If Climate Changes, It May Change Quickly

Past warmings or coolings occurred in decades — or less.

By WILLIAM K. STEVENS

IN the debate over global warming, there has been a widespread assumption that if humans are changing the earth's climate, the effects will be felt gradually and smoothly, making it easier to adapt to the change.

But a growing accumulation of geological evidence is making it ever clearer that in the past, the climate has undergone drastic changes in temperature and rainfall patterns in the space of a human lifetime, in a decade or in even less time.

The implications for Federal and international climate policy are enormous because heat-trapping carbon dioxide produced by the burning of fossil fuels like coal and oil is steadily accumulating in the atmosphere and putting increasing pressure on the climate system.

Many experts believe that late in the next century, concentrations of the gas will be double their pre-industrial levels. If that happens, mainstream scientists say, the average surface temperature of the globe will rise by 2 to 6 degrees Fahrenheit, compared with a rise of 5 to 9 degrees since the depths of the last ice age. That much warming, the scientists say, would lead to rising seas and more severe droughts, rainstorms, heat waves and floods, as well as broad shifts in climatic and agricultural zones that would benefit some regions and harm others.

Could the pressure exerted on the climate system by carbon dioxide and other greenhouse gases trip a trigger at some point, forcing these changes on humanity suddenly rather than gradually?

Scientists do not know for sure, but the question gives them pause.

"The climate system is an angry beast and we are poking it with sticks," said Dr. Wallace S. Broecker of Columbia University's Lamont-Doherty Earth Observatory, who was one of the first to raise the alarm about abrupt climate change. "We don't know whether it's going to pay attention to the pokes. But if it does, it might rise up and do something we don't like."

In uncovering one of the latest pieces of evidence of abrupt climate change, American scientists led by Dr. Jeffrey P. Severinghaus of the University of Rhode Island examined climatic clues taken from corings of ancient ice in Greenland.

The Severinghaus team determined that when the world began its final

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NASA

John Glenn aboard a space shuttle at Kennedy Space Center last week.

If the Climate Changes, It May Do So Fast, New Data Show

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ascent out of the last ice age more than 11,000 years ago, temperatures in Greenland initially spiked upward by about 9 to 18 degrees Fahrenheit — at least a third, and perhaps more, of the total recovery to today's warmth — in, at most, mere decades and probably less than a single decade. They also found that the impact of the sudden warming had been felt at least throughout the Northern Hemisphere.

That amount of heating, coming so quickly, is astounding, said Dr. Richard Alley of Pennsylvania State University, a member of the study team. Another recent study, by Dr. Peter deMenocal, a paleoclimatologist at Lamont-Doherty, examined clues in Atlantic Ocean sediments off subtropical North Africa. He discovered that every 1,500 years or so since the end of the ice age, ocean temperatures there have fluctuated widely and abruptly.

In a cold phase, they fell by 5 to 15 degrees, and seasonal rains on the continent were severely curtailed — all within no more than 50 to 100 years, and possibly less (the sediment analysis is not fine enough to tell). Then, in another 1,500 years, the picture reversed just as abruptly, causing flooding rains and creating widespread lakes in what is now the Sahara.

"The transitions are sharp," Dr. deMenocal said. "Climate changes that we thought should take thousands of years to happen occur within a generation or two" at most. The changes may have wreaked havoc on nascent civilizations in Africa and the Middle East. "It was certainly something that would have rocked somebody's world," Dr. deMenocal said.

Until recently, scientists thought that the climate system responded to what they call "forcings" — like, for instance, rising atmospheric concentrations of carbon dioxide or stronger solar radiation — much as a stereo set does: turn up the volume and the sound gets gradually louder. But now it is increasingly evident that the system behaves, at least some of the time, more like an electrical

Could greenhouse gases lead to abrupt warming?

switch: increasing pressure has no effect (or a relatively small effect, in the case of climate) until a certain threshold is reached, and then the switch clicks, initiating a new state.

Dr. Kendrick Taylor, a paleoclimatologist at the Desert Research Institute of Nevada at Reno, a division of the University of Nevada, says there is "a growing awareness" that the question of climatic thresholds is serious. Dr. Taylor, like Dr. Severinghaus, has also found that the warming in Greenland at the end of the ice age was abrupt.

"If we find out that we're far away from one of these thresholds, we might be able to change atmospheric carbon dioxide a lot and not have any impact," Dr. Taylor said. "On the other hand, we may find we're very close to one of these thresholds and that as a society it may behoove us to pay more attention."

There are other uncertainties as well. For one thing, no one knows at what point in the future the climate switch might be tripped, naturally or otherwise, or where various thresholds might lie. It is "like walking the plank blindfolded," said Dr. Thomas J. Crowley, a paleoclimatologist at Texas A&M University in College Station.

