GLACIOLOGY

Eons of insight emerge from cylinders of ice

Hundreds of thousands of years are locked away within the ice crystals that make up every glacier on Earth. The glaciers chronicle the history of the world, but drop by melting drop, they are vanishing.

"It's equivalent to losing the only library on Earth that tells us what was happening in the Greek period," said Paul Mayewski, director of the Climate Change Institute at the University of Maine.

As Earth warms, the very glaciers that can tell scientists what caused similar climate changes in the past are disappearing. For glaciologists like Mayewski, it's literally a race against time.

Of all the climate records available, ice cores — long, narrow cylinders from drill holes reaching miles below the surface of glaciers — offer the clearest glimpse into past climates.

Each winter's snow is compacted and becomes a distinct layer, much like a tree ring. Historical remnants such as the layer of ash from the eruption of Mount Vesuvius in A.D. 79, can help researchers assign years to the various layers.

But the science of glaciology advanced exponentially after particularly long "perfect" ice cores from Greenland were extracted in 1989. Frequently, portions of cores will have melted and refrozen, distorting the layers. But these 2-mile long cylinders from Greenland offered a precise record for most of the past 110,000 years, said Mayewski, who was a member of the team that drilled the holes.

By matching the characteristics of ice layers with the direct temperature and precipitation measurements available for the past century, scientists were able to "calibrate" the ice record in the cores for the remaining 109,900 years.

Dr. Paul Mayewski, director of the Climate Change Institute and professor in the Department of Earth Sciences at the University of Maine in Orono, holds an ice core he retrieved from 45 meters below the surface of the South Pole. This and many other ice core samples from the Northern and Southern hemispheres are stored in the -30° F (-34° C) ice core library at the university.

"It's not 100 percent foolproof, but neither is looking at instrument records," said Kirk Maasch, an atmospheric scientist with the institute.

In addition to considering the color and thickness of the layers, researchers analyze the chemical makeup of the snow itself, which can reveal important clues about the atmosphere through which it fell. For instance, the presence of sodium and chlorine can indicate a particularly stormy period, when more sea salt ends up in the ice.

"Snow is not just H2O," Maasch said, estimating that ice core analyses consider many major and minor elements.

The Greenland ice cores, and many shorter records from around the world, definitively proved that Earth's climate can shift quickly — with temperatures rising or dropping by dozens of degrees in just a few years. Such a change today would be comparable to Maine developing the climate of northern Virginia by 2008.

The idea of this rapid climate change turned the world of geology on its head. Mountains grow and canyons develop by fractions of inches each year. For decades, glacier experts had believed that climate behaved in the same way.

Now researchers are working to understand why rapid climate changes occur. But their research depends on collecting more ice cores from rapidly melting glaciers scattered from Patagonia to China to the Arctic.

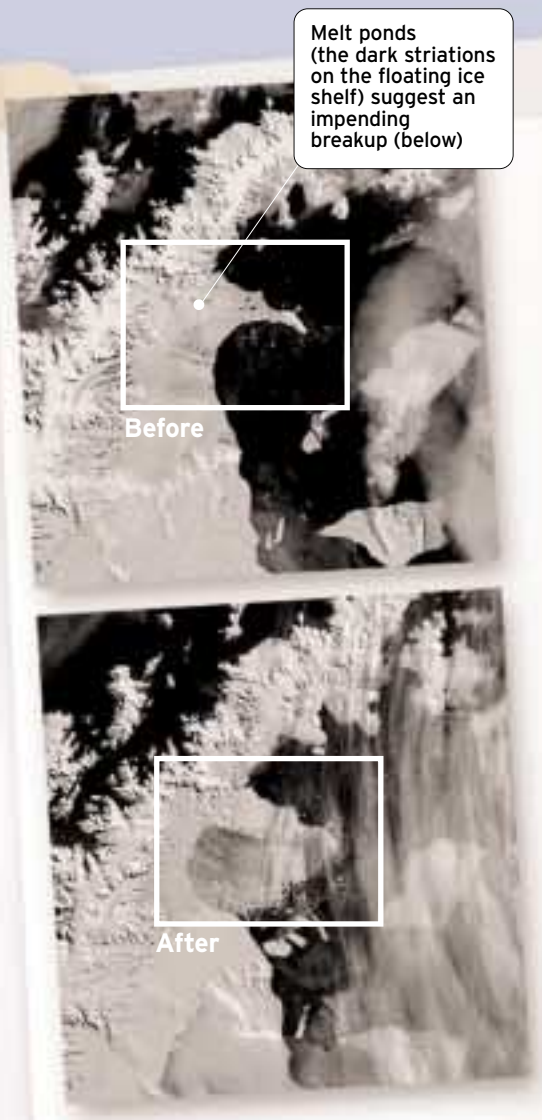
In 1979, Mayewski conducted his research in Asia at elevations of 15,000 feet. Today, he must climb to 18,000 or 20,000 feet to find the same quality of ice.

