UCAR CORPORATE REPORT 1992

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

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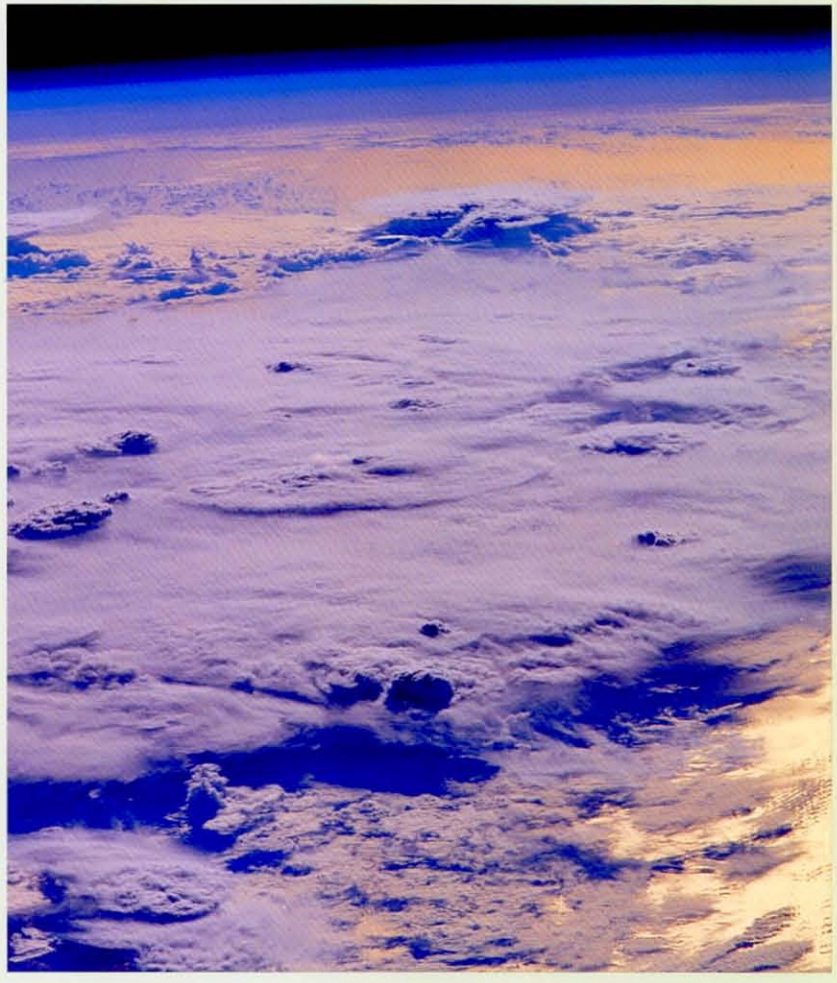
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH
BOULDER, COLORADO



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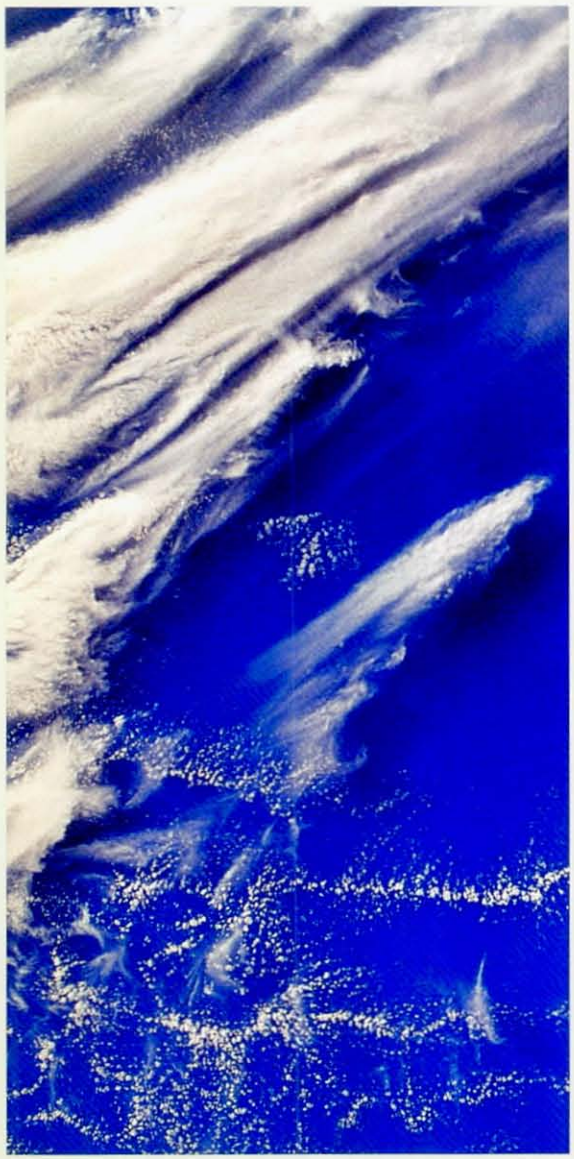

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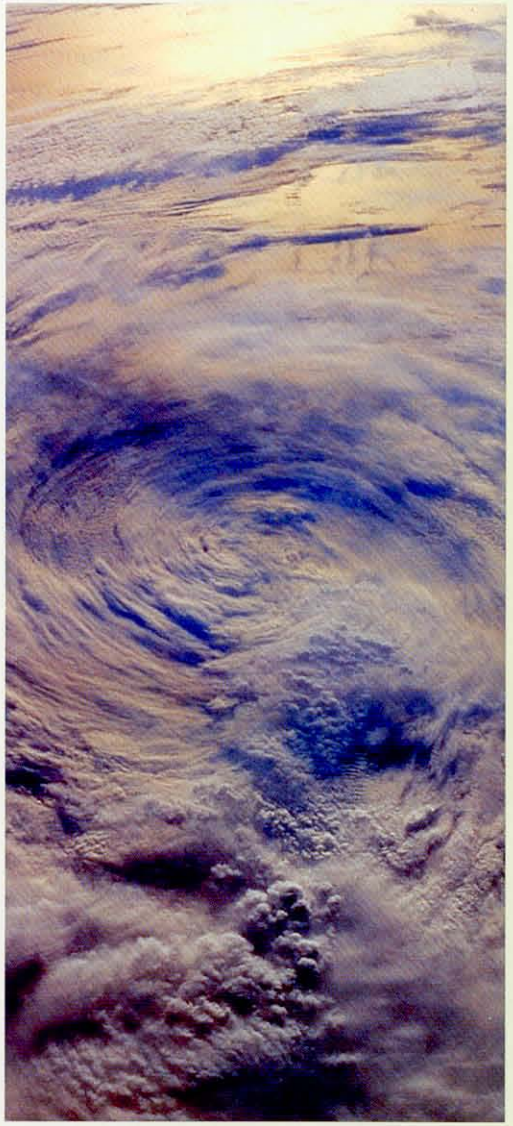
Cover: History may look back on 1992 as the Year of the Hurricane. Andrew was the United States' most destructive storm ever, while two other unusually intense hurricanes struck Hawaii and Guam. A camera aboard the U.S. space shuttle took this photo of Hurricane Bonnie as the storm spun over the western Atlantic Ocean on 19 September.

What is UCAR?

In the late 1950s, a handful of U.S. universities saw the need for a more coherent approach to what was then limited to meteorology and weather forecasting. These 14 institutions sought a more rigorous examination of the atmosphere. Believing that their efforts would be most effective if combined, the schools formed the University Committee for Atmospheric Research (UCAR). This committee recommended creation of a national institute—a place where superb scientists and tools could extend the universities' capabilities and serve the discipline as a whole. Thus, the National Center for Atmospheric Research (NCAR) was established in 1960 in Boulder, Colorado, with the National Science Foundation as its sponsor and UCAR—by then a corporation—as its managing body.

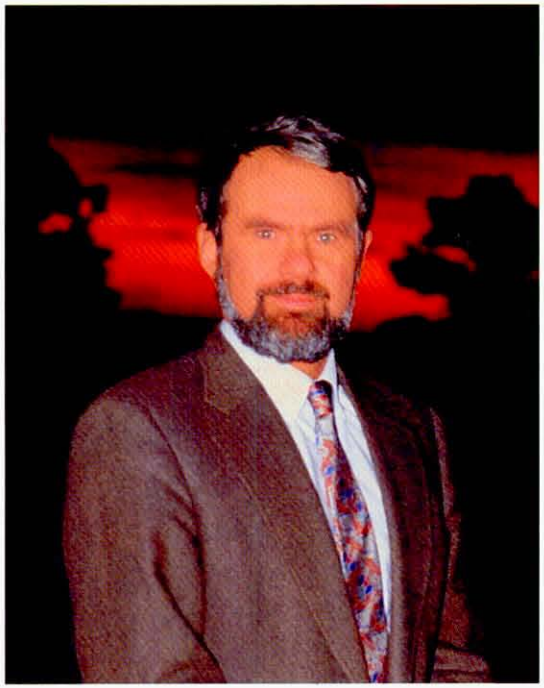
Through the 1960s and 1970s, NCAR grew dramatically in response to the needs of atmospheric science and a growing national research budget. A core research program evolved at NCAR while aircraft, a supercomputer, and other research tools were developed, acquired, and operated for the community. The 1980s brought new challenges and opportunities; in response, UCAR began to manage a number of related programs organizationally separate from NCAR, aimed at meeting the new opportunities while broadening UCAR's support to the universities.

Today, some 1,000 people work in over a dozen UCAR programs that encompass theory, laboratory work, field programs, technology, education, and public awareness. The ultimate goal of all these ventures is the same: to further the strength and cohesiveness of the atmospheric and related sciences and to advance our understanding of them.



PRESIDENT'S MESSAGE

Our Global Trajectory



In January 1992, after more than a year of extensive thought, planning, and community consultation, the UCAR Trustees adopted *UCAR 2001: A Strategic Outlook for the University Corporation for Atmospheric Research*. *UCAR 2001* sets the course for UCAR throughout the remainder of this century, a period of human history bound to be marked by rapid and significant change.

Driven by the seemingly irrepressible force of human activities, our global, regional, and local environments are undergoing increasing stress. The cold war—which set the nation's scientific agenda for decades—is over. The unprecedented national debt puts inexorable limitations on all resources, including those of the nation's research communities. Scientists more and more are being asked to show practical value in return for society's support. And while significant progress is being made on understanding the global climate and weather systems that affect humans daily, important questions about the coupled system of ocean, land, atmosphere, and biosphere remain.

UCAR has undertaken internal changes to be better able to implement *UCAR 2001* and to meet the challenges of the next decade and beyond. The basis is laid for renewal of the next five-year cooperative agreement with the National Science Foundation for the operation and management of NCAR, the research and support activities of the Institute for Naval Oceanography have been transferred to the University of Southern Mississippi and Mississippi State University, new collaborations among UCAR's programs are developing, and educational activities are receiving new emphasis. Several highlights are described in the text of this report, whose theme—"Broadening the World of Atmospheric Science"—was chosen to illustrate the global nature and significance of UCAR's programs.

Fundamental and widespread change will be required, in my opinion, to meet the challenges ahead. The term "global trajectory" (borrowed from a colleague), refers to the projected quality of life on Earth in the 21st century and beyond. This trajectory must be a sustainable one, and I believe that science and technology

have a special responsibility to help move us onto it. As sources of innovation, they can lead us to less consumption, pollution, and depletion of nonrenewable resources and to lowered population growth rates. Atmospheric science has a special role to play in providing the basis for wise environmental regulations and predicting future consequences of human actions on our earth's system. Significant and fundamental change is required at every level—individual, institutional, governmental, and international.

I begin another year as UCAR president with a renewed appreciation of the potential for the atmospheric and related sciences to serve humankind—and a growing sense of urgency to realize that potential. We can, and should, be agents of change for the better in the next decade.

Rick Anthes
UCAR president

Inside UCAR

With a mixture of local and global activities, basic and applied research, and disciplines spanning the earth system, UCAR is unique among institutions devoted to the study of the atmosphere. As it moves through the 1990s on a newly broadened path, UCAR has six chief goals, each outlined in the following pages. The first two goals—which are top priority—are supported by the others, each important in itself.

