate has remained relatively warm and stable in recent millennia.

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Until a few years ago, these anomalous reversals in greenhouse gas trends and their resulting effects on climate had escaped notice. But after studying the problem for some time, I realized that about 8,000 years ago the gas trends stopped following the pattern that would be predicted from their past long-term behavior, which had been marked by regular cycles. I concluded that human activities tied to farming—primarily agricultural deforestation and crop irrigation—must have added the extra CO₂ and methane to the atmosphere. These activities explained both the reversals in gas trends and the ongoing increases right up to the start of the industrial era. Since then, modern technological innovations have brought about even faster

sun have exerted the dominant control over long-term global climate for millions of years. As a consequence of these orbital cycles (which operate over 100,000, 41,000 and 22,000 years), the amount of solar radiation reaching various parts of the globe during a given season can differ by more than 10 percent. Over the past three million years, these regular changes in the amount of sunlight reaching the planet's surface have produced a long sequence of ice ages (when great areas of Northern Hemisphere continents were covered with ice) separated by short, warm interglacial periods.

Dozens of these climatic sequences occurred over the millions of years when hominids were slowly evolving toward anatomically modern humans. At the

cluding changes in the concentrations of the greenhouse gases. A three-kilometer-long ice core retrieved from Vostok Station in Antarctica during the 1990s contained trapped bubbles of ancient air that revealed the composition of the atmosphere (and the gases) at the time the ice layers formed. The Vostok ice confirmed that concentrations of CO₂ and methane rose and fell in a regular pattern during virtually all of the past 400,000 years.

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My claim that human contributions have been altering the earth's climate for millennia is provocative and controversial. Other scientists have reacted to this proposal with the mixture of enthusiasm and skepticism that is typical when novel ideas are put forward, and testing of this hypothesis is now under way.

The Current View

THIS NEW IDEA builds on decades of advances in understanding long-term climate change. Scientists have known since the 1970s that three predictable variations in the earth's orbit around the

end of the most recent glacial period, the ice sheets that had blanketed northern Europe and North America for the previous 100,000 years shrank and, by 6,000 years ago, had disappeared. Soon after, our ancestors built cities, invented writing and founded religions. Many scientists credit much of the progress of civilization to this naturally warm gap between less favorable glacial intervals, but in my opinion this view is far from the full story.

In recent years, cores of ice drilled in the Antarctic and Greenland ice sheets have provided extremely valuable evidence about the earth's past climate, in-

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Particularly noteworthy was that these increases and decreases in greenhouse gases occurred at the same intervals as variations in the intensity of solar radiation and the size of the ice sheets. For example, methane concentrations fluctuate mainly at the 22,000-year tempo of an orbital cycle called precession. As the earth spins on its rotation axis, it wobbles like a top, slowly swinging the Northern Hemisphere closer to and then farther from the sun. When this precessional wobble brings the northern continents nearest the sun during the summertime, the atmosphere gets a notable boost of methane from its primary natural source—the decomposition of plant matter in wetlands. After wetland vegetation flourishes in late summer, it then dies, decays and emits carbon in the form of methane, sometimes called swamp gas. Periods of maximum summertime heating enhance methane production in two primary ways: In southern Asia, the warmth draws additional moisture-laden air in from the Indian Ocean, driving strong tropical monsoons that flood regions that might otherwise stay dry. In far northern Asia and Europe, hot summers thaw boreal wetlands for longer periods of the year. Both processes enable more vegetation to grow, decompose and emit methane every 22,000 years. When the Northern Hemisphere veers farther from

Overview/*Early Global Warming*

- A new hypothesis challenges the conventional assumption that greenhouse gases released by human activities have perturbed the earth's delicate climate only within the past 200 years.
- New evidence suggests instead that our human ancestors began contributing significant quantities of greenhouse gases to the atmosphere thousands of years earlier by clearing forests and irrigating fields to grow crops.
- As a result, human beings kept the planet notably warmer than it would have been otherwise—and possibly even averted the start of a new ice age.