REPEATING THE

Frozen in Greenland's Jakobshavn Fjord is evidence that climate did the unthinkable some 8,200 years ago. Now scientists wonder if the same thing could happen again in coming decades.

UNTHINKABLE

BY ROBERT MONROE

Could the "8.2K Event" be the template for climate change this century?

IN THE SUMMER 2004 movie *The Day After Tomorrow*, rapid climate change ices over New York City and obliterates Los Angeles with tornadoes—all within the course of about a week.

Every film employs a bit of dramatic license and this was no exception. Everyone knows climate can't change that quickly. But that's not to say that climate change happens at an orderly, glacial pace either.

Though a general warming trend observed over the past half century seems subtle to most of us, Scripps geoscientist Jeff Severinghaus and others have found that, throughout history, climate change has not always followed a neat progression. In the past, it has taken place in short, calamitous surges and bursts.

A recent report prepared for the Department of Defense regarding climate change in the twenty-first century paints a scenario hardly more pleasant than *The Day After Tomorrow*. The 2003 study considered the national security implications of an abrupt shift in climate, defined as a sharp warming or cooling trend taking place in a decade or less. Possible consequences, said the authors, include a dwindling of natural resources, ranging from freshwater to food, as drought and severe storms wrack major portions of the planet. Countries may turn on each other as basic survival trumps religion, ideology, or

nationalism as the prevailing cause for aggression, the report warns.

The changes in nature that precipitate the global conflict envisioned in the report came not from computer simulations or speculation. Rather they reflect the impact of the work of Severinghaus and a community of researchers studying paleoclimate. The Department of Defense study was based on global climate events that occurred 8,200 years ago—the last time Earth's climate did something unimaginable.

REVERSAL OF FORTUNE

Researchers call it the "8.2K Event." In five years, climate effectively turned on a dime. Annual average temperatures dropped 6°Celsius (10°Fahrenheit) during that period in Greenland, where the ice cores Severinghaus studies bear a natural record of atmospheric change. This cooling trend dominated the weather over a 60-year period in the middle of what was a stable warm period similar to what we are currently experiencing. It caused rain belts to shift south of the equator, leading to dry, windy weather and widespread drought in the Northern Hemisphere.

There is evidence that the 8.2K Event coincided with the end of one era of human history. From evidence in dig sites in present-day Iraq, Jordan, and Israel, scientists have speculated that this event caused the collapse of the first human settlements and a societal relapse into a fragmented, hunt-and-gather existence.

Above and left, *"You can walk along here and walk through time," said Scripps's Jeff Severinghaus. At the Pakitsoq ice margin research site, horizontal banding of ice layers shows thousands of years of ice formation in stark detail. Bands of darker "dirty" ice are a sign of colder years.* **Opposite page, Top,** *In the field, Severinghaus (below) and others melt ice chunks looking for rare carbon isotopes in air trapped for millennia.*

When the cooling trend finally reversed, a warming almost as sharp began, heating the planet 6°Celsius (10°Fahrenheit) over 100 years. For comparison, researchers' forecasts of warming trends in the twenty-first century show an increase from 1° to 5°Celsius (2° to 9°Fahrenheit). Even at the probable lesser rate, scientists see the potential for a host of floods, increased severe storm activity, and other climate problems over the coming decades.

"Studying these events is important for understanding how humans are going to change the climate in the next 100 years," said Severinghaus, a member of Scripps's Geosciences Research Division. "The reason is that nature has already done all these experiments on the climate system herself, so all we have to do is try to tell what happened, to read the record."

For three years, Severinghaus and colleagues have been sampling ice cores from a site at Greenland's Jakobshavn Fjord, building a body of evidence for the abrupt climate events. New research, led by Severinghaus's graduate student Takuro Kobashi, provides high-precision validation of the findings that researchers began to identify in the early 1990s.

AN EVENT OF UNPRECEDENTED NATURE

Researchers believe that in or around the year 6217 BC, climate abruptly and catastrophically began to reverse itself in a trend that would see average temperatures drop 6°Celsius (10°Fahrenheit) in a five-year period. The likely catalyst was the sudden flood that took place when a retreating ice sheet gave way and let loose the ancient Lake Agassiz from its location along the modern-day border of the United States and Canada. The flood sent a giant pool of freshwater into the northern Atlantic Ocean. The pool disrupted the natural circulation of heat in that ocean region, setting off a chain of disastrous events. Wide-spread drought and bitter cold swept across the Northern Hemisphere as rain belts shifted southward below the Equator. Swamps in North America and lakes in Africa dried up, never to be seen again in some cases. Anthropologists have also seen evidence of fundamental societal shifts that took place at or near that point in history. The cooling trend could be what led to the demise of the world's first known cities and towns as people returned to living off the land. Analysts have considered how such a climate event would affect present-day society.

