Climate

Richard Monastersky reports from Baltimore at the spring meeting of the American Geophysical Union

CO_2 jumps before ice sheets slump . . .

To fully understand the threat of rising carbon dioxide levels, scientists are trying to decipher what role this greenhouse gas played during previous shifts in climate, namely the last several ice ages. New work on ice cores from Antarctica suggests that during one episode, about 130,000 years ago, carbon dioxide took center stage by helping to melt the massive ice sheets that covered large sections of the globe.

The new evidence comes from tiny samples of ancient air, locked in bubbles buried deep within the Antarctic ice cap. Soviet researchers have spent nearly two decades drilling a 2.5-kilometer-deep hole at their Vostok base to collect samples of ice that formed as far back as 160,000 years ago. When French researchers analyzed the air bubbles, they discovered that atmospheric levels of carbon dioxide dropped substantially during the ice ages and rose again during warm periods. But they could not tell whether the carbon dioxide fluctuations were a cause or an effect of climate change, partly because they could not directly compare the ice bubble data with information from deep-sea sediments. While the ice bubbles record atmospheric changes in carbon dioxide, the sediments contain information about sea level variations caused by the advance and retreat of continental ice sheets.

Todd Sowers from the University of Rhode Island at Narragansett proposes a way to skirt the problem. Working with U.S., French and Soviet colleagues, he suggests the ice bubbles themselves contain information about the growth of ice sheets in Europe and North America. Oceanographers traditionally study ice sheet history by measuring the ratio of different oxygen isotopes in sea sediments, which reflects the isotopic composition of ancient sea water. But Sowers and his co-workers think the isotopic ratio of the air trapped in ice can serve as a proxy for the ratio in the ancient sea water. They conclude that carbon dioxide levels rose about 3,000 years before the ice sheets melted at the end of the second to the last ice age. Since carbon dioxide helps heat the atmosphere, a rise in its concentration would have spurred the melting. They suggest the gas changes amplify slight variations in Earth's orbit, which serve as the pacemaker for the glacial cycle.

The proposed isotopic link between sea water and the atmosphere is complex, and the researchers must convince others the link is justified. If so, their method could help resolve what drives the changes in carbon dioxide levels.

. . . and methane plays along too

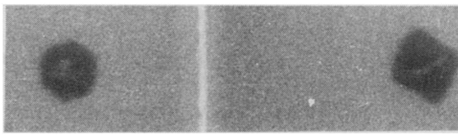
Air bubbles from the Vostok ice core also reveal that methane levels have undergone extreme fluctuations over the last 160,000 years, report Dominique Raynaud and colleagues from the Laboratory of Glaciology and Geophysics of the Environment in St. Martin d'Hères, France, and from the Soviet Union. During warm periods, methane builds to almost double its ice age level of 350 parts per billion by volume.

Methane levels during the last 300 years have risen at an exponential rate, from 700 to 1,700 parts per billion, most likely because of human activities. The Vostok record suggests that during the 160,000 years before humans had an impact, methane levels never rose as quickly as they are now rising, nor did they reach such heights.

Both methane and carbon dioxide trap surface heat, and the researchers calculate that the buildup of these greenhouse gases could have caused about half the 4.5°C warming between the glacial and interglacial periods. "If that's really true, then it says the climate is very sensitive to the atmospheric chemistry," says Nicklas G. Pisias of Oregon State University in Corvallis. Indeed, on the basis of the ice age data, Raynaud's group estimates that a modern doubling of carbon dioxide will warm the world by a significant 3.6°C to 4°C.

Physical Sciences

When bubbles go bad



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Air bubbles in water can sometimes oscillate, rhythmically expanding and contracting at a characteristic rate. But what happens to the oscillations when sound waves of a given frequency hold a single bubble in place while driving its pulsations? Experiments carried out at the National Center for Physical Acoustics in Oxford, Miss., and the Technische Hochschule Darmstadt in West Germany show that such a bubble, instead of remaining spherical, shifts back and forth between a spherical shape and one resembling a triangle, a cube or some other lobed figure. Moreover, the oscillations occur erratically. There seems no way of predicting precisely how long a driven, oscillating bubble would remain in its contorted form before returning to a spherical shape.

Using bubbles about 80 to 90 microns in diameter and a sound-wave frequency of approximately 24.5 kilohertz, the researchers took high-speed photographs to capture the bubble shapes. The photo above shows a spherical bubble (left) and its corresponding contorted form (right). The shape of the contorted form seems to depend on the bubble's radius. The researchers also recorded the intensity of laser light scattered from an oscillating bubble to determine when the shape changes occurred.

"We didn't know that bubbles would indeed oscillate chaotically," says mechanical engineer R. Glynn Holt of Yale University in New Haven, Conn., who described the research at last month's Acoustical Society of America meeting in State College, Pa. "We were just seeing how bubbles would oscillate, hoping to get some sort of fuel to add to the fire to get theoretical work going on the subject."

Loosely packed spheres

Uniform ball bearings poured into a large pitcher would most likely fill between 60 and 63 percent of the space inside the container. Those limits, originally determined by experiment, represent the range over which random packings of uniform spheres can rest in stable arrangements. Such random packings have long been of interest as models for the arrangement of atoms in simple liquids and glasses.

George Y. Onoda and Eric G. Liniger of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., have now taken a closer look at the lower limit on packing density. Their experiments show that the fraction of space occupied by randomly packed spheres in arrangements that can still support a load can be as low as 55.5 percent — if the gravitational force acting on the spheres is in effect zero. Their results appear in the May 28 PHYSICAL REVIEW LETTERS.

To minimize the effects of gravity, Onoda and Liniger immersed glass spheres, about 250 microns in diameter, in a liquid with a density close to that of the spheres. After letting the spheres settle gently in the liquid-filled, 500-milliliter graduated cylinder, they measured the fraction of space that the randomly placed spheres took up within the container. The fraction they obtained corresponds to a continuous, rigid network of touching spheres.

The researchers also demonstrated that this packing fraction seems to determine the onset of dilatancy, an important property of granular materials such as sand. Dilatancy occurs when particles must spread apart in order to move past each other in response to a shear force applied to the material. That causes the overall volume occupied by packed particles to increase. The research results show that the packing fraction must be higher than 0.555 for dilatancy to occur.

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