"A lot of the sites that we could have sampled 20 years ago are gone," he said.

Today, scientists have enough data to predict what Earth's climate will look like in 10,000 years. But to make predictions on a fine enough scale for governments to make plans, researchers need to double their efforts to understand how past changes occurred, Mayewski said.

Information about how climate change affected the Southern Hemisphere is seriously lacking, and retreating glaciers in Asia, Canada, Alaska, New Zealand and South America still contain valuable data, he said.

"It would be nice to get these records before the whole thing disappears," Maasch said.



A changing coastline
The collapse of a 1,250-square-mile section of the Larsen Ice Shelf in Antarctica took just over a month in early 2002. Without ice shelves to act as dams, the continent's glaciers might move faster toward the coast, ultimately contributing to rising sea levels.

Sea-level change
As a result of global climate change, scientific models predict the average sea level will rise by a minimum of 20 centimeters (about 8 inches) but will more likely rise by 0.6 to 1 meter, or about 2 to 3 feet, in the next 100 years.

The importance of the Arctic to global climate

Polar ice caps, continental ice sheets, glaciers, permafrost and all other frozen aspects of the planet are collectively known as the cryosphere.

Polar ice holds at least 80 percent of the planet's fresh water. The biggest share is in the Antarctic, whose ice sheets constitute more than 7 million cubic miles of ice, one-third of the ice that existed during Earth's regular glacial periods, or ice ages, which are currently occurring every 100,000 years or so. These glacial cycles are paced by the cycles in Earth's orbital mechanics, regular changes in its tilt, wobble and eccentricity, but are amplified by ice and snow.

Changes to the cryosphere can occur in many ways, however, with these changes affecting overall global climate in three major ways. One involves changes in the reflectivity of the surface as snow and ice melt and vegetation cover changes; the second involves changes to ocean circulation as Arctic ice melts, adding fresh water to the oceans; and the third involves changes in the amounts of greenhouse gases emitted to the atmosphere from the land as warming progresses.

The Greenland Ice Sheet Project 2, or GISP2

National Science Foundation effort is the most detailed and complete record of Earth's paleoenvironment

By late spring 1989, equipment was on the ice in Greenland to begin a project that would last the next five spring-summer seasons, led by Paul Mayewski, an internationally recognized leader in climate change research who now serves as director of the Climate Change Institute at the University of Maine. The National Science Foundation's Greenland Ice Sheet Project 2, or GISP2, involved 25 universities working together to develop new techniques for extracting information from the longest ice cores ever taken from the planet's harshest environments. GISP2 retrieved the longest continuous ice core record collected to date from the Northern Hemisphere, and the most detailed on Earth. A massive drill chewed its way through the glacier for just under two miles until it hit rock that hadn't been disturbed for perhaps 400,000 years. The project's amazing frozen records document 100,000 years of climate history with evidence of major environmental events such as volcanoes and forest fires. They also reveal the dramatic influence that humans have had on the chemistry of the atmosphere and climate change through substantial additions of greenhouse gases, acid rain and stratospheric ozone depletion.

Ice cores indicate that changes in climate over the last 100,000 years have been produced by several different agents, such as Earth's orbital cycles of eccentricity (greater than 70,000 years), obliquity (38,500 years) and precession (22,500 + 11,100 years) and that dramatic change in the chemistry of the atmosphere has occurred over the last century due to human activity. Other cycles were found to be related to ice sheet dynamics, ocean circulation and solar variability.

From GISP2 it was determined that the Chernobyl nuclear accident released radioactive fallout that spread throughout the Arctic and high latitudes of the Northern Hemisphere.

Change of Greenland Ice Sheet

The total volume of land-based ice in the Arctic has been estimated to be about 3,100,000 cubic kilometers, which corresponds to a sea-level equivalent of about eight meters. Most glaciers and ice caps in the Arctic have been in decline since the early 1960s, with this trend speeding up in the 1990s. The Greenland Ice Sheet dominates land ice in the Arctic.