While much analysis takes place on-site in Greenland, climate researchers also ship many of their samples home. At Jeff Severinghaus's Scripps lab, ice cores are preserved, identified, and cataloged for detailed study of what is trapped within them.

The Greenland ice cores contain air trapped inside bubbles, and it is possible, by means analogous to tree-ring dating, to tell the exact year that containment took place. The air can also be used to learn the temperature at the time of containment. Air in the snow layer on top of the glacier separates slightly because of temperature changes, with heavy forms of gas (called isotopes) migrating toward colder parts of the snow. Nitrogen is a major component of air, and has two isotopes (nitrogen-15 and nitrogen-14). From the presence or absence in air samples of these isotopes of nitrogen, as well as argon, the Greenland team can extrapolate what

the average temperature must have been in a given year.

Severinghaus's colleague, geochemist Ed Brook of Oregon State University, has led similar efforts to measure concentrations of methane in air samples. With those data, he has been able to estimate how much water must have been present in ancient lakes,

swamps, and other land-surface features.

The story told by the nitrogen and argon records is clear enough to produce an approximate date for the beginning of the trend. The temperature plummet began in 6217 BC, give or take 10 years. Within another five to 10 years, a sharp decrease began in the amount of atmospheric methane, signifying the beginning of a period of severe drought. The absence of methane in the samples means there was less standing water available to produce it, which suggests that swamps and wetlands in equatorial regions rapidly dried up on a vast scale.

"So it's an incredibly fast response to climate change," Severinghaus said. "It wasn't just Greenland, it was all the places that make methane. The atmosphere is well mixed on a time scale of one year, so if you take a sample of methane concentrations in one location, it's the same anywhere."

WILL NATURE REPEAT ITSELF?

But how does the cooling of 6217 BC relate to today?

The climate change appears to have been triggered by a disruption in thermohaline circulation, the movement of heat and salt through the world's oceans

that controls climate like a thermostat. A key node of that circulation is the North Atlantic Ocean where the warm North Atlantic Current flows past Europe toward the Arctic Circle. It brings with it the warmer winds and higher temperature, that make Rome so much balmier than New York City, despite being at the same latitude. If the circulation in the North Atlantic were shut off, the results would be felt not just in Europe but worldwide.

Just before the 8.2K Event, such a shutdown may have taken place. Lake Agassiz, a body of water twice the size of the five Great Lakes combined, covered a large portion of southern Canada after the last ice age, with the lake separated from the Hudson Bay by the retreating Laurentide ice sheet. As the Northern Hemisphere warmed, the ice sheet gave way sufficiently to cause a catastrophic drainage of Lake Agassiz into the bay and eventually into the North Atlantic, flowing as far east as Iceland. Scientists believe that nearly 39,000 cubic miles of freshwater may have made it to the sea in as little as a year.

Such a rush of freshwater into the North Atlantic would have stopped or rerouted thermohaline circulation by preventing the coldest ocean water from sinking, triggering the cooling trend.

Brook, who has worked with Severinghaus since they were postdoctoral students at the University of Rhode Island, said that, if nothing else, the flood scenario would make a present-day repeat of the 8.2K Event seem less likely. Nature

Above top, *Jeff Severinghaus displays a 300-year-old bubble-filled ice segment from the so-called "Little Ice Age," a cooling period powerful enough to cause famine and displacements despite being much milder than the 8.2K Event.*

This page, *Jeff Severinghaus and graduate student Melissa Headly use a mass spectrometer to identify isotopes of key elements.*

can't easily replicate that one-time event. In that, Brook finds comfort but retains a caveat: "If it wasn't the flooding that caused it, then you think maybe something more subtle could have been happening, which could be disturbing," Brook said.

In their Scripps lab, Severinghaus's students are discovering nuances of abrupt climate change events of the past. Graduate student Melissa Headly is measuring ice-core concentrations of krypton, a gas released in greater quantity by oceans when water temperatures rise. The work could lead to a better understanding of the causes of ice ages and of natural variations of carbon dioxide, the main gas associated with the greenhouse warming of Earth. The researchers plan to continue trips to the Greenland ice sheet, using corers, band saws, and evacuated flasks to tease out answers.

"We all feel we could learn more about the mechanisms of these events if we could understand the sequences when these events are going on," Brook said.

Abrupt climate change similar to the 8.2K Event has happened 23 times in the last 100,000 years in no particular pattern, Severinghaus said. It is unclear whether, in each case, a major event like the Lake Agassiz flood provided the impetus. Other researchers report that the North Atlantic has again become less salty in recent decades, an indication of freshwater introduction taking place—perhaps more slowly than it did 8,200 years ago but significant nonetheless.

How useful will the example of the 8.2K Event be in the end? It's a long shot events will play out like that again in the near future, Severinghaus said.

"But it is possible and it's something we should be thinking about," he added.