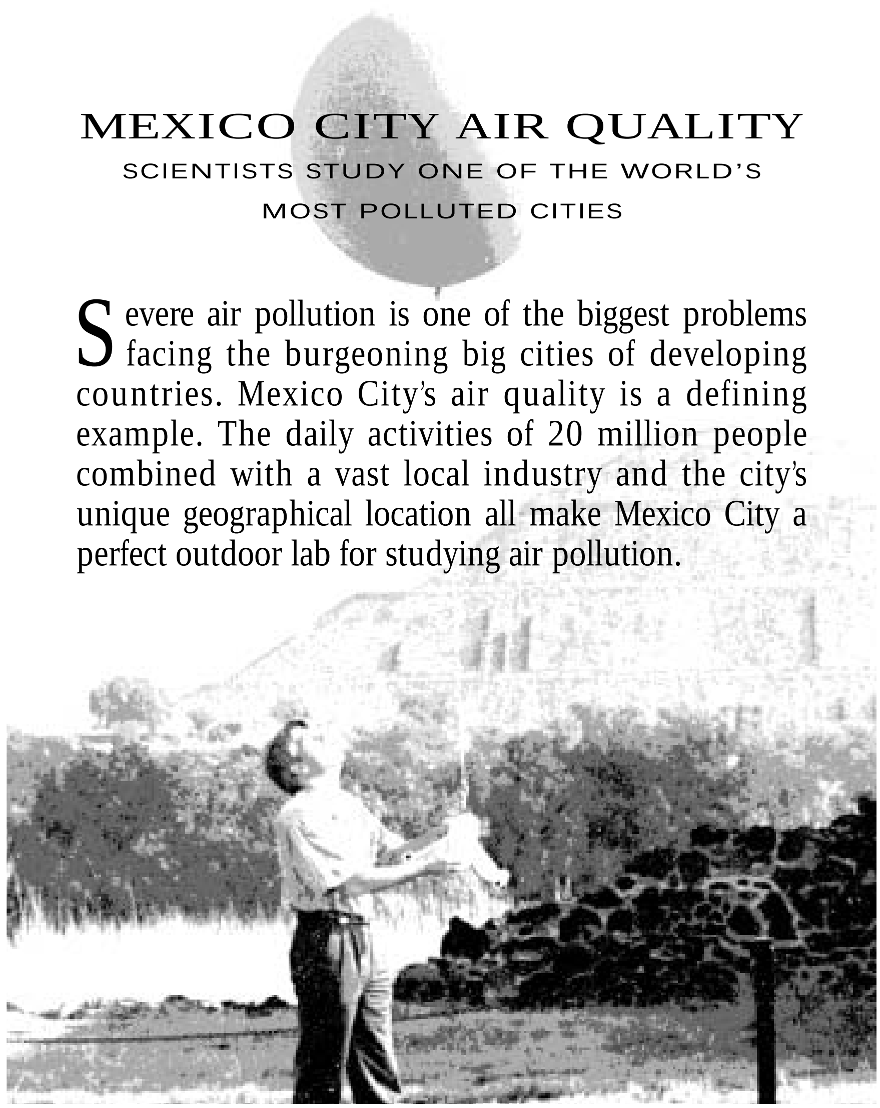
LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE
LOS ALAMOS

MEXICO CITY AIR QUALITY

SCIENTISTS STUDY ONE OF THE WORLD'S MOST POLLUTED CITIES

Severe air pollution is one of the biggest problems facing the burgeoning big cities of developing countries. Mexico City's air quality is a defining example. The daily activities of 20 million people combined with a vast local industry and the city's unique geographical location all make Mexico City a perfect outdoor lab for studying air pollution.



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Los Alamos researcher John Archuleta (right) and a Mexican researcher at the Los Alamos meteorological site in Chalco. In the background is a mobile unit for environmental monitoring provided by the Instituto Mexicano del Petroleo.

Atmospheric scientists from Los Alamos, Pacific Northwest, and Argonne national laboratories, and NOAA's Environmental Technology Laboratory recently took part in a U.S.-Mexico field study to gather data on air flow inside the Mexico City basin. The scientists will use the data to develop advanced computer models that can predict air pollution in Mexico City and U.S. cities such as Los Angeles and Denver, which have similar complex, geographical settings.