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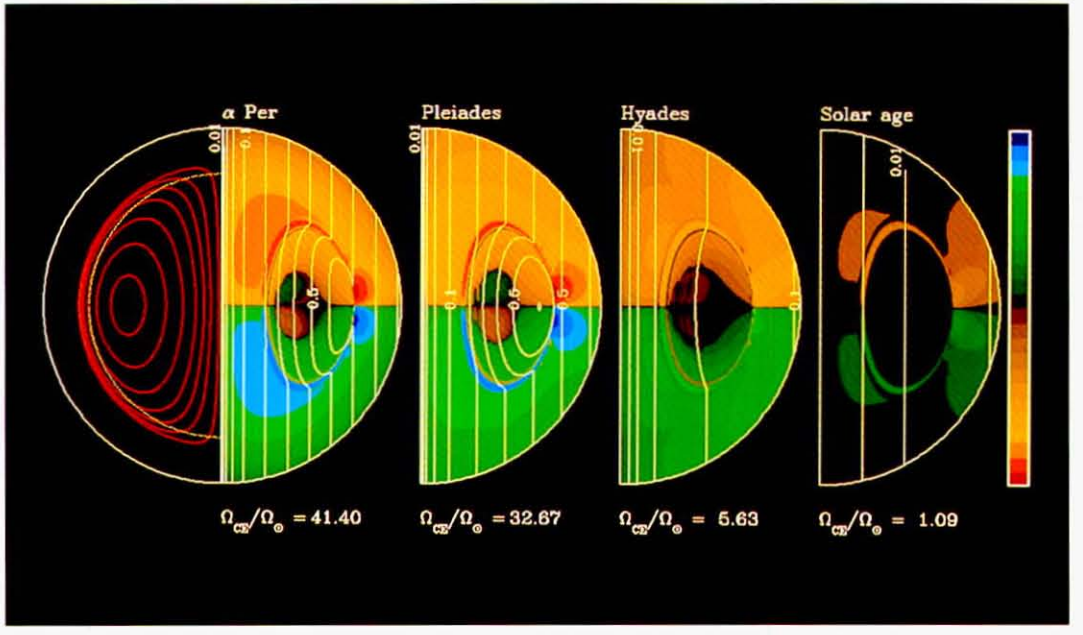
SCIENCE
Glimpsing the Future

The National Center for Atmospheric Research is the keystone of UCAR's programs. Vigorous basic and applied research at NCAR has led to major strides in understanding such phenomena as the Antarctic ozone hole, the workings of the sun, the formation of hailstones, and the risk of a heightened greenhouse effect.

Predicting the future of the earth system—a unit made up of the atmosphere, flora, fauna, oceans, soil, and the sun—is a challenging priority. More than ever, NCAR scientists rely on computer models, the mathematical simulations of the "real world," as their main forecasting tool. This year NCAR completed a major revision of its so-called community climate model, a resource used by scientists worldwide since its advent in 1982. The new version includes better representation of some key variables that are exceedingly hard to quantify, such as radiation reflected from clouds, heat exchanged between the atmosphere and earth, and the circulation of trace chemicals.

UCAR 2001 Goal

Foster a broad scientific program of highest quality



Computer models of the sun's interior can take our understanding beyond present data. These images are cross sections from a simulation of the sun's evolution, beginning early in its lifetime, when it apparently rotated up to 50 times faster than it now does. Intense magnetic fields, produced as the solar wind torques and slows down the spinning sun, act to slow the rotation further. At each time step, the evolving magnetic field appears in yellow and red at the top right and in blue and green (for the opposite polarity) at the bottom right. The first three cross sections correspond to the present age of the star clusters alpha Persei, Pleiades, and Hyades, with the last panel representing the present solar age.

Two UCAR programs are devoted solely to climate modeling. The Model Evaluation Consortium for Climate Assessment, or MECCA, is aimed at identifying and reducing uncertainties in the climate change induced by greenhouse gases (page 20). Among the issues being examined by the Climate System Modeling Program (page 37) are the twists and turns taken by climate from decade to decade.

Other prediction research in UCAR examines more immediate time scales. For example, day-to-day weather forecasts diminish greatly in accuracy after about five days, because small errors in a weather analysis become much larger when extrapolated through time (a result of the phenomenon known as chaos).

However, by intentionally varying the initial data in small amounts, researchers can produce a family of forecasts that shows how much uncertainty lies in a given pattern. Such work at NCAR will lead to forecasts that provide not only the usual details but also an idea of how accurate the forecast itself might be.

Thunderstorms challenge the skills of forecasters on an even shorter time scale. With several universities, NCAR conducted a large 1992 field program in northeast Colorado using computer models, along with data from Doppler radar and other instruments, to predict individual storms within an hour or so prior to their formation. Storm spotters verified hail and tornadoes that were indicated from a distance by radar and software. Out of this experiment and research based on it will emerge improved techniques for warning aviators and the public of storm hazards.

To make their computer forecasts valid and to fully understand the atmosphere, scientists must have base-line data on processes ranging in scope from the molecular to the planetary. A group of atmospheric chemists from NCAR traveled with colleagues to the Arctic to track the chain of chemical events that led to a substantial wintertime drop in ozone levels above parts of North America. Two new satellite-borne sensors are relaying fresh data to NCAR on the sun's ultraviolet radiation output. Looking even farther into space, NCAR solar physicists are using a new instrument that polarizes sunlight to reveal the sun's magnetic field in three dimensions, from a distance of nearly 150 million kilometers (93 million miles).

FACILITIES
Serving the Scientist

UCAR's airplanes, computer systems, and instruments are among the most advanced and widely used in all of atmospheric science. Giant field programs that collect data on large-scale, long-term atmospheric processes rely on NCAR-based equipment, but smaller projects use it as well. Some UCAR facilities provide service well beyond single field efforts: for instance, the Unidata program assists over 100 universities and colleges in obtaining and processing weather data continuously.

Four aircraft make up the NCAR fleet: a Beechcraft Super King Air, a North American Rockwell Sabreliner, a Schweizer sailplane, and a four-engine Lockheed Electra. The Electra, with a large cargo capacity and an altitude range of up to 10,000 meters (33,000 feet) above sea level, is the workhorse of the group. In 1992 scientists used the plane to assess biomass burning in Brazil, stratocumulus clouds

At sites ranging from the exotic to the mundane, the University NAVSTAR Consortium tracks the motion of the earth's crust via satellite signals. Two UNAVCO technicians set up equipment near Rotorua, New Zealand.

Instrument packages dropped from aircraft are an essential way to study hurricanes and other hard-to-observe weather events. NCAR developed this lightweight instrument package as well as its unique square-cone parachute, whose design was patented this year.

over the Azores, and ozone depletion above Greenland. Added this year was the Electra Doppler radar, a unique dual-transmitter system that will provide insight on thunderstorms and other cloud processes.

Simulating climate is the main task for NCAR's two supercomputers. The larger of these, a CRAY Y-MP 8/864, ran at full capacity throughout the year with nearly 1,000 users across North America—plus over 450 within UCAR—logging onto it. Aside from running climate models, this computer was also used in January and February to make forecasts for the Stormscale Operational and Research Meteorology Program's Fronts Experiment System Test, or STORM-FEST (page 16). A second Cray computer at NCAR, funded by an industry consortium, is dedicated to the MECCA project noted above.

Part and parcel of NCAR's full-service computing resource is a staff of consultants who provide in-person help and write documentation. A growing scientific visualization lab brings computer output to life with full-color images on film and videotape. In the spirit of community that drives UCAR science, many computer models created at NCAR—whether regional or global, chemical or biological—are shared with scientists elsewhere.

When a new or unusual type of measurement is needed, NCAR's design and fabrication shop can custom-make a suitable instrument. NCAR's division for atmospheric technology advances the leading edge of meteorological sensing by improving systems that measure the atmosphere remotely (such as radar) or directly (such as balloon-borne packages to sense temperature, humidity, and pressure).

UCAR 2001 Goal

Acquire and develop state-of-the-art research facilities

A few experiments each year call for one of the self-contained facilities with which NCAR provides both instruments and the people to operate them. A collection of 49 portable, solar-powered weather stations can be arranged to form a dense network. A specially built van deploys and tracks weather balloons. A set of 15-meter (50-foot) instrumented masts measures the state of the lowest atmosphere. New this year is an integrated system that uses upward-pointing radar beams to measure moisture, wind, and temperatures through the lower atmosphere as often as every half hour.

EDUCATION
Starting Young

This was a year of growth for UCAR's education efforts. Middle-school teachers from four states came to NCAR in July 1992 to begin a three-year, hands-on training program (page 22). Later in the summer, scientists and educators came to a UCAR workshop to consider another new idea: using computer-accessed weather data to help children learn math. The planning workshop for this project—called Skymath—involved government agencies, school districts, and private firms. Over a proposed 18-month demonstration period, several UCAR universities hope to conduct field tests and develop materials.

Project Skymath is building on a proven success: UCAR's Unidata program, by which colleges and universities receive weather information for teaching and research. Unidata provides affordable access to a satellite broadcast of real-time weather data through a contract with a commercial firm. The program also provides software to capture and display the data in a variety of ways, including a new image-analysis package released this year.

UCAR 2001 Goal

Educate students and scientists, with emphasis on women and minorities

Continued interest in global change among college students has triggered the creation of new teaching aids. NCAR is working with educators to develop a set of self-contained modules that will help professors relay a variety of global-change concepts to undergraduates. Out of a UCAR-organized summer workshop for graduate students has emerged a comprehensive text on climate system modeling, edited by NCAR senior scientist Kevin Trenberth and published by Cambridge University Press late in 1992.

Many motivated students visit NCAR to pursue research. NCAR's Advanced Study Program this year hosted 24 graduate students and 28 postdoctoral researchers who are working with NCAR scientists as part of two-year fellowships. For other recent Ph.D.s, UCAR collaborates with the National Oceanic and Atmospheric Administration (NOAA), the Office of Naval Research, and the National Weather Service (NWS) to sponsor visiting scientists in the areas of climate and global change, ocean modeling, and operational forecasting.

UCAR scientists were particularly active this year as trainers and mentors of a diverse new set of atmospheric researchers. A summer program for minorities paired each of 17 undergraduates with a UCAR adviser for research and report writing. Long-time NCAR scientist Warren Washington was featured in a nationwide video-conference aimed at African-American high-school and college students. NCAR members of Women in the Atmospheric Sciences served as role models for young women interested in science. And a number of NCAR staff joined a local tutoring program to work one-on-one with students in elementary, middle, and high schools. (In synch with these efforts, an internal committee on institutional equity laid out an ambitious plan to establish UCAR as a model workplace in equality, diversity, and fairness.)

UCAR's Summer Employment Program connects promising undergraduates with scientist-mentors. NCAR's David Erickson (left) reviews satellite data with Atul Saran (Stanford University).

ADVOCACY AND COMMUNICATION
Spreading the Word

The first president of UCAR, Walter Orr Roberts, believed passionately that science must serve humanity. UCAR continues to carry that message, one that resonates more deeply as we further understand humanity's impact on the atmosphere.

NCAR's Environmental and Societal Impacts Group examines how human actions influence the environment and vice versa. Composed of economists, political scientists, geographers, and other specialists, ESIG works closely with researchers across the world to assess regional climate impacts. For instance, this year ESIG showed how overfishing can magnify the ill effects produced in the world's fisheries by climate variability. Another ESIG topic: how the occurrence of extreme weather events (floods, blizzards, and the like) might change in a changing climate. A quarterly newsletter issued by ESIG and supported by the United Nations Environment Programme surveys the field of climate impacts.

UCAR 2001 Goal

Improve communication among scientists, policymakers, and the public

Much of UCAR's communication is designed to update the public on atmospheric research in easy-to-understand ways. In cooperation with NOAA's Office of Global Programs, UCAR's Office for Interdisciplinary Earth Studies is producing a series of colorful booklets on climate and global change topics. A half-million copies of the second in this series, *Our Ozone Shield*, were published in late 1992, with the majority going to some 30,000 science teachers and their students. These and many other technical and nontechnical publications can be obtained from UCAR free of charge, and items from NCAR's extensive collection of slides, photos, and videos are available for a nominal usage fee (page 35).

Each year thousands of people make first-hand contact with NCAR by coming to the Mesa Laboratory, famous for its I.M. Pei design and dramatic setting. Both guided and self-guided tours include exhibits on NCAR research and instruments. NCAR scientists—and local citizens who volunteer as tour guides—spoke to the thousands of schoolchildren who toured the Mesa Lab in 1992.

Some two million people are expected to see an NCAR-prepared traveling exhibit that will explain how aviation weather

Among the many visitors at NCAR in 1992 was a group of meteorologists and spouses who convened for the 50th anniversary of a World War II training class in military weather forecasting. Here, some of the group examine the prototype for a traveling display on wind shear.

hazards are detected. Interactive elements will include simulations of wind shear and a walk-through air-traffic control tower. Two copies of the exhibit will rotate among 20 airport terminals and science museums across the country between 1993 and 1995.

UCAR continues to inform federal officials on research results in the atmospheric sciences and to link those results to national priorities. Along with channeling information to and from Congress and the executive branch, the UCAR Office of Government Affairs (OGA) arranges for expert testimony on topics such as global warming and air pollution, and sponsors visits of congressional members and staff to UCAR. The office established new ties with the National Association of State Universities and Land-Grant Colleges and launched a monthly newsletter, *OGA Briefs*, that covers science policy, regulations, meetings, and other government-related news.

TECHNOLOGY TRANSFER
Bringing Innovation to Industry

Much of the technology developed in the course of UCAR research has useful application beyond the laboratory. UCAR has the responsibility to make this technology—a national resource—available to other parts of the public and private economy. In this way, UCAR's achievements produce the broadest societal benefit and contribute to the United States' economic and scientific well-being.