It is also unclear to what extent the big, abrupt climatic shifts in Greenland affected the rest of the world. Changes in global temperature tend to be more extreme at high latitudes like Greenland than they are farther south, and the biggest jumps could have been limited to the North Atlantic region.

But the idea that thresholds exist is becoming widely accepted, and the suspicion that they may be the dominant mode of climatic change is growing.

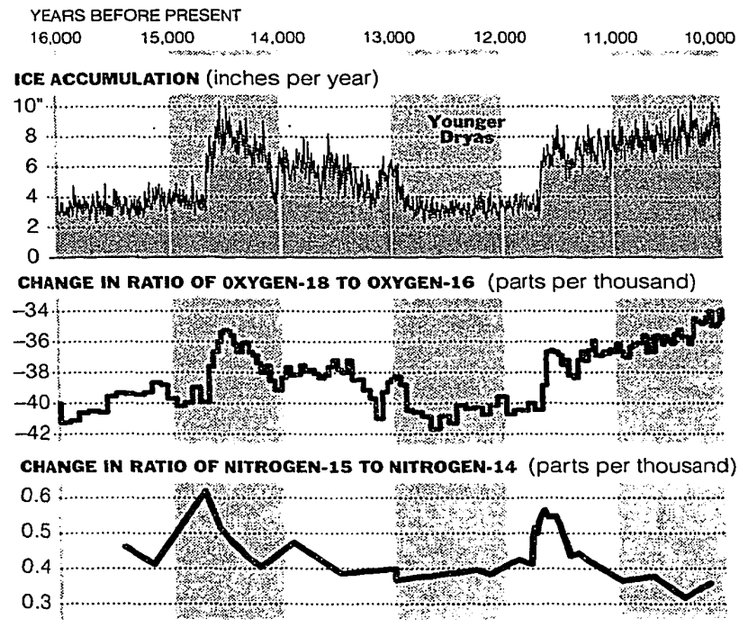
The question surged to prominence in 1993, when scientists reported on the basis of Greenland ice corings that the climate of the last interglacial period, a 10,000-year warm period that began about 130,000 years ago and at some times was slightly warmer than today, fluctuated widely from warmth to extreme cold in spans of decades or less.

Another Greenland coring, however, suggested that the climate of this long-ago interglacial interval, called the Eemian period, had been in a stable state of warmth. Scientists said the first ice sample had apparently been distorted when the bottom of the flowing glacier from which it was taken passed over uneven ground.

But ice core studies in the last five years have avoided that problem by focusing on more recent strata within the ice, most notably those representing the climate in and around a centuries-long period, called the Younger Dryas, that began about 12,000 years ago. The Younger Dryas was the last gasp of the last ice age, a relatively brief plunge back into glacial cold after the climate had already warmed up.

Signs of Sudden Climate Changes

Three sets of measurements suggest that some climate changes might take less than a decade. An abrupt change occurred between 11,000 and 12,000 years ago, at the end of the Younger Dryas period, which was the last gasp of the last ice age. Another jump is seen around 15,000 years ago. Changes in the relative abundance of oxygen forms, or isotopes, preserved in glacial ice in Greenland, indicate temperature changes. Changes in the relative abundance of nitrogen isotopes indicate abrupt temperature change.



Sources: Dr. Todd Sowers; Dr. Richard Alley (ice accumulation); Dr. Jeff Severinghaus (Nitrogen); Dr. Peit Grootes (Oxygen)

The New York Times

In 1993, a team headed by Dr. Alley found that the accumulation of snow in Greenland had doubled sharply, in possibly one to three years, as the Younger Dryas gave way to warmer temperatures. In sub-Arctic latitudes like Greenland, more snow and ice accumulate in warm periods, when there is more moisture in the atmosphere, than in cold ones.

Last October, a team headed by Dr. Taylor reported that it had analyzed another Greenland core segment and discovered that most of the transition from the deep freeze of the Younger Dryas to the warmth of the last 10,000 years, called the Holocene period, had come in two quick temperature jumps, each of nearly 10 degrees and each lasting less than a decade, within a 40-year transition period.

Dr. Severinghaus and his colleagues have made a similar discovery and, in addition, have found evidence that the climatic change signified by the ice corings extended beyond Greenland to the wider world. The discoveries were reported in the Jan. 8 issue of the journal Nature.

Scientists have a number of ways to detect climatic changes preserved in ancient ice. They can analyze bubbles in the ice for the presence of lighter or heavier forms, or isotopes, of oxygen; the changing ratios of the two forms allow researchers to infer temperature change. They can analyze the dust content of the cores to infer cold periods (colder is drier) and warm ones (warmer is wetter).

Dr. Severinghaus used yet another technique, one especially suited to detecting abrupt change. The technique analyzes the behavior of relatively lighter and heavier isotopes of nitrogen.