The team traveled to Mexico City this winter and spring when air pollution levels were very high. The scientists chose the four corners of the Mexico City basin as their meteorological sites to observe wind and temperature structure. Los Alamos scientists were positioned at a site southeast of the city in Chalco.

Mexico City sits in a basin more than 7,400 feet above sea level, surrounded on three sides by mountain ranges. The only significant

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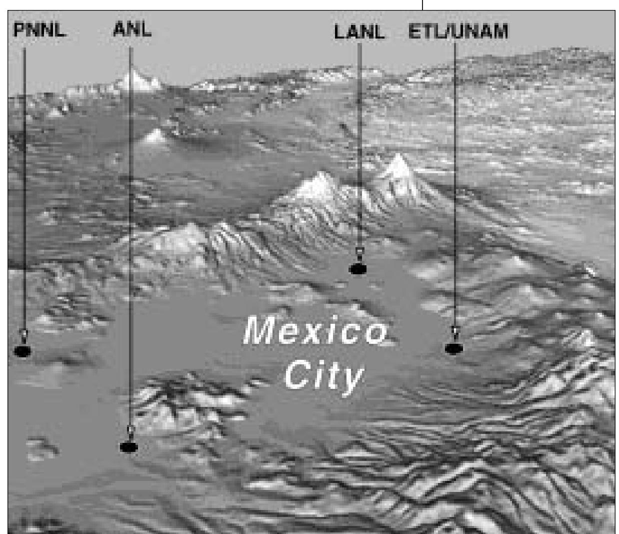
opening lies to the north. The surrounding mountains tend to isolate the city from the winds of regional weather patterns. Thus geography is an important contributor to the phenomenon of temperature inversion in which a cap of warm air sits over a surface layer of cold air and traps air pollutant emissions.

Scientists at all four sites released airsondes, balloons with temperature sensors attached, into the atmosphere five times a day beginning at 8 a.m. Each site also used radar wind profilers to continuously measure wind up to 4 kilometers above the ground. Another technology, SODAR, which uses sound to detect air flow, gave higher resolution measurements but only up to 1 kilometer. Ground meteorological stations at each site recorded wind, temperature, and humidity data as well.

Another component of the program involved measuring air pollution in the industrialized and more polluted areas of the city. The Desert Research Institute of Nevada managed data collection at these sites. Aerosol data along with meteorological data is needed to analyze the air pollution problem. It is the aerosol particles that are responsible for the deleterious health effects and for the very obvious visibility degradation.



The Mexico City basin. Top of the map is due south. The four major meteorological sites are pinpointed within the basin.

The study is a follow-on to the highly successful project that Los Alamos and Mexico conducted in 1990-1993. The Mexico City Air Quality Research Initiative, known as MARI, resulted in a set of analytical tools for Mexico City to use in making decisions on air-quality management.

This year's study is supported by the U.S. Department of Energy and the Instituto Mexicano del Petroleo.

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UNDER THE VOLCANO

3-D IMAGE OF MOLTEN ROCK PROMOTES NEW THINKING ON AN ANCIENT CALDERA

A three-year study of seismic waves traveling through the heart of an ancient volcano has provided researchers at Los Alamos with the first comprehensive three-dimensional image of the caldera and new and important information about the volcano's plumbing system. The purpose of the study was to assess volcanic hazards, determine geothermal resource potential, and better understand how large rhyolitic calderas form and evolve.

↑ The crater of an ancient volcano — the Valles Caldera — lies west of Los Alamos.

The study reveals a large low-velocity zone 8 miles in diameter, centered at a depth of 8 miles below the caldera. This zone contains at least 10 percent molten rock, or magma. The researchers can't rule out the possibility that the zone of magma, or magma chamber, is the remnant of volcanism from more than a million years ago. However, they favor the idea that it represents the emplacement of a relatively new pulse of magma into Earth's crust.

A deeper zone of low velocity, found at depths of about 23 miles, is interpreted to reflect the source rocks — possibly molten — of the magmas that formed the shallower magma chamber.