The Office of Industry Relations (OIR) is the intermediary between UCAR and industry. OIR's staff monitor the scientific output of NCAR and other UCAR programs, identifying technologies that have commercial value. They then help scientists through the intricate process of securing rights to their inventions or other intellectual property. Typically, a manufacturer or distributor is licensed to make or sell products based upon the technology. The products thus marketed bring royalties and license fees back to UCAR to enhance scientific programs.

In 1992, 55 technologies created within UCAR programs were examined by OIR, and 40 of those were considered to be potentially patentable. Twelve patent applications were pending at the end of the fiscal year, and two patents were issued—one for an NCAR air-sampling technique and the other for the design of an instrument-bearing parachute (page 39).

Doppler radar data and thunderstorm formation are two of the topics covered in training modules prepared on laser discs by UCAR's Cooperative Program for Operational Meteorology, Education, and Training. The modules are being used to train thousands of weather forecasters at their home offices.

Some UCAR research is developed with applications in mind from the start. NCAR's Research Applications Program is

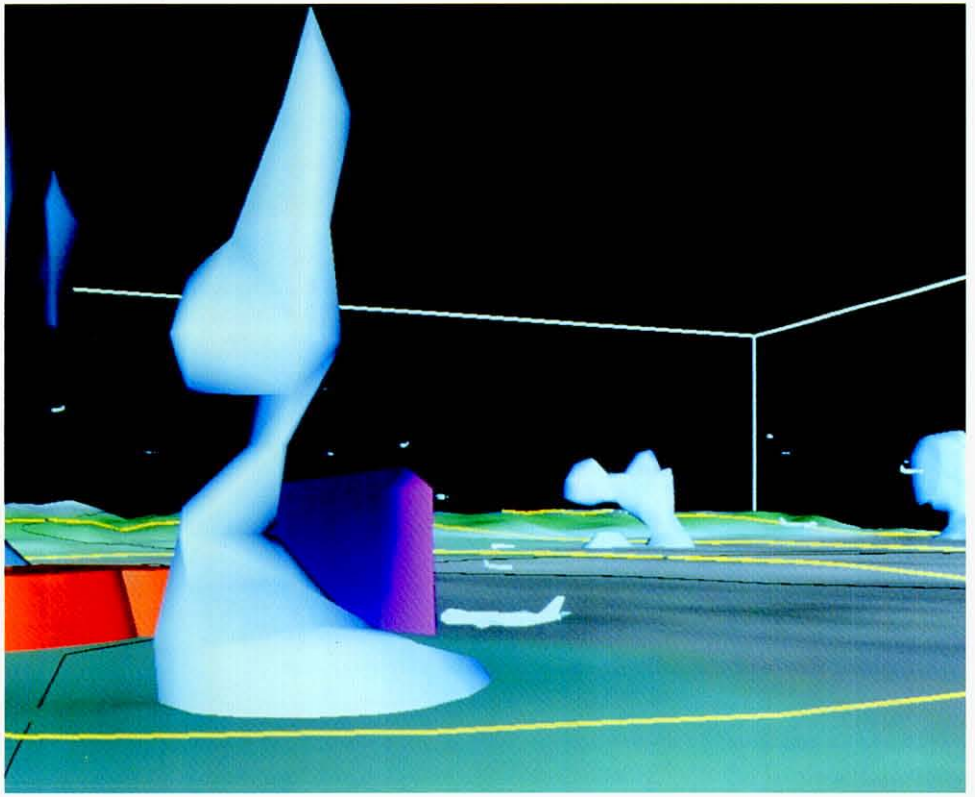
collaborating with NOAA and other researchers on the Aviation Weather Development Program, aimed at improving weather information available to pilots, air traffic controllers, and others, as well as their access to that information. Funded largely by the Federal Aviation Administration, the program began with Doppler-radar detection of hazardous wind shear. It has since expanded to icing forecasts and other kinds of prediction. Airports across the country are now installing commercial versions of NCAR-created technology that warns pilots and controllers of wind shear. Planes soon may carry humidity sensors and de-icing devices invented at NCAR.

UCAR 2001 Goal

Transfer technology to the public and private sectors

Another application of UCAR's work involves a convenient new means of data storage and transfer: CD/ROMs (compact discs with read-only memory). This year UCAR put the voluminous data from the STORM-FEST experiment and those from six months of global weather analyses onto CD/ROMs. Eventually, five years of the latter analyses will be available.

UCAR's Cooperative Program for Operational Meteorology, Education, and Training (COMET) has used laser discs to create computer-based learning modules that bring practical research results to NWS forecasters. To date, some 600 module units have been delivered to COMET sponsors (including the NWS, the Air Weather Service, and the Naval Oceanographic Command), while over 75 have been distributed to other users by Weather Information Technologies, Inc., a for-profit subsidiary of the UCAR Foundation. Created in 1986, the Foundation is the exclusive agent for the licensing of products based on UCAR technology.



Storms and other aircraft threats come alive in a new three-dimensional display created at NCAR. Using the technique of virtual reality, it can depict weather hazards existing along a path taken by a pilot on approach to an airport (other planes are visible at various points). Shown in red are microbursts—pockets of descending air. Regions of rain and hail are in white. The purple zone represents a gust front traversing the area.

PARTNERSHIPS
Joining Forces

Itself a partnership, UCAR continuously works with allied government laboratories, universities, other research centers, and related professional associations. One of the prime venues for such effort is in support of large research programs. In 1991, UCAR became the management home for one of the largest and most complex field programs of all time: a four-month study in the western Pacific called TOGA COARE, the Tropical Ocean and Global Atmosphere Program's Coupled Ocean-Atmosphere Response Experiment. TOGA COARE involved 1,200 people from 19 nations in the winter of 1992–93. UCAR is also handling many of the logistics for the U.S. Weather Research Program, a national initiative to understand storm-scale weather. NCAR is the U.S. headquarters for the Global Tropospheric Chemistry Program, analyzing the chemical processes of the lowest 90% of the atmosphere.

UCAR's service to its community is strengthened by the worldwide interactions resulting from a steady stream of visitors. Collaborative papers among NCAR scientists and those at other institutions are the norm, and the total research time spent by visiting scientists is roughly the same as that from scientists on staff. Major conferences and workshops draw thousands more for shorter stays.

UCAR also sponsors scientific visitor programs outside of Boulder. The UCAR Visiting Scientist Programs support some 50 researchers who work at other national centers and schools. Subjects of study include climate and global change, ocean modeling, and numerical weather prediction. As of 1992, 17 institutions have hosted at least one participant in these programs.

UCAR 2001 Goal

Strengthen partnerships, especially among operational and research scientists

Among other partnership-building efforts of UCAR:

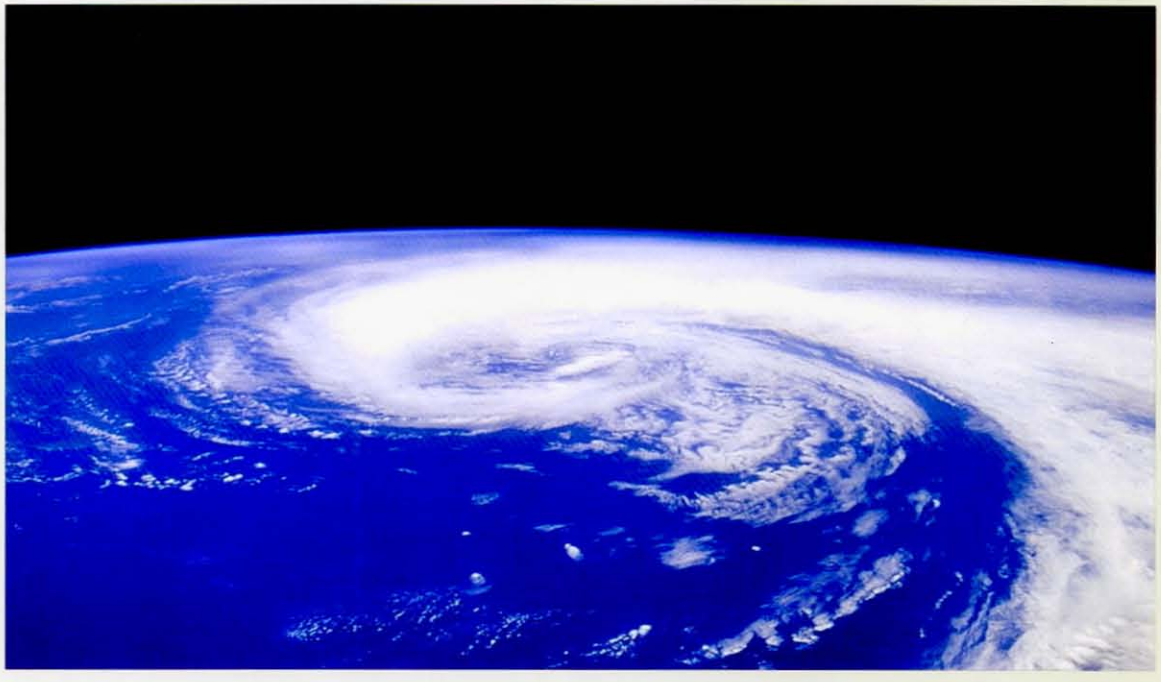
- The Academic Affiliates Program brings universities and colleges with nondoctoral programs in atmospheric or related science into contact with UCAR and its members.
- The International Affiliates Program comprises universities and research centers in 15 nations that exchange information, visitors, and students with other institutions and with UCAR programs.
- The Corporate Affiliates Program helps companies make use of atmospheric research and technology.
- COMET connects research and operational meteorologists, fostering collaboration and use of research results in daily forecasting.

The tail section of NCAR's Electra airplane sported a new invention this year: the Electra Doppler radar. Built through a partnership between NCAR and a French scientific agency, ELDORA features two transmitter/receivers that send high-resolution signals toward and away from the plane's direction of travel.

Blank

The World of UCAR

Global concerns call for globally oriented research. Whether it be with a computer program or a field program, UCAR ultimately looks to the entire earth system as its field of inquiry. Herein are the stories of nine places to which UCAR and its collaborators went in 1992 for work that led—in a variety of ways—to a better understanding of our ever-changing earth.



KANSAS CITY

A Close-Up Look at Winter Storms

Steven Semmer takes a sample of Kansas soil as part of a project within STORM-FEST to measure the exchange of heat and moisture between the atmosphere and the ground.

Late in the winter of 1992, some dormant cropland just northwest of Kansas City became highly productive—not agriculturally, but meteorologically. From January to March, a dense network of instruments atop the cold brown soil measured the structure of wintertime fronts and the rain, snow, and sleet they brought.

It was part of a study in the U.S. heartland called STORM-FEST, the Fronts Experiment Systems Test of the Stormscale Operational and Research Meteorology Program. STORM-FEST was conducted by the UCAR Office of Field Project Support, along with some 150 people from over 20 universities and institutions, particularly the National Oceanic and Atmospheric Administration (NOAA). The mission: to investigate winter storms and to test new equipment, forecast techniques, and computer models.

It is still a challenge for forecasters to predict the details of a winter storm, such as its precise track and local snowfall amounts. Improvements in weather data expected in the 1990s will help, but also needed is a better understanding of exactly what goes on inside a winter storm and how it interacts with the surrounding atmosphere and the ground below.

Enter STORM-FEST. Its field operations were centered at Richards-Gebaur Air Force Base, near Kansas City and at the heart of a 13-state study area spanning the Great Plains. Three research aircraft were based at Richards-Gebaur, with another in Houston. A wealth of other equipment, both research and operational, came into play: profilers and radiometers (two types of vertically pointing sensors), Doppler radars, portable surface observing stations, and radiosondes (weather balloons)—all supplemented by standard weather-service data collected separately.

Although STORM-FEST observations were managed out of Richards-Gebaur, much of the expertise needed in computer modeling and forecasting was in Boulder.

The two sites were connected by a high-speed teleconferencing line specially installed for the program. Each day a weather briefing was telecast to Richards-Gebaur from NOAA's Forecast Systems Laboratory in Boulder, where the latest computer forecasts were available. Through the interactive hookup, scientists from both sites were able to confer after each briefing.

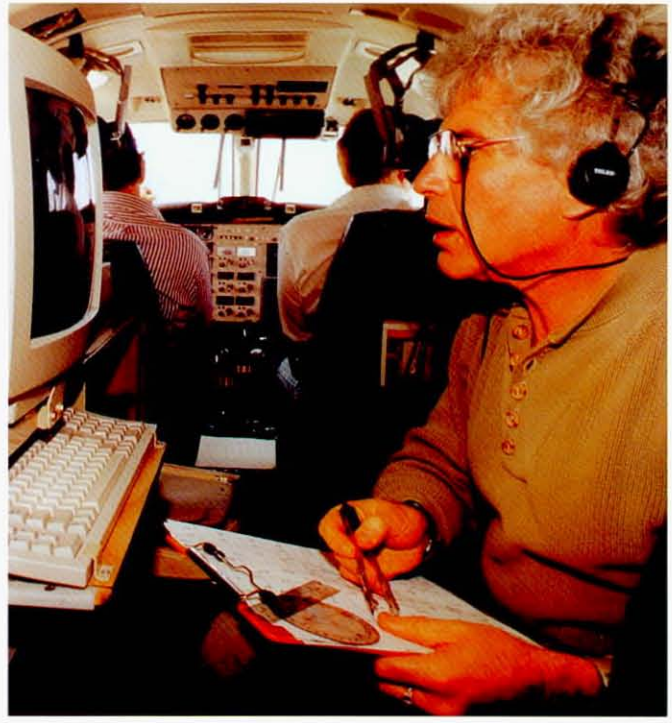
Some of the most helpful guidance came from the mesoscale limited-area model–Version 4 (MM4), a computer forecast model designed by NCAR and Pennsylvania State University to study weather systems the size of a winter storm. The MM4 was run each morning on NCAR's CRAY Y-MP 8/864 supercomputer. The results, looking 36 hours into the future, were transmitted to Kansas City in time to guide operations for the next two days. Thanks to output from the MM4, aircraft and ground sites were well prepared for the winter's biggest storm, a March blizzard that dumped over a half-meter (20 inches) of snow on parts of northeast Colorado before bringing heavy rain and snow across the central plains.

STORM-FEST data gathering was most concentrated over northeast Kansas. Within a region about 50 kilometers (30 miles) on each side was one of the densest networks ever assembled to study the lowest mile of the atmosphere, known as the boundary layer. It is within this layer that weather systems interact with the ground, producing turbulence and exchanging heat and moisture. Four instrumented towers were furnished by NCAR to monitor the surface-air interchange. They were surrounded by five profilers, ten surface stations, and two Doppler radars. The result: a detailed, three-dimensional weather snapshot every five to ten minutes.

While using STORM-FEST data to analyze the structure and evolution of winter storms, researchers will assess how the experiment itself evolved—how instruments, facilities, computer models, and other elements came together and performed. The assessment will be provided to the National Weather Service to help guide its nationwide modernization and restructuring, which will involve instruments and techniques much like those used in STORM-FEST. Data from the experiment are being made available to researchers in a state-of-the-art management system, both on line and on CD/ROM compact discs.

A sequel to STORM-FEST is being planned: a major spring and summer field experiment scheduled for the central United States in 1995. Instead of snow and Arctic blasts, that project will focus on storm systems that hammer the Midwest with heavy rain, high winds, hail, and tornadoes.

NOAA scientist Robert Grossman checks data aboard NCAR's Electra aircraft.



TURKEY

Measuring Earthquakes via Satellite

The Turkish city of Erzincan was ravaged by a March 1992 earthquake.

For 3,000 years, through oral histories and myths, shepherds and villagers in eastern Turkey have passed on to their daughters and sons vivid accounts of waters surging from the ground, buildings collapsing, and the earth ripping apart into dark chasms. In March 1992 a modern-day apocalypse occurred when a Richter-magnitude 6.9 quake struck southeast of the densely populated city of Erzincan, leaving up to 800 dead and thousands homeless. Certainly this latest disaster entered the centuries-old oral record. But this time, the earth's movement was also documented by a satellite network that can track the earth's restless crust to within millimeters.

At the time of the March quake, 17 Global Positioning System (GPS) satellites operated by the U.S. military were orbiting the earth at 20,000 kilometers (12,000 miles) altitude, far above communications satellites. Although scientific researchers are not privy to the military's signal codes, they can use the radio signals from the satellites to measure the relative positions of points on earth—much as a sailor at sea can guide his ship by a lighthouse even if he cannot decipher the light's on/off pattern.

The University NAVSTAR Consortium (UNAVCO), which has 48 university members, provides equipment, engineers, and training to researchers around the globe, enabling them to use this high-tech positioning system for a variety of earth science applications. Supported by the National Science Foundation's Earth Science Division, UNAVCO joined UCAR in October 1991. Its staff is now working on ways to use the GPS network for measuring polar ice sheets and, eventually, water vapor or other qualities of the global atmosphere.

We know that the earth is not a single solid chunk but more like a three-dimensional puzzle. The large, irregular pieces fit together—not exactly, but with some space and give between them. When these puzzle pieces, called tectonic plates, writhe from the pressure of heat escaping from the earth's core, a catastrophic earthquake can occur, shattering the earth at ground level even though the actual "slip" may be tens of kilometers underground.

The eastern Turkey section of this global puzzle has long been a geological hot spot. As the Eurasian and Arabian tectonic plates shove headlong into each other along the North Anatolian Fault, where the March 1992 quake occurred, they squeeze the Anatolian Block (Asian Turkey) westward into the Aegean Sea. Simultaneously, this same wedge of land is being pulled south toward Africa by the Hellenic Arc (Greece). With all this pulling and shoving, Turkey is traveling at a speed of several inches per year.

A UNAVCO receiver, perched high above Turkey's North Anatolian Fault, collects GPS signals.

Because these drifting plates in the eastern Mediterranean bear highly populated areas, a team of researchers supported by UNAVCO and led by Robert Reilinger (Massachusetts Institute of Technology) began tracking the plates' motion in September 1988. But how could scientists measure these changes in the earth's crustal puzzle if all the pieces in it are moving?

Reilinger and his colleagues set round steel pins slightly wider than a pencil at 20 sites throughout the region, including one pin on either side of the North Anatolian Fault in eastern Turkey. Above each of the markers, the team set up standard GPS equipment: a round antenna on a tripod 1.5 meters (5 feet) high, attached to a yellow shoebox-sized receiver powered by solar-rechargeable batteries. Signals beamed from the GPS satellites were simultaneously recorded by each station, allowing the base-line distances between them to be calculated within millimeters.

In September 1991, the team returned to Turkey and remeasured the station positions; six months later, the quake hit. The North Anatolian Fault had ruptured within 20 to 30 kilometers (12 to 18 miles) of the two steel pins.

Within 24 hours UNAVCO sent two field engineers and four GPS receivers to the site. Reilinger promptly joined the UNAVCO team with fellow researchers from MIT, Turkey's General Command of Mapping, and the Kandilli Observatory in Istanbul. The researchers' computer models, with the new data plugged in, showed that a one-meter slip had occurred from 200 meters to 15 kilometers (0.1 to 9 miles) beneath the ground, extending 40 kilometers (25 miles) along a segment of the North Anatolian Fault. When Reilinger combined this new information with his earlier studies, he concluded that accumulated stress along the fault had not been sufficiently relieved. He predicts that an even larger earthquake will strike soon.

By plugging hard numbers like these into theoretical models, researchers better understand our planet's crustal maneuverings. The tales of dark chasms and surging waters will continue to enter the lore wherever humans are rendered helpless in the face of unexpected earthquakes. But, with UNAVCO's help, scientists are working toward the day when they can use this increased understanding to save lives and property.

BOULDER

Practical Answers on Global Warming

NCAR's Mesa Laboratory is the home of the supercomputer devoted to MECCA.

The issue of global warming often seems to have more questions than answers. Scientists debate its extent and causes; some question its existence. Policymakers struggle to set reasonable yet effective controls on emissions of greenhouse gases, often without knowing either what will be effective or what is reasonable. There is a sense of urgency, a concern that if we are to understand and prepare for the possibility of global warming, we need to act soon. But our actions are frustrated by a troubling awareness of our own ignorance about how the earth's climate works. Society needs answers now, and we need them on a regional scale, because that is the level at which the impacts will be most noticed.

The purposes of the Model Evaluation Consortium for Climate Assessment (MECCA) are to quantify the probable range of future climate change and to assess the uncertainties in computer-model predictions of climate change. MECCA-supported researchers around the world are working to evaluate the computer models on which global-warming predictions are largely based, to provide policymakers with information they can use to coordinate decisions with scientific developments, and to identify key topics needing research to improve climate forecasts.

MECCA is supported by a multimillion-dollar international partnership that includes UCAR and representatives of industry, government, and academia from France, Italy, Japan, the Netherlands, and the United States (see listing on page 37). Other scientists from Australia and elsewhere around the world are contributing on specific research components. A two-processor CRAY Y-MP super-computer installed at NCAR is dedicated to MECCA research.

The project is being carried out in two major phases. Phase I, which began in 1991, is aimed at finding out which variables—such as the amount of increased carbon dioxide (CO_2), the contribution of other greenhouse gases, or tropical deforestation—have the greatest effect on potential climate change. Preliminary results have been presented at various international meetings, including the 1992 United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil. In summary, the MECCA Policy Committee reports the following:

- As atmospheric CO_2 increases, the rate of global warming decreases, with a

less-than-linear increase in mean temperatures at midlatitudes. This finding is important in considering a tolerable upper limit for atmospheric CO_2.

- While current climate simulations "forced" by greenhouse gases indicate that temperatures should rise more at polar than at middle latitudes, 30 years of observations detect no warming trend in the Arctic. This helps document the natural variability inherent in the Arctic climate that interpretations of simulated climate have to take into account.

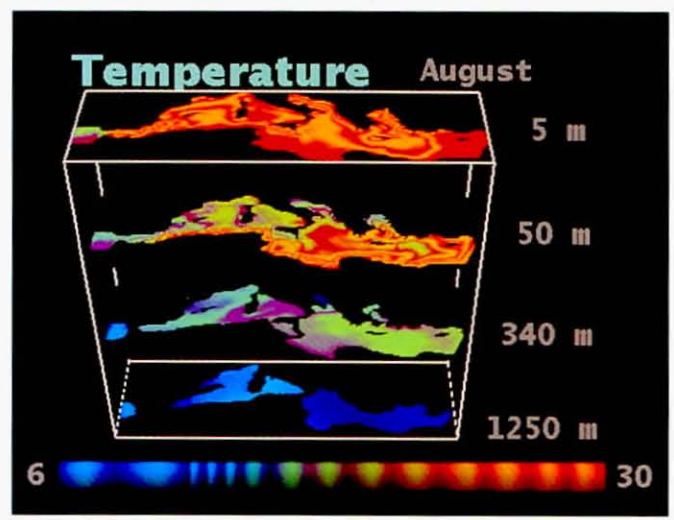
- Contrary to prior assumptions, the manner in which each of the other greenhouse gases (chlorofluorocarbons, methane, ozone) control the global balance of radiation is quite different from the influence of CO_2. This finding substantially changes various assessments of "global warming potentials" and will be important in assessing, for example, tradeoffs between increases in CO_2 and decreases in chlorofluorocarbons.

- Initial findings indicate that modeling on regional scales is critical to realistic understanding of the greenhouse-gas issue. But these regional simulations depend on the quality of the input conditions supplied by global climate models. If the large-scale circulations simulated by the global models are inaccurate, the regional simulations generated from them may have significant errors.

Phase II of MECCA will work to fill in some of the missing pieces from Phase I research. It will feature a smaller number of studies, with subcomponents that are standardized among several research teams so that the results can be usefully compared with each other. Phase II also will shift the focus of MECCA, as it incorporates the results of the earlier experiments and applies them to the assessment of impacts on the earth and on society.

One such study, begun in Phase I, investigates the effect of land-surface changes—specifically, tropical deforestation in the Amazon and Southeast Asia—on climate change. So far, the research has found that Amazon deforestation increases both mean surface temperature and its variability and affects precipitation patterns in surrounding regions. Another MECCA team is studying regional climate change scenarios for the United States and Europe. They have found that ecosystem impacts in the northern Great Plains may be slower to emerge and take much longer to reach equilibrium than previously believed, because the impacts may be largely dependent on soil chemistry and nutrient changes.

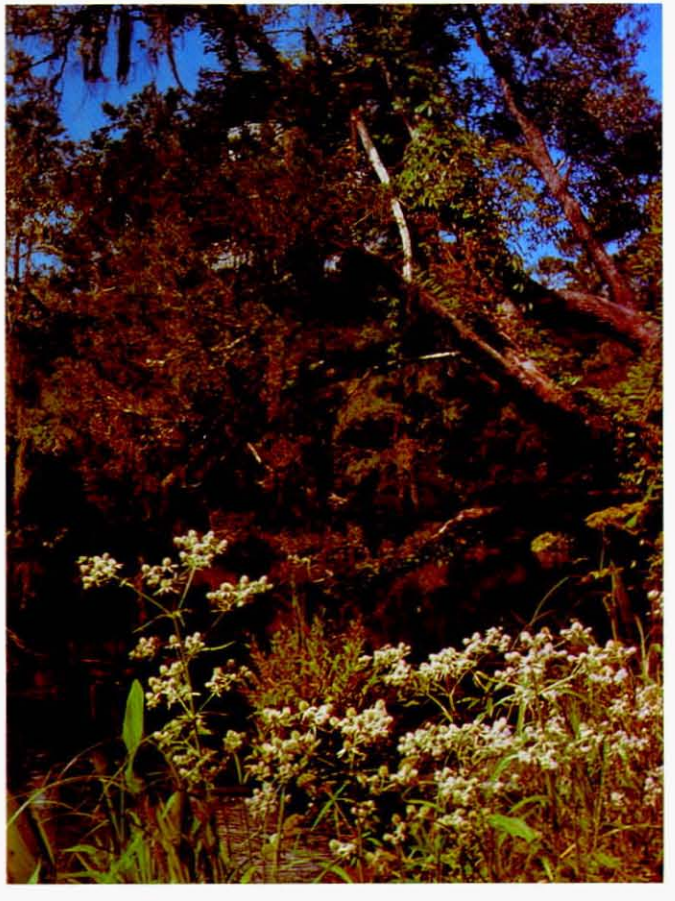
No single effort will produce all of the answers needed to confront global warming. But by the end of its scheduled three-year lifetime, MECCA should provide some of the answers—and a much clearer understanding of the most important questions.