In a stratum of ice representing a time period when the temperature changed sharply, the lighter forms migrate to the top while heavier ones gravitate to the bottom. Applying this analysis to the Younger Dryas-Holocene transition, the Severinghaus team discovered that the transition had begun with a sharp rise of about 9 to 18 degrees Fahrenheit, on the way to an increase of about 27 degrees. A computer analysis of the nitrogen isotopes' behavior suggested that the initial jump had taken place in less than a decade.

The team also looked for methane, which in cold times is locked up in frozen wetlands but in warm ones is liberated into the atmosphere as the wetlands thaw. The ice core record showed that within no more than 30 years after the initial spike of warming that ended the Younger Dryas, atmospheric methane had increased. Because the thawing wetlands were presumably far from the permanently frozen Greenland ice cap, the scientists inferred that the climatic change after the Younger Dryas had extended at least through the Northern Hemisphere.

The methane results say nothing, however, about how large the abrupt temperature change was in lower latitudes, away from Greenland. Since the average global temperature of the world is now 5 to 9 degrees higher than in the ice age, compared with the 27-degree rise detected in Greenland, it suggests that the impact of the sudden initial warming following the Younger Dryas was somewhat more muted in what is now the United States than in the sub-Arctic. Dr. Crowley said computer simulations suggested that the size of the temperature changes in the northeastern United States might be about 20 percent of those in Greenland. In the case of the rebound from the Younger Dryas's chill, that would be about 2 to 3.5 degrees.

But even modest changes can have big effects. The sulfuric haze cast aloft by the 1991 eruption of the Mount Pinatubo volcano in the Philippines, for instance, reflected sunlight and cut the global average temperature by about 1 degree in 1992. But that small drop was accompanied by record low temperatures

Ice in Greenland provided evidence of a climate spike.

that effectively aborted summer in much of the northeastern United States and Upper Midwest.

"The extreme events that accompany moderate global change may be more dramatic and important than the small change in the global average," said Dr. James E. Hansen, a climatologist who directs the NASA Goddard Institute for Space Studies in New York.

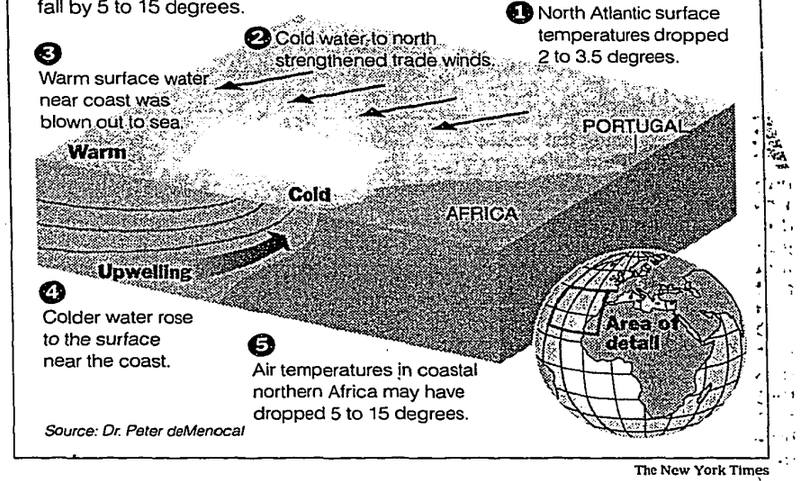
It is unclear what causes climatic triggers to trip suddenly. Some scientists say abrupt shifts in atmospheric circulation could be responsible. But the most favored candidate appears to be a change in the strength of great ocean currents that transport heat, or even a temporary cessation of the currents.

One way in which this might happen is that an atmosphere that had already begun to warm could produce more precipitation and melt more ice and snow in Arctic areas. That could flood with fresh water the critical current that transports heat to the North Atlantic, diluting the salt content on which the current's functioning depends. With this heat-conveying current halted or greatly weakened, parts of the North Atlantic region, especially Europe, could become much colder than today. One study, reported last fall in Nature, suggested that the current could shut down altogether if atmospheric concentrations of carbon dioxide doubled within 100 years, as many scientists believe is inevitable.

"It's kind of ironic," Dr. Taylor said, "but it's possible that the greenhouse warming we are likely to be producing now may lead to a warming period followed by a dramatic cold period."

Magnifying the Chill

Small, abrupt climate changes can be amplified and transported through a cascade of effects. Every 1,500 years or so, scientists have found, sea-surface temperatures in the North Atlantic change suddenly. In the cold phase of this oscillation, the temperatures drop by 2 to 3.5 degrees Fahrenheit. That strengthens the trade winds and blows surface warm water away from the northern African coast, allowing deep cold water to replace it. So the coast may have seen air temperatures fall by 5 to 15 degrees.



Source: Dr. Peter deMenocal

The New York Times