Researchers Lee Steck of Los Alamos and William Lutter of the University of Wisconsin led a team of researchers who recorded travel times of seismic waves from distant earthquakes traveling through the Valles Caldera in Northern New Mexico. The seismic waves analyzed by the researchers are essentially sound waves that travel faster in stiffer material and slow down in more pliable material, such as magma.

Using tomography, a method similar to the computer-aided tomography, or CAT scan, of medical imaging, geophysicists produced a 3-D computer model that shows seismic waves slow down by as much as 35 percent in specific locations beneath the Valles Caldera.

The Valles Caldera, located about 70 miles north of Albuquerque, formed during two explosive episodes that occurred 1.6 million years

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ago and 1.2 million years ago when more than 90 cubic miles of rock erupted. The caldera's most recent volcanic activity ended 50,000 years ago. The 14-mile-wide Valles Caldera is one of the most well-known resurgent calderas in the United States. Scientists have been studying this region since the 1920s to learn about the fundamental processes of magmatism, hydrothermal systems, and ore deposition.

Resurgent calderas form after a huge volcanic eruption, when the roof of the magma chamber collapses into the space voided by gas-rich magma. The collapsed crater then fills partially with volcanic ash and pumice.

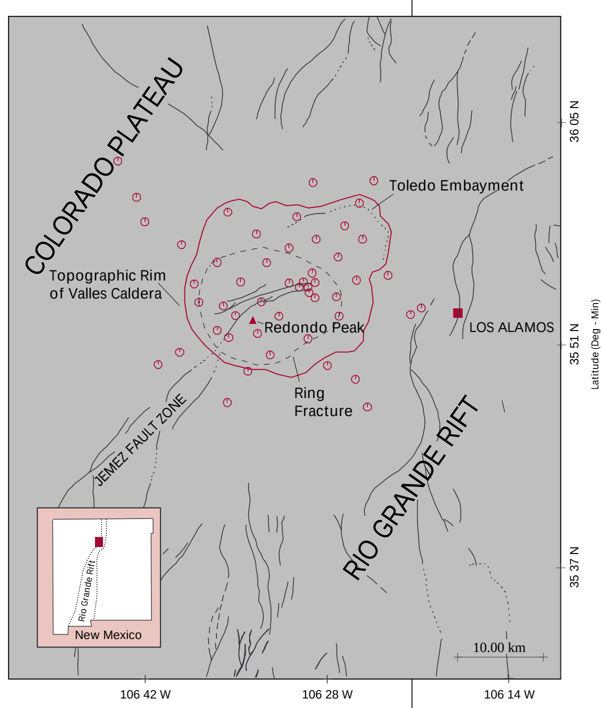
The research team placed 50 seismic monitoring stations around and within the Valles Caldera, which lies just west of Los Alamos in the Jemez Mountains. This monitoring network produced a detailed picture of the velocity structure down to depths of 24 miles below the surface. Data were gathered from 216 distant earthquakes, most of which occurred during the 1993 and 1994 Jemez Tomography Experiment. Data gathered from a 1987 experiment by Los Alamos researcher Peter Roberts were also included in the study.

Researchers analyzed 4,872 seismic waves. Seismic waves from faraway earthquakes approach the instruments nearly vertically, while seismic waves from earthquakes that are closer come in at a more horizontal angle. The researchers need both near and far earthquakes for a wide variety of angles to produce the 3-D model.

When the Valles Caldera collapsed nearly 1.2 million years ago, researchers believe it occurred in a more stair-stepped than piston-like manner, resulting in deeper areas filled with more volcanic ash and sediments. Steck and Lutter's research confirms that theory.

The research team found several areas of shallow low-velocity zones slightly deeper than a mile from the caldera floor that were slower than surrounding areas by about 10 to 17 percent. The

Location of the Valles Caldera on the western flank of the Rio Grande Rift in Northern New Mexico. Seismic stations are indicated by small red circles.