Since water retains heat much longer than air does, the earth's oceans and atmosphere interact in ways that are challenging—but crucial—to understand. This diagram shows one month's average temperature for the Mediterranean Sea in cross-sections taken at four depths, labeled in meters (temperature is in degrees Celsius). It came from a MECCA computer simulation that followed the Mediterranean over several decades. In Phase II, this model will be linked to a model of the North Atlantic Ocean.

NORTH CAROLINA

Atmospheric Science and a Can of Soda



Emily Roberts teaches physical science at J.F. Webb High School in Oxford, North Carolina. The rolling landscape around Oxford is thick with tobacco and pine forest, lined by waterways, and often topped with haze.

Roberts noticed the humidity of her region more than ever in the fall of 1992, after she had spent a summer in Boulder attending a unique teacher-preparation workshop conducted by NCAR. "Sometimes the simplest things are the most useful," says Roberts. One simple thing she found was the lack of moisture on the outside of a can of soft drink during a hot, dry Boulder afternoon. "I've already used this in class to illustrate the concept of condensation. The students just can't imagine a cold can of soda without water on the outside of it."

A 15-year veteran of the classroom, Roberts is one of 40 teachers from four states coming to NCAR for three consecutive summers as part of Project LEARN (Laboratory Experience in Atmospheric Research at NCAR). The program is one of many being sponsored by the National Science Foundation to improve the nation's elementary and secondary science education in the 1990s.

For Roberts and her 39 colleagues, most from middle schools, Project LEARN offered a chance to get out of the classroom and into a research environment. The first summer included a crash course of sorts: over 20 seminars and hands-on activities led by UCAR scientists on a wide range of weather and climate topics. "I brought back a lot of new knowledge about meteorology," says Roberts. The attendees also worked with fellow educators to refine their ways of teaching science and to develop their leadership skills. In the 1993 and 1994 sessions, the Project LEARN teachers will further sharpen their classroom technique. During the intervening school years, they are meeting in their respective states to share their LEARN experience among themselves and with other teachers. They are also devising local studies to be carried out by students. The project's directors are biologist and educator Joyce Gellhorn, science-education specialist Carol McLaren, and NCAR climatologist Patrick Kennedy.

Roberts's district (Granville, North Carolina) is studying temperature variations across different microclimates: forest

canopy, a highway blacktop, an open field. "We're going to be taking readings at different depths in the soil. We have a wooded area with red clay 50 feet [15 meters] from my classroom," says Roberts. Her students will take temperatures every day, which she expects will be a good antidote for "the tendency to research science fair projects the night before. Research is a long, drawn-out process. You don't just take one measurement and say, 'That's a fact.' "

Though Roberts says her students are most fascinated by tornadoes and hurricanes, "what I was looking for in Boulder were some concepts to bring into my teaching of physical science as a whole. I wanted some demonstrations that were not just easy, but effective." Along with the serendipitous soft-drink can, Roberts brought back an illustration of hot air's buoyancy using the tissue paper that separates boxed sheets of transparencies.

"You fold the paper into three sections, put it on a table, set the corners on fire, and it takes off. The kids love it. Otherwise, I probably would have been throwing out every one of those tissues."

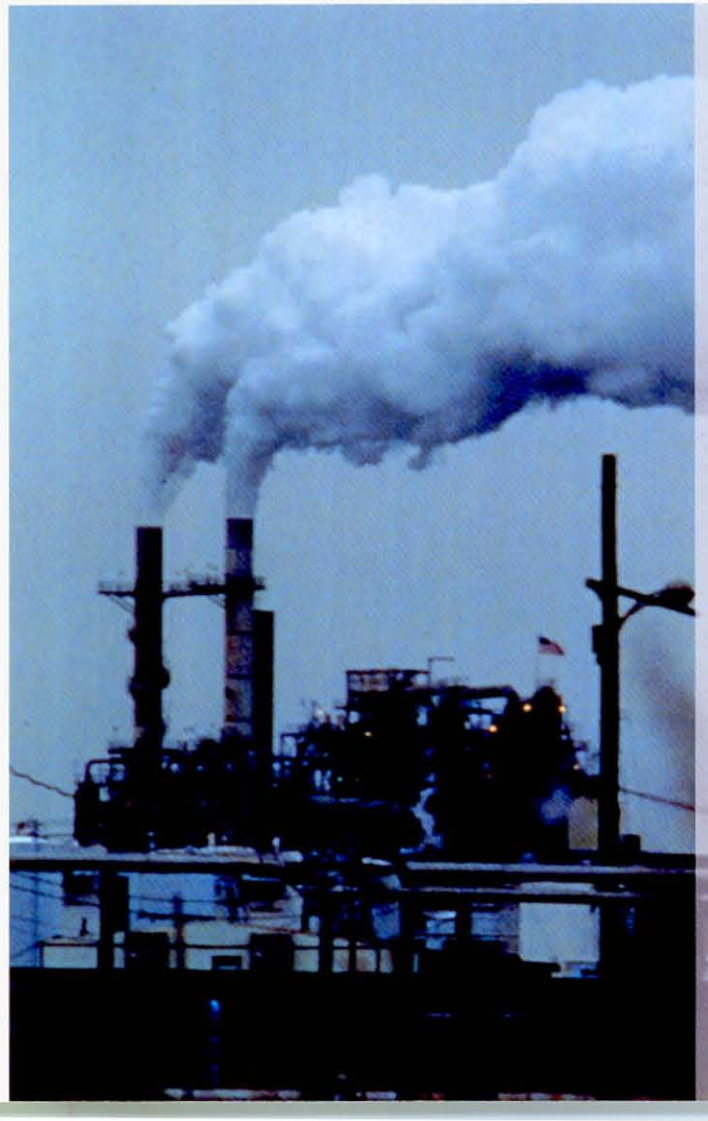
The planners of Project LEARN designed it so that its impact will branch out in time, with the 40 teachers inspiring hundreds of peers and motivating thousands of students. "I wish that more teachers could participate. I think anybody and everybody should have this experience," says Roberts. As she drives 100 kilometers (60 miles) each workday to Oxford and back from her home in Buffalo Junction, Virginia, Roberts watches the atmosphere with a new perspective.

"We have a milky sky here and you can't see individual clouds very often. But after being in the West all summer, a cloud is never, ever going to be the same again. I look at the clouds and their transformations more than I ever did. It's amazing to me. Going to the workshop really opened me up."

Emily Roberts confers with Patrick Kennedy, a principal investigator in Project LEARN.

SNOWMASS

Industry and Ecology Meet Face to Face



Summer in Colorado's high country brings to mind sunny days, cool evenings, and tranquil mountain hikes—not an intense discussion of how humans are impacting our earth. That more sober pursuit drew 51 people to a retreat in the Colorado Rockies last July. Scientists, industrialists, environmentalists, and government officials met for two weeks to explore together a brand-new discipline: industrial ecology.

It was the fifth in the Global Change Institute series, organized by the UCAR Office for Interdisciplinary Earth Studies (OIES) and sponsored by a number of U.S. government agencies. Previous annual sessions, all held in Colorado's Snowmass Village, have focused on trace gases and the biosphere, historic and prehistoric records of climate change, modeling of the earth system, and changes in land use and land cover.

These are all gatherings of several related scientific disciplines. Each year a search committee casts its net worldwide, bringing renowned experts on the subject at hand from the natural, applied, and social sciences. Director of this year's institute was Robert Socolow of Princeton University's Center for Energy and Environmental Studies.

Each institute is split into two parts. First comes a four-day set of invited talks that give background on the problem at hand. This year's goal was "to add coherence to the thinking about industrial ecology by clarifying what is more and less important and what is well and poorly understood—in short, to launch a field." Over the next week, attendees entered the institute's second phase: they divided into three working groups that held in-depth discussion and, eventually, produced a set of written reports to be compiled into a book-length report in late 1993.

Given the range of interests represented at the institute, there was noteworthy agreement that the threat posed by global industry to our planet's integrity is indeed real. Even greater agreement emerged that industry needs to start from a new "square one," seeing the earth as a fragile partner rather than an unlimited resource. Participants defined industrial ecology as resting on the interfaces of engineering, ecology, economics, and the earth sciences—looking at an environmental problem as a whole rather than trying

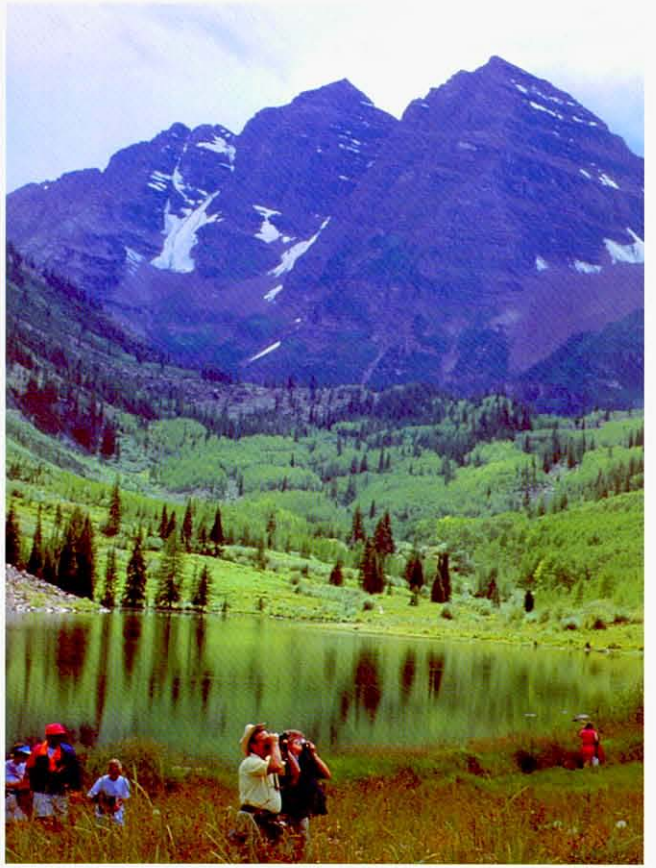
to understand it by studying its components in isolation.

One of the institute's conclusions was that a coalition among industry, environmental and social science, and government must be built for industrial ecology to work. Those devoted to protecting the environment tend to overestimate the flexibility of industry, while manufacturers often see our natural ecosystems as being more pliable than they actually are. But paradigms can shift. Several institute speakers envisioned a reasoned blend of government incentives and regulations—along with a logical demonstration that efficiency can reduce costs—to bring the change in perspective needed by all parties.

Several examples of practices in line with industrial ecology were presented at the institute. These included AT&T's on-site generator for electronic process chemicals, Dow Chemical's continuous reductions in energy consumption and waste production during chemical manufacture, Hewlett-Packard's recycling and reuse of computer printer cartridges, General Motors–Europe's commitment to take back and recycle its Opel automobiles at the end of their useful life, and Volvo's development of an index for ranking the environmental desirability of alternative designs of automotive components such as engines and bumpers.

Among the institute's findings:

- Biomass fuels have great potential to supplant fossil fuels and thus mitigate any global greenhouse effect, but care must be taken to avoid adverse impacts on land use, biodiversity, and local economic and social structures.
- Some technologies discarded in developed countries because of adverse environmental impacts, such as leaded gasoline, are being deployed in developing countries. Solutions to this problem will require international teamwork.
- Much can be gained by transforming the economy from goods to services, since often what is desired by consumers is not a product itself, but the features it provides, such as transportation or safety. An electric utility can "sell" energy efficiency as well as energy supply, benefiting the whole economy; or a chemical company can reduce pesticide use by providing a range of pest-control options rather than selling only chemicals.
- Concern for the environment is often seen as a constraint upon economic activity, when in fact it may stimulate innovation and create many opportunities for economic growth.