The extent of seasonal surface melt on the Greenland Ice Sheet has been observed by satellite since 1979 and shows an increasing trend, with the total area of surface melt on the Greenland Ice Sheet breaking all records in 2002. In addition to contributing to the rise of sea levels worldwide, this process adds freshwater to the ocean, with potential impacts on ocean circulation and, in turn, regional climates.

How glaciers record climate

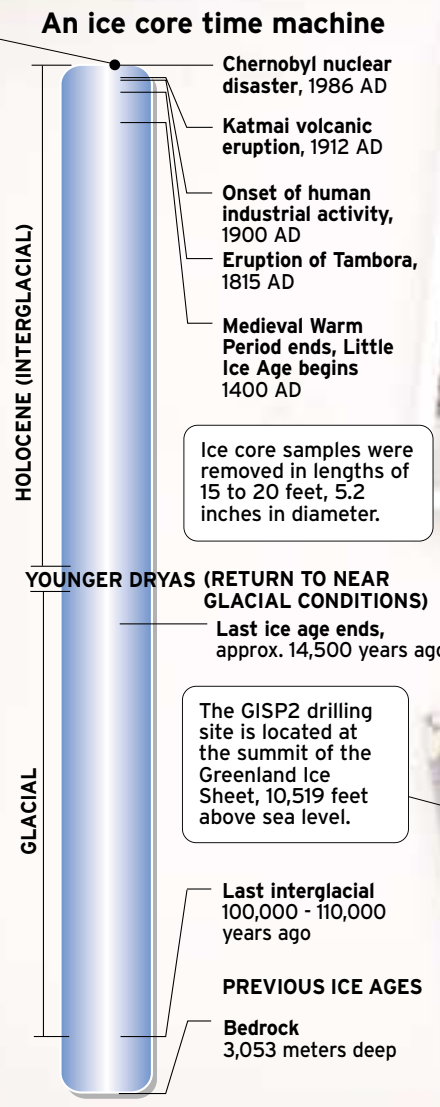
Greenland's massive ice sheet, (Antarctica's ice sheet is the only other one) is the result of thousands of years of falling and compacting snow. And when snow falls on an ice sheet, it carries with it the dust and chemicals from the atmosphere.

Consequently, the ice sheet has preserved, in small air pockets, samples of the atmosphere's chemistry from those times before direct records were taken, storing them in sequential layers. GISP2 ice core samples allow us to view a 110,000-year-long climate record from times before we were able to measure it, allowing us to study the relation between greenhouse gases and climate in the past.

Acid Rain precursors in the atmosphere revealed in the GISP2 ice core

The GISP2 record has shown a dramatic increase in both nitrate and sulfate, major components of acid rain, during the 20th century relative to the past 1,000 years. Changes in sulfate are closely tied to industrial activity in North America and Europe: the beginning of the Industrial Revolution, the Great Depression, World War II, the period of most intense burning of sulfur-rich 'dirty' coal, and the beginning of the Clean Air Act. Most of the short-term (up to 1-2 years) increases in sulfate that were observed were the product of volcanic activity, such as the Tambora eruption of 1815 and the Laki eruption of 1773.

An ice core time machine



1587
A small group of British colonists at Roanoke Island, off North Carolina, disappears. Climate records have revealed that the American coastline was experiencing an unusual drought — the driest growing season in 800 years.

1604
Samuel de Champlain and Pierre Dugua, Sieur de Mons attempt to found the first French colony in America in the middle of the St. Croix River. After a single year, however, and a harsh winter in which half the colonists died, the Frenchmen moved the colony to warmer shores, in present-day Nova Scotia.

1608
A British colony near the mouth of the Kennebec River fails after just one year when all 100 colonists either die or return to England. Popham Colony, originally founded as a sister settlement to more southerly Jamestown in Virginia, is beset by bad luck, including a particularly severe winter that came on far sooner than colonists had anticipated.

1629
The Indian monsoon, which regularly brings desperately needed rains to Asia, fails to occur for two straight years, causing a famine that kills thousands of people and millions of cattle in India. Some areas do not recover for more than 50 years.

1769
In Great Britain, inventor James Watt refines the steam engine, which becomes a major power source for the Industrial Revolution in Europe and America. Pollution from the coal used to fuel the new factories becomes a major factor in the increase of carbon dioxide in the atmosphere that begins during this period.