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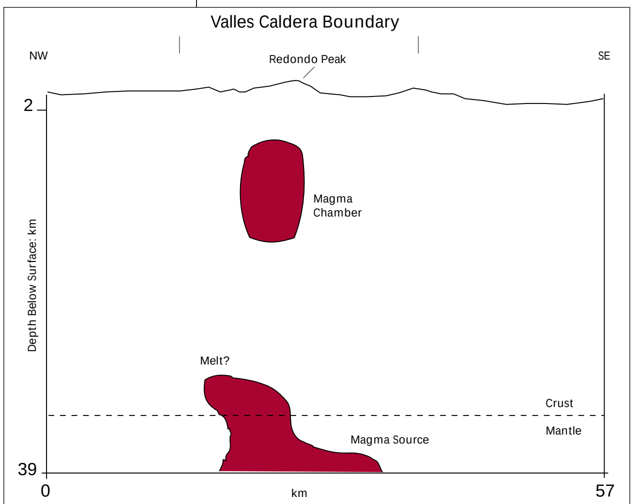

↑ Researchers' interpretation of the magma chamber centered at a depth of 8 miles below the caldera, and the deeper zone of magma found at depths of about 23 miles.

research team believes these represent the greater accumulation of pyroclastic deposits in areas of deeper collapse on one side of the caldera.

There are three possible interpretations of the 3-D velocity image. The first is that the original million-year-old magma is still cooling underneath the caldera. The second is that the original magma chamber was rejuvenated or in contact with the mantle to periodically receive more melt. The third interpretation is that the observed low-velocity zones represent a completely new pulse of magma.

Steck and Lutter agree that the original magma chamber may still exist and could retain up to 10 percent of its melt products, but certainly not more. However, they say the calculations supporting this premise require numerous simplifying assumptions and may not be realistic. From these and other arguments, the researchers favor the third interpretation.

Taken together, the low-velocity regions at depths of 8 and 23 miles are believed to show the relationship between magma emplacement at the base of the crust, and its subsequent rise to the middle crust to form a magma chamber. The research method can only image an area larger than about 2 miles. If there are conduits or connections between the magma chamber and the deeper low-velocity region, and they are smaller than 2 miles in diameter, the technology cannot image them.

The research project is part of the Jemez Tomography Experiment, a cooperative and interdisciplinary research program involving scientists from Los Alamos, the University of Wisconsin, San Diego State University, the University of Texas at Dallas and El Paso, Purdue University, and the U.S. Geological Survey.

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GO FOR THE BURN

OXYGEN SENSOR IMPROVES AUTO PERFORMANCE AND FUEL EFFICIENCY

Nationwide, two-thirds of the carbon monoxide emissions come from transportation sources, with the largest contribution coming from automobiles on the highway. Carbon monoxide, an odorless and poisonous gas, results from incomplete combustion of fuel and is emitted directly from vehicle tailpipes.

The 1990 Clean Air Act requires the Environmental Protection Agency to regulate air toxins from motor vehicles in the form of standards for fuels, or vehicles, or both. To help American automobile manufacturers meet these standards, Los Alamos has developed a family of oxygen sensors that are more sensitive across a wide range of oxygen concentrations and more cost effective than current oxygen sensor technology.

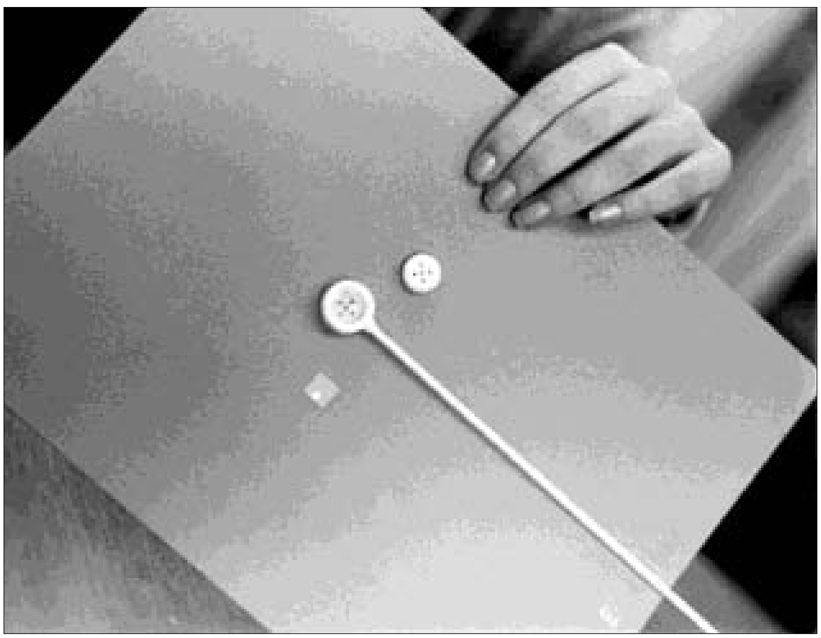
↑

Automobile exhaust is a major source of carbon monoxide pollution. A newly developed oxygen sensor will help engines burn cleaner and pollute less.