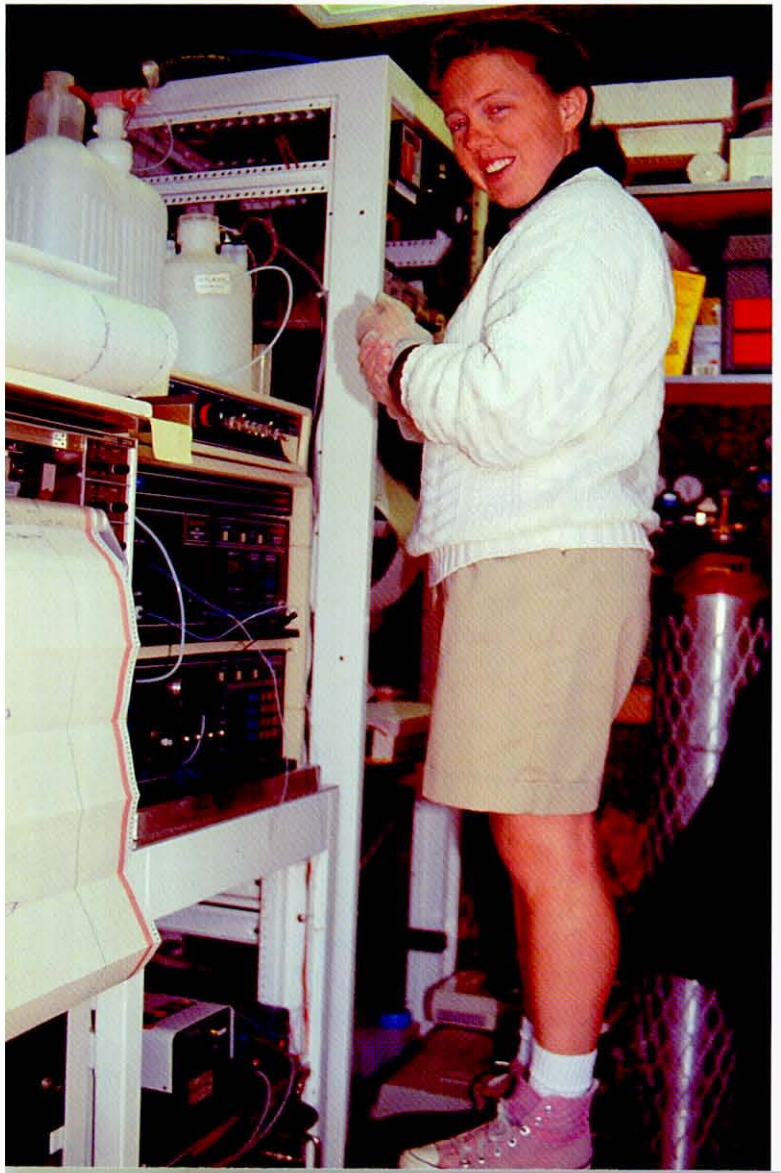


The beauty of Snowmass Village served as counterpoint for the environmental degradation discussed at the Global Change Institute.

Most of the participants in the 1992 Snowmass institute came to the Colorado high country not knowing each other. They left as colleagues, partners in a new discipline that promises to find many ways for nature's integrity and people's ingenuity to coexist.

HAWAII

The Chemistry of Clean Air



At the center of Hawaii's Big Island is a pair of volcanic peaks extending far above the Pacific Ocean. The ambiance near the tops of Mauna Kea and Mauna Loa has nothing to do with leis, palm trees, and surf. These highlands, made up of volcanic lava, are devoid of vegetation and almost never reach room temperature.

The sterility of this cool land is what brought a team of 40 scientists, including 25 from NCAR, here for the second Mauna Loa Observatory Photochemistry Experiment (MLOPEX II). Many of these atmospheric chemists first came to Mauna Loa in 1988 to study what happens to air in the troposphere (the lowest few miles of the atmosphere) when it is relatively free of pollution, dust, or vegetation effects. Sitting at over 3,400 meters (11,000 feet) above sea level and thousands of miles from any large land mass, the site allows for frequent sampling of "free" tropospheric air, the kind not directly influenced by land.

NCAR's Teresa Campos at work inside one of the MLOPEX seatainers

MLOPEX I provided the longest continuous record to date from the remote Pacific of many sparse but highly reactive chemical species—nitrogen oxides, hydrocarbons, organic acids, and peroxides—that shape the atmosphere far out of proportion to their numbers. But because it only lasted two months, MLOPEX I led to another important question: What happens to these trace gases over a full season or a year's time? In response, MLOPEX II occupied four two-month phases, each within a season, from October 1991 to August 1992.

The Mauna Loa site is already renowned in climate annals. It is the place where 35 years of carbon dioxide measurements taken at a National Oceanic and Atmospheric Administration site show an inexorable rise in that greenhouse gas. NOAA's scientists at Mauna Loa were joined for MLOPEX II by colleagues from other NOAA installations, NCAR, Brookhaven National Laboratory, the Georgia Tech Research Institute, Washington State University, the Universities of Colorado and Rhode Island, and the Australian Nuclear Science and Technology Organization. Most participants devised and brought their own specialized sensors.

Charged with establishing the MLOPEX II site, NCAR shipped four "seatainers"—seaworthy containers about

the size of mobile homes—from Colorado to Hawaii and then up 75 kilometers (47 miles) of rough road from Hilo to Mauna Loa. Scientists and technicians made the daunting round trip each day that they worked. Most of them also traveled from Hawaii to the mainland between the four intensives to tend to other responsibilities.

What did these dedicated people accomplish? For one thing, they proved that the Hawaiian atmosphere varies notably in its chemical make-up across the four seasons. Much of that variation is caused by differences in weather patterns through the year. Pollutants in winter and spring are transported across the ocean from Pacific Rim countries over periods of a week or longer. In summer, air tends to come more often from the equatorial Pacific. Data on these seasonal changes will help climate modelers as they incorporate chemistry into global simulations.

Sunlight is another key player in the seasonal equation. Many important reactions are driven by the sun, including the formation and destruction of ozone. Some of these minute processes are well understood; others are still mysterious. One of the most evasive chemicals in these cycles is the hydroxyl radical (OH). It lasts a fraction of a second between reactions and makes up less than a trillionth of the atmosphere, but it is crucial to oxidation and other solar-driven effects.

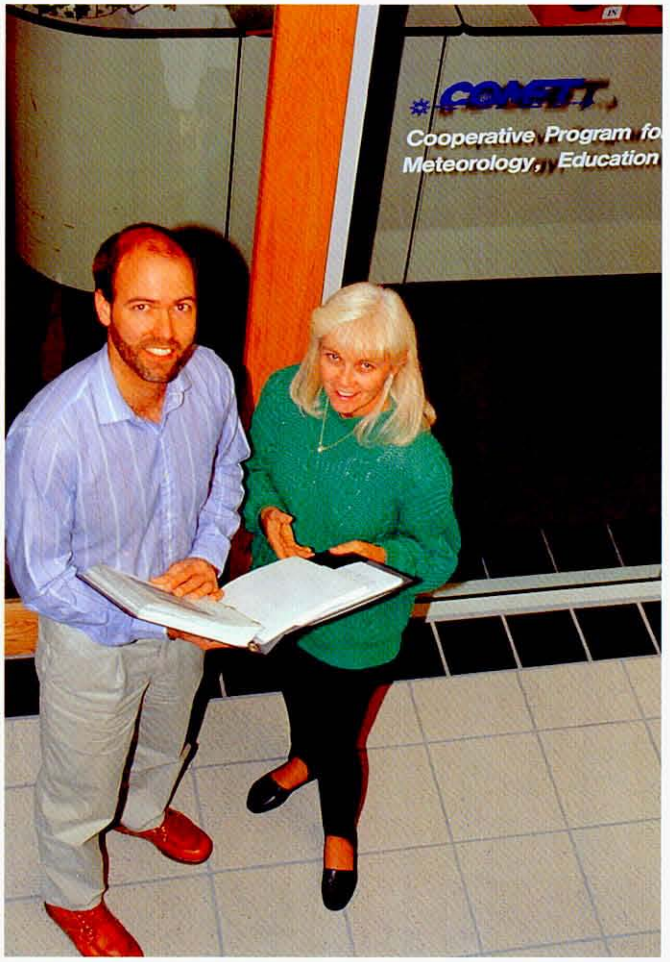
One way to track OH's presence is to measure the longer-lived and more prevalent chemicals with which it interacts. Using that approach in 1988, NCAR chemists found a discrepancy between the OH data and what computer models had predicted. This year MLOPEX II included more extensive, indirect OH measurements, while a Georgia Tech team directly measured OH with a new mass-spectrometric technique. Such double and triple checking was used for other chemicals as well. If the new data still conflict with computer models, the latter may have to be revised. For example, it appears that the models may not be removing chemicals in the same way that the real atmosphere does.

MLOPEX II scientists are spending 1993 at their home sites analyzing the project's exhaustive data. Once that work is done, they hope that the answers to some key questions concerning the chemistry of the remote atmosphere will become as clear as Mauna Loa's air itself is clean.

Participants in MLOPEX II walked their final few meters to work each day to avoid contaminating the site with auto exhaust.

SEATTLE

Researchers and Forecasters Unite



Though its summers are sunny and dry, Seattle is renowned for its cloudy, wet winters. The city is nestled amid mountains that intercept moisture from the Pacific Ocean. The result much of the time is cloudiness, dampness, and coolness.

However, there is a variety to western Washington's weather that goes beyond the stereotype. Snowstorms can cripple transportation and commerce. Rainfall varies greatly from year to year and from point to point: one Olympic Peninsula site averages only 40 centimeters (16 inches) a year, another spot 15 times that. Winds can blow at 160 kilometers (100 miles) an hour in one town and be calm in the next county over.

Forecasters in Seattle have to contend not only with this variety but with a lack of data. Upper-air measurements are taken well away from the city, and Pacific storms cannot be analyzed in great detail until they approach the coast, where topography complicates matters. "We don't have enough data to understand some of the small-scale features that are important," says Clifford Mass, atmospheric science professor at the University of Washington.

Brad Colman, of the Seattle NWS, and Vickie Johnson, manager of the COMET Outreach Program

Seattle's two main centers for meteorology—the university's atmospheric science department and the city's National Weather Service (NWS) office—teamed up in the late 1980s to study western Washington weather in depth. In the 1990s the collaboration has intensified, largely due to a boost from UCAR's Cooperative Program for Operational Meteorology, Education, and Training (COMET). Funded largely by the National Weather Service, COMET aims to prepare the weather service for its long-term modernization by training forecasters in new observational and forecasting techniques and teaming them with university colleagues for new research.

In Seattle, a modest grant from COMET has already paid off. For instance, Mass and his Washington colleague Mark Albright have tracked down 20 independent weather-observing networks that were being run by local utilities and businesses. Four of the networks are now on line, providing up to 200 reports an hour that feed directly from the university to the local weather service. Upper-air winds will soon be tracked by a profiler (upward-pointing

Doppler radar) funded by several U.S., state, and local air-pollution agencies and the Port of Seattle. The goal is to improve knowledge of local wind patterns, especially those conducive to air pollution.

There is more to the Seattle story than better observations. "This is only part of a multifaceted program to improve our knowledge of the climate of this area," says Mass. One recent study examined the origin and evolution of western Washington snowstorms and found a drastic drop in Seattle snowfall during El Niño years (when the eastern tropical Pacific Ocean warms, causing widespread climatic effects).

One of the biggest COMET-supported projects in Seattle examined a recurring feature called the Puget Sound convergence zone. Westerly winds diverted by the Olympic range tend to reunite just north of Seattle, enhancing rainfall there when the zone is strongest. "We've been adjusting our forecasts to account for the zone," says Bradley Colman, science and operations officer for the Seattle NWS. "What we didn't know was the vertical structure of the zone."

A network of recording barometers was deployed around the sound, staffed by volunteer observers, and accompanied by weather balloons launched every 90 minutes from the NWS office. The study

featured heavy involvement from weather service personnel. According to Colman, "It's very beneficial for the forecasters to be involved. The experience gives them a better understanding of the physics, which in turn feeds back into better forecasts." Subsequent case studies will help the forecasters further refine their techniques. Meanwhile, computer modelers at the university have had some success in duplicating the zone's behavior using the MM4 mesoscale computer model developed by Pennsylvania State University and NCAR.

This kind of synergy between academia and the weather service is just what COMET and its sponsors had in mind. Similar team efforts are under way in the Raleigh-Durham area of North Carolina; Tallahassee, Florida; and elsewhere. The ultimate outcome of these outreach efforts will be strengthened teamwork between those studying the weather and those predicting it—not to mention better understanding of local weather.

"Just one good forecast of a major storm," says Cliff Mass, "can save society millions of dollars."

NORWAY

An NCAR Affiliate in the Land of Midnight Sun

Four kilometers (two and a half miles) northwest of the city's downtown area stands the University of Oslo. Inside a modest, attractive brick building funded by the Rockefeller family in 1930 is the office of Egil Leer, astrophysics professor. Though he likes his work setting, Leer's main inspiration comes from far beyond it—from the physics of the solar system itself. That interest has led to a fruitful cross-Atlantic collaboration with UCAR.

Leer is one of about two dozen people from around the world who serve as NCAR affiliate scientists. These accomplished researchers come to Boulder each year for several months; while at their home institutions, they continue to collaborate with Boulder colleagues. The program is ideal for someone like Leer, whose home is Norway but who thrives on the stimulation of working with NCAR's long-standing program in theoretical solar physics.

On a visit to Boulder in 1976, Leer renewed acquaintance with a former colleague from graduate school, NCAR's Thomas Holzer. Together he, Holzer, and their associates are now studying the solar wind—the gas propelled outward from the sun in the form of invisible charged particles that occupy interplanetary space.

Egil Leer

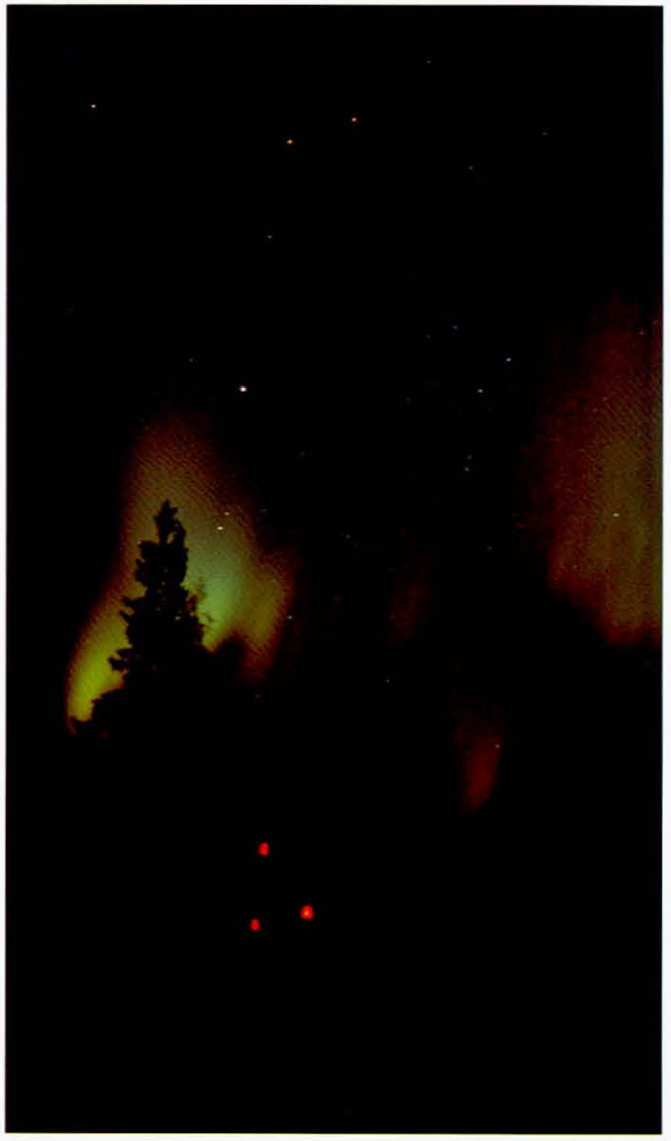
They hope to find the number of those particles, their temperatures, and their speed. The nightly appearance of the auroras (northern or southern lights) in bands around the earth's poles is evidence of continuous solar wind. By understanding the mechanics of the flow of particles from the sun, ultimately Leer and associates will be able to better understand similar winds that emanate from other stars.

One way of analyzing the solar wind outside of computer models is by examining the sun's corona (its outermost atmosphere), which becomes visible during a solar eclipse. Leer is working to describe the structure of the corona as well as bursts of heat and magnetism that fuel the solar wind. He also hopes to learn how the outflowing gas reaches its measured speeds of up to 800 kilometers (500 miles) an hour. According to theory, the flow speeds should be significantly lower, a feature that has puzzled scientists for many years.

Another conflict Leer wants to resolve is why the measured number of protons (positively charged particles) in solar wind streams remains relatively constant when theory tells him that the numbers should vary significantly. Still another question mark is the gaseous makeup of the solar corona. Hydrogen is thought to compose more than 90% of the corona, with helium making up virtually all the rest. If the helium content is in fact higher, then the process of accelerating particles from the sun must be different than current theory has it.

Although Leer has been studying these phenomena for more than 20 years, his research assumes new significance because of an impending joint mission of the National Aeronautics and Space Administration and the European Space Agency. Together they will launch the Solar Heliospheric Observatory (SOHO) satellite in 1995 to study the solar wind. The mission will provide some long-awaited data to test theories developed by Leer and other astrophysicists around the world.

To do the research he loves, Leer must travel beyond Norway and meet others involved in similar work. For that, he says, NCAR is close to perfect. "Scientists from all over the country and all over the world are attracted to NCAR for the same reasons. It offers the broadest obtainable variety of atmospheric scientists and intellectual stimulation. Added to that appeal is the fact that Boulder is such a beautiful city."



WASHINGTON, D.C.

Information for Policymakers

Winds of change swept Washington late in 1992. Over 100 congressional incumbents were replaced and a new administration was elected. During the months leading up to November, UCAR and the American Meteorological Society (AMS) joined forces to produce *Weather and Climate and the Nation's Well-Being*, a 28-page summary of the most significant challenges facing the atmospheric and related sciences. Intended to brief the incoming Congress and the new administration, the document is part of UCAR's role as an advocate for the sciences connected to our earth's atmosphere.

Weather and Climate and the Nation's Well-Being summarizes the significant advances scientists have made in the past four years— in understanding severe thunderstorms and ozone depletion, for instance. It goes on to discuss the significant challenges that remain, such as predicting severe storms minutes or hours in advance or droughts that may be decades off. The underlying theme throughout the book is water, an important shaper of climate in its multiple guises: greenhouse gas, cloud component, fuel for severe storms, key element in drought and flooding.

Behind the document are two organizations that represent major segments of the atmospheric sciences community. The AMS, the meteorologists' professional society, speaks for 10,000 individual members. UCAR represents its 60 member universities, international and other affiliates, and its national center, NCAR. The text was crafted by a team of weather and climate specialists well versed in both research and observational issues. With a single voice, this group hopes to forge a consensus with those in Washington who are instrumental in making scientific progress possible.

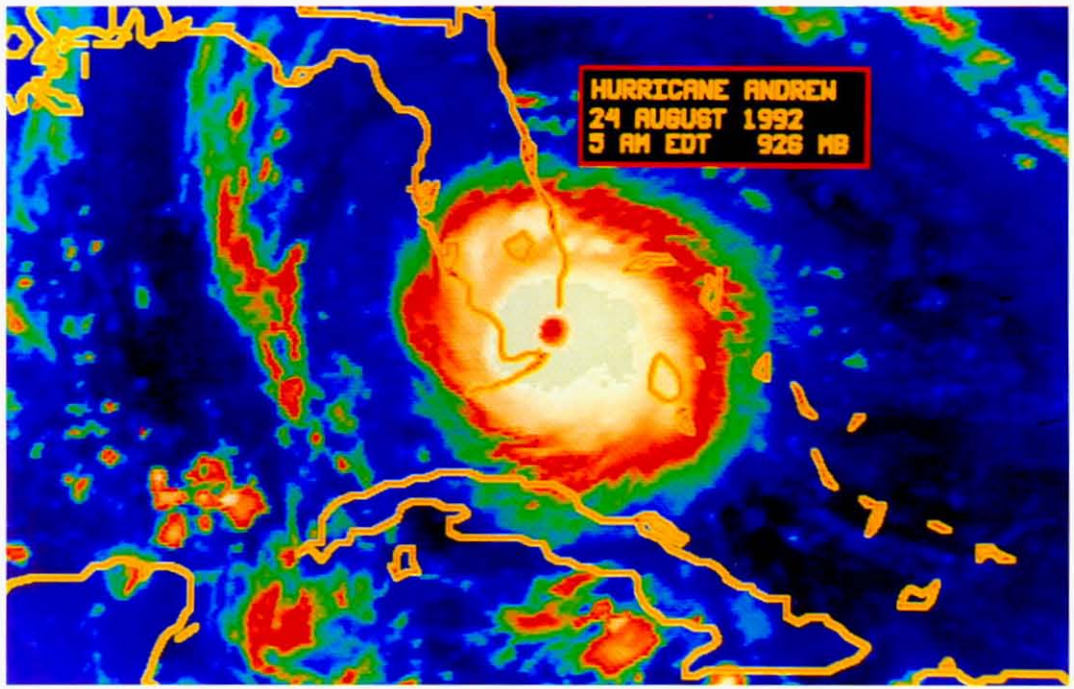
From the report's conclusion:

The challenges and opportunities posed by weather and climate are inherently intertwined through the common theme of water: the threat of severe storms and drought, the life-giving powers of rain and snow. Coordinated efforts to observe, understand, and predict weather and climate are critical components of a

national strategy for predicting, adapting to, and perhaps mitigating the adverse effects of weather and climate.

We know that throughout the history of the earth, weather and climate have had profound effects on all life, including humans. We also know that in the past, global climates have been very different from the present climate and that human activities are causing changes in atmospheric composition at an unprecedented rate. Although large uncertainties remain in projecting future climate changes, the scientific consensus is that the earth will warm over the next 50 years to a level and at a rate unprecedented in human history. Given this level of understanding, a prudent and far-sighted society, guided by leaders in government and the private sector, would develop a strategy that guards against possible future climate and weather changes while at the same time positioning itself to take full advantage of the resource that weather and climate represent.

A coherent strategy will provide immense benefits to the nation even if changes in climate and weather do not materialize. Much can be done now, at a negligible cost compared to what is at stake, even while an accelerated research program is under way to improve weather forecasts and warnings and reduce the uncertainties in predicting future climate change.



This satellite image shows Hurricane Andrew as it crashed into the coast of southern Florida on August 24, 1992. Andrew's death toll was remarkably low, thanks largely to effective, well-received warnings. UCAR's advocacy helps keep policymakers informed on the successes and challenges of atmospheric science.

Recommendations:

- The U.S. Weather Research Program should be implemented immediately and the National Weather Service modernization should be completed as quickly as possible.
- The U.S. Global Change Research Program should receive the full support of the administration, the Congress, and the nation.

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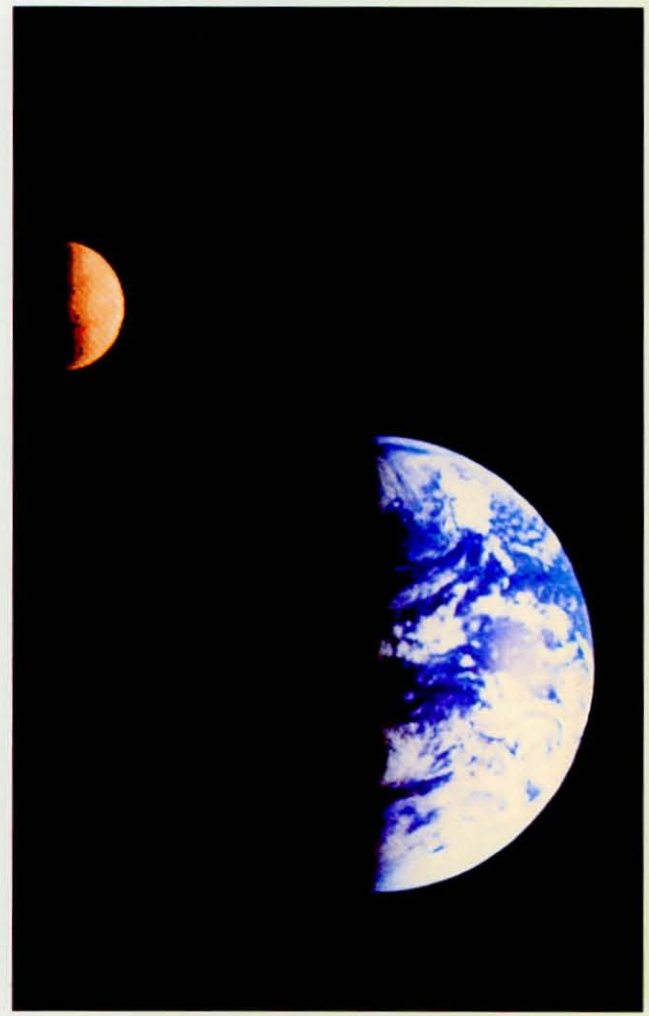
UCAR at a Glance

All UCAR programs on the following pages may be reached through P.O. Box 3000, Boulder, CO 80307-3000, phone 303-497-1000. Specific contacts and their phone numbers are listed with each program. Many related publications and audiovisuals can be obtained from the NCAR Information and Education Outreach Program, 303-497-8600.



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NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Director: Robert Serafin
303-497-1111

Purpose: Conduct basic and applied research on atmospheric and related processes leading to an understanding of the earth system, manage and maintain technological resources used by the research community, and apply research results in the service of society

NCAR includes the following programs and divisions:

Advanced Study Program (ASP)

Director: John Firor
303-497-1600

Purpose: Help ensure the future health of the atmospheric and related sciences by integrating new scientists into research programs at NCAR through graduate and postdoctoral fellowships and summer colloquia

Atmospheric Chemistry Division (ACD)

Director: Guy Brasseur
303-497-1456

Purpose: Study the evolution and composition of the natural atmosphere and its interaction with the ocean and the biosphere, focusing on global- and regional-scale problems

Robert Serafin, NCAR director

Atmospheric Technology Division (ATD)

Director: Richard Carbone
303-497-8830

Purpose: Provide specialized facilities and analysis support for atmospheric measurements by remote sensing (radar and lidar), in-place sounding systems, instrumented aircraft, surface observing systems, and field operations control

Climate and Global Dynamics Division (CGD)

Director: Warren Washington
303-497-1321

Purpose: Develop, improve, and use mathematical models of the atmosphere and its chemistry, oceans, sea ice, and the biosphere to understand climate processes and to link them with global ocean dynamics

Environmental and Societal Impacts Group (ESIG)

Director: Michael Glantz
303-497-8119

Purpose: Conduct research and outreach activities (lectures, workshops, reports, and visitor programs) geared toward improving the understanding of the interactions between atmospheric processes and society

High Altitude Observatory (HAO)

Director: Thomas Holzer
303-497-1500

Purpose: Study the solar interior, the influences of magnetic fields on the structure and dynamics of the solar atmosphere, and the links between the variable solar output and the earth's magnetosphere and outer atmosphere

Mesoscale and Microscale Meteorology Division (MMM)

Director: Robert Gall
303-497-8160

Purpose: Analyze the physics and dynamics of atmospheric circulation systems, ranging in scale from cyclones to fronts to convective systems to the detailed processes within clouds and the boundary layer

Research Applications Program (RAP)

Director: John McCarthy
303-497-8422

Purpose: Support the transfer of NCAR science and technology to federal mission agencies and the private sector, with a focus on mesoscale meteorology in general and aviation weather systems in particular

Scientific Computing Division (SCD)

Director: Bill Buzbee
303-497-1206

Purpose: Provide the advanced computer power and related services needed by atmospheric researchers for extensive modeling and data analysis and furnish storage for the very large data collections involved

UCAR OFFICE OF PROGRAMS

Director: William Bonner
303-497-8655

Purpose: Provide specialized services in support of national and international scientific activities within the atmospheric and related sciences community, especially those for which university interactions and governance are essential

Cooperative Program for Operational Meteorology, Education, and Training (COMET)

Director: Timothy Spangler
303-497-8473

Purpose: Support the professional development of weather forecasters and hydrologists through in-residence courses and remote learning tools and by encouraging partnerships between researchers and forecasters in solving operational forecasting problems

William Bonner, director of UCAR programs

Joint Climate Projects/Planning Office (JCP/PO)

Director: Karyn Sawyer
303-497-8681
Purpose: Help implement global climate research programs by providing detailed logistical services; foster and support international research protocols and agreements

Office of Field Project Support (OFPS)

Director: Richard Dirks
303-497-8987
Purpose: Assist in the coordination, planning, and implementation of National Science Foundation, interagency, and international field projects; collect and disseminate information on national and international field projects

Southern Oxidants Study (SOS)/UCAR Management Center

Director: Bill Curtis
303-497-8632
Purpose: Provide management support for SOS, an observational and theoretical program aimed at improving knowledge of the mechanisms responsible for ozone pollution in the southern United States during summer months

TOGA COARE International Project Office (TCIPO)

Director: David Carlson
303-497-8657
Purpose: Plan and implement COARE (the Coupled Ocean-Atmosphere Response Experiment of the Tropical Ocean and Global Atmosphere Program, conducted in the western Pacific from November 1992 to February 1993); communicate COARE information to participating scientists, agencies, and nations; and establish and implement a data management policy and system

UCAR Visiting Scientist Programs (VSP)

Director: Meg Austin
303-497-8649
Purpose: Implement three visiting scientist programs designed to support and broaden education and research in the atmospheric, oceanic, and related sciences, with around 50 fellowships granted each year at graduate, postgraduate, and senior levels

Unidata

Director: David Fulker
303-497-8644
Purpose: Empower universities through innovative application of current computing and networking technology to make the best use of atmospheric and related data for enhancing education and research

University NAVSTAR Consortium (UNAVCO)

Director: Randolph Ware
303-497-8005
Purpose: Provide equipment and technical support to the scientific community using the NAVSTAR Global Positioning System satellites for precise surveying and other research applications

OTHER UCAR ACTIVITIES

Climate System Modeling Program (CSMP)

Scientific director: Francis Bretherton, University of Wisconsin
Project scientist: David Schimel
303-497-1610
Purpose: Accelerate progress toward reliable predictions of global and regional climate changes in the decades ahead

Institute for Naval Oceanography (INO)

The INO was disestablished on 1 October 1992. Its staff and programs were transferred to the University of Southern Mississippi and Mississippi State University so that its important work can continue.

Model Evaluation Consortium for Climate Assessment (MECCA)

Project manager: Charles Hakkarinen, Electric Power Research Institute (EPRI)
UCAR representative: Wayne Shiver
303-497-1674
Purpose: Quantify the probable range of future climate change; provide policymakers with information useful in coordinating decisions with scientific developments; and identify key topics needing research to improve climate forecasts
Members: Central Research Institute of Electric Power Industry (Japan); Electricity of France; EPRI; Italian Agency for New Technologies, Energy, and Environment; National Supercomputing Center for Energy and the Environment, University of Nevada, Las Vegas; N. V. Kema (Netherlands); Southern California Edison; UCAR

PRIVATE DONATIONS TO UCAR, 1991–92

Bank One (formerly Affiliated National Bank) $10,000
Boulder, Colorado
Intergenerational Symposium on the Environment, Walter Orr Roberts Institute, UCAR

Burlington Northern Foundation $15,000
Fort Worth, Texas ($50,000 over three years)
Burlington Northern Fellowship for Agricultural Impacts of Climate Variability, Climate Systems Section, NCAR Climate and Global Dynamics Division

Deloitte & Touche $10,000
Denver, Colorado
Intergenerational Symposium on the Environment, Walter Orr Roberts Institute, UCAR

General Service Foundation $17,000
Boulder, Colorado
Reforestation research project, El Salvador

The Frost Foundation $45,000
Denver, Colorado ($110,000 over three years)
Frost Biotic Research Facility for Trace Gas Biogeochemistry Section, NCAR Atmospheric Chemistry Division

Holland & Hart $10,000
Denver, Colorado
Intergenerational Symposium on the Environment, Walter Orr Roberts Institute, UCAR

MITRE Corporation $25,000
Bedford, Massachusetts ($50,000 over two years)
Walter Orr Roberts Institute, UCAR

North Star Foundation $1,000
Carbondale, Colorado
Walter Orr Roberts Institute, UCAR

Ed and Mary Wolff $2,500
Boulder, Colorado
Walter Orr Roberts Institute, UCAR

Office for Interdisciplinary Earth Studies (OIES)

Interim directors for FY 92: Beverly Lynds, Bill Curtis
Director-designate: Tom Wigley
303-497-1680
Purpose: Serve the U.S. Global Change Research Program and the International Geosphere-Biosphere Programme through advocacy, dissemination of information, and the definition and instigation of scientific research

UCAR Office of Development

Director: Cynthia Schmidt
303-497-2107
Purpose: Promote the development, growth, and well-being of UCAR by seeking grants from public and private sources; assist in the development of education and outreach programs

Cynthia Schmidt, director of UCAR development

Gervaise Dupree, Office of Government Affairs director

UCAR Office of Government Affairs

Director: Gervaise Dupree
303-497-2107
Purpose: Educate and communicate with both the policymaking and scientific communities on policy issues arising from the atmospheric, environmental, and related sciences.

Walter Orr Roberts Institute

303-497-2107
Purpose: Forge partnerships between scientists, policymakers, educators, and government agencies and inform citizens about issues concerning the atmospheric and related sciences, with the goal of helping humankind to live in an ecologically sound manner

Office of Industry Relations (OIR)

Director: Jeff Reaves
303-497-8585
Purpose: Provide an organizational base for UCAR corporate outreach, intellectual property management, and technology commerical-ization; comprises the Corporate Affiliates Program, Intellectual Property Management Program, and Technology Commercialization Program, along with operational management of the UCAR Foundation and Weather Information Technologies, Inc.

Corporate Affiliates Program (CAP)

Director: Stephen Dickson
303-497-8588
Purpose: Promote interactions among affiliate companies and UCAR programs and staff, in order to maximize opportunities for research, business, and information exchange.

Jeff Reaves, Office of Industry Relations director

UCAR Foundation

303-497-8588
President: John Dutton, Pennsylvania State University
Officers: Richard Anthes, director ex officio; Harriet Barker, assistant secretary; Haradon Beatty, general counsel; John Dutton, president and director ex officio; Najeeb Halaby, chair; Gene Keluche, vice chair; James Kimpel, director ex officio; R. C. Mercure, secretary/treasurer; William Rawson, assistant treasurer; Jeff Reaves, vice president; David Reynolds, assistant treasurer; Charles Zraket, director;
Purpose: Act as UCAR's exclusive agent for commercialization of UCAR's technology assets

Weather Information Technologies, Inc. (WITI)

Chairman: R. C. Mercure
President: Bruce Donaldson
303-497-8587
Purpose: As a for-profit company controlled by the UCAR Foundation, engage in applied consulting work related to aviation weather hazards as they affect international airport operations. The current focus of this activity is the new airport in Hong Kong. WITI also distributes software developed by UCAR's COMET program to nonsponsor users. As compensation for use of licensed technologies, WITI pays royalties to the UCAR Foundation.

UCAR Technology Patented in Fiscal Year 1992

Icing Hazard Detector

U.S. Patent #5,028,929
Inventors: Wayne Sand, NCAR; Robert Kropfli, National Oceanic and Atmospheric Administration
Description: An airborne system that uses dual-frequency radar beams transmitted into a cloud ahead of an aircraft to detect icing hazards. The reflected signals at each of the two frequencies are compared and processed to determine the presence, amount, and location of regions of supercooled water. In this way, the system provides advance indication of an icing area, helping the pilot to avoid it and thus reducing the risk of ice formation on the aircraft.

Square-Cone Parachute

U.S. Patent #5,149,019
Inventor: Sig Stenlund, NCAR
Description: A pyramid-shaped parachute made of lightweight, rip-stop nylon. Air-permeable mesh at the point and around the perimeter allow for stability, gradual deceleration, and low opening shock load to the attached cargo. The parachute uses only one riser line so that strings do not tangle during descent. It features a near-100% deployment rate and is currently used for the deployment of lightweight dropsondes, particularly over oceanic storms.

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All things by immortal power,
Near and far
Hiddenly
To each other linked are,
That thou canst not stir a flower
Without troubling of a star.

— *Francis Thompson (1859–1907)*
from The Mistress of Vision

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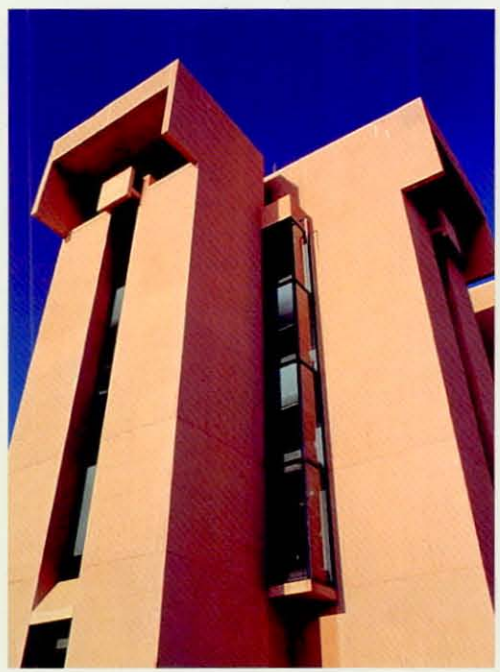
Financial Summary

The renowned Mesa Laboratory (left) and the Fleischmann Building (bottom right), both built in southwest Boulder in the 1960s, are joined in the 1990s by the Foothills Laboratory (top right). Acquired three years ago, the Foothills Lab was renovated to suit UCAR's unique needs and equipped with energy-saving features. The two sites now house over 1,000 staff.



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Deloitte & Touche

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One Civic Center Plaza
Denver, Colorado 80202-5151

Telephone: (303) 837-3000
ITT Telex: 4995604
Facsimile: (303) 830-2007

INDEPENDENT AUDITORS' REPORT

Board of Trustees,
University Corporation for Atmospheric Research:

We have audited the accompanying balance sheets of the University Corporation for Atmospheric Research (UCAR) as of September 30, 1992 and 1991, and the related statements of revenues, expenditures, and changes in fund balances (deficits) and of changes in financial position for the years then ended. These financial statements are the responsibility of UCAR's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, such financial statements present fairly, in all material respects, the financial position of the University Corporation for Atmospheric Research as of September 30, 1992 and 1991 and the results of its operations and the changes in its financial position for the years then ended in conformity with generally accepted accounting principles.

Our audits were conducted for the purpose of forming an opinion on the basic financial statements taken as a whole. The supplemental schedules of expenditures by object of expenditure classification for the years ended September 30, 1992 and 1991 are presented for purposes of additional analysis and are not a required part of the basic financial statements. These schedules are the responsibility of UCAR's management. Such schedules have been subjected to the auditing procedures applied in our audits of the basic financial statements and, in our opinion, are fairly stated in all material respects when considered in relation to the basic financial statements taken as a whole.

Deloitte & Touche

January 