An oxygen sensor measures post-combustion oxygen in the exhaust from the engine. As engine conditions change, for example during acceleration or deceleration, the oxygen sensor detects changes in oxygen concentration in the exhaust, providing a closed-loop feedback to the fuel injector. The fuel injector can be set to provide the right amount of fuel to optimize the performance of the vehicle and minimize pollution from the exhaust.

The typical oxygen sensor found in most automobiles today has platinum electrodes on a zirconia electrolyte. This type of sensor produces a voltage that is proportional to the logarithm of the ratio of oxygen concentration on either side of the sensor. One side is exposed to air and the other to the exhaust of the car. This sensor provides a large-voltage signal to the car's computer, but only near the stochiometric fuel mix — where the oxygen and air intake to the engine is exactly balanced to burn the amount of gasoline from the fuel injector.

The Los Alamos-developed sensor uses thin-film conducting ceramic electrodes on a thin zirconia electrolyte. The ceramic electrodes act as a diffusion barrier for oxygen. This results in a sensor with linear response to oxygen concentration. Such a sensor could be used to control automobile engines operating with lean fuel mixes. Under these conditions, the engine is more energy efficient and potentially less polluting.



The Los Alamos-developed thin-film oxygen sensor (the small square) and its ceramic casing.

Consumers also gain from the low-heat capacity of the device because ceramic oxygen sensors must be heated to high temperatures before they can begin to function. Consequently, today's cars pollute most when the catalytic converter is cold or when the closed-loop engine control is not functioning. A sensor that can be heated to operating temperature in seconds means that fuel efficiency begins immediately after start-up rather than after a couple of minutes of engine warm-up.

Los Alamos' thin-film oxygen sensor also is cost effective. Thin-film oxygen sensors for cars should cost substantially less than the oxygen sensors used today.

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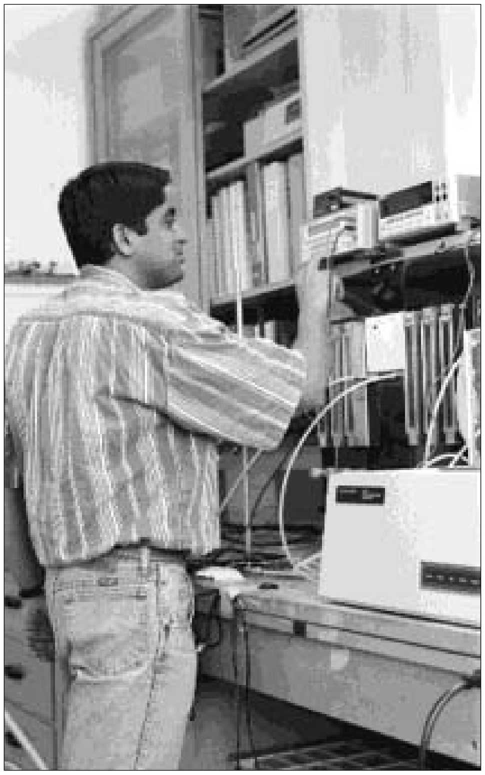

➔ Researcher Rangachary Mukundan programs test equipment to measure the oxygen level in exhaust gas samples.

In another application, oxygen sensors are used in combustion control processes at manufacturing plants. However, one of the biggest problems in burning hydrocarbon fuels is that many times those fuels contain some sulfur. Today's oxygen sensor technology is not very rugged in a sulfur environment. Also, temperature recommendations for current sensors make it impossible to put the sensor close to the combustion process. The Los Alamos-developed sensor can be placed much closer to the combustion source because the materials used to produce the sensor are less susceptible to chemical attack or deterioration due to extreme temperatures.

The Los Alamos oxygen sensor was developed under the Laboratory's Directed Research and Development program. A portion of the program included a Cooperative Research And Development Agreement with Delphi Automotive Systems of General Motors.

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NO STRAIN, NO GAIN

SISTERS WIN 7TH SUPERCOMPUTING CHALLENGE

Two sisters from Highland High School in Albuquerque designed a computer program that reveals strain on automobile wheels to capture first place in the New Mexico High School Supercomputing Challenge. Both sisters received $1,000 savings bonds.

The sisters, Nguyen Van Anh and Nguyen Anh Thu, used a method known as Delaunay triangulation to enclose the wheel, add boundary points, and continually form new triangles that create a mesh of points which completely describe a car's wheel. This two-dimensional mesh provides the basis for calculating which regions of the wheel show the greatest strain.

The sisters were mentored by Highland High School teachers Donald Downs and Gale Borkenhagen. Last year, the same team finished second with a computer program that demonstrated how such mechanisms as light absorption and temperature changes during morphogenesis determine the colors of flower petals.

Sisters Nguyen Van Anh (second from left) and Nguyen Anh Thu pose with Terry Bowlinger of New Mexico Technet (far left) and Kane Denbeste of Gateway 2000 after winning this year's Supercomputing Challenge. Gateway 2000 donated computer equipment to the schools of the first- and second-place prize winners.

The Supercomputing Challenge was conceived in 1990 by Los Alamos Director Sig Hecker and Tom Thornhill, president of New Mexico Technet Inc., a non-profit company that in 1985 set up a computer network to link the state's national laboratories, universities, state government, and some private companies.

Second place went to a trio from Española Valley High who made an environmental computer model of the Mediterranean Sea to study global warming.

Nearly 4,000 students have competed in the Supercomputing Challenge since its inception. Many groups from private industry and academia joined Los Alamos and Technet in sponsoring this year's event.

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CLEAN DRY CLEANING WINS AWARD

POPULAR SCIENCE: "BEST OF WHAT'S NEW"

A Los Alamos-developed technology that replaces environmentally hazardous dry cleaning chemicals with a liquid carbon dioxide cleaning process has won an award from *Popular Science* magazine. Los Alamos shares the award with Hughes Environmental Systems Inc., a subsidiary of Hughes Aircraft Co., which is commercializing the technology that could revolutionize the dry cleaning industry.

Each year the editors of *Popular Science* select 100 innovative technologies and new products for distinction as the "Best of What's New." The winners were highlighted in December's issue of the magazine. The technology also won the Readers' Choice Award on the World Wide Web in January of this year.

Under about 800 pounds of pressure, carbon dioxide acts like a liquid and serves as an organic, entirely recyclable solvent that extracts dirt from clothing. When the liquid carbon dioxide is allowed to return to its gaseous state, dirt falls out of the gas. Repressurized, the carbon dioxide can be used again. The only waste generated by the process is the dirt removed from the garments.

Craig Taylor: the man and his award.

Los Alamos researchers say carbon dioxide does a great job of dissolving sweat, oils, and dirt and is a better solvent than what is currently in use. It also cleans faster, and it is environmentally benign. (See related article in August 1996 *Dateline: Los Alamos*.)

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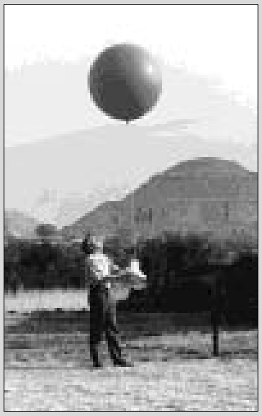

On the cover

Los Alamos researcher Scott Elliott prepares to release an airsonde, a balloon with a temperature sensor attached, into the atmosphere as part of a multilaboratory, U.S.-Mexico field study to gather data on air flow inside the Mexico City basin. The data collected will help scientists develop an advanced computer model capable of predicting air pollution in Mexico City and U.S. cities that have similar complex geographical settings. The month-long study took place in April. Scientists from Los Alamos took their wind and temperature structure measurements at a site in Chalco, a city southeast of Mexico City and one of four sites chosen to conduct the study. Rising in the background is the Pyramid of the Moon at the Teotihuacan archeological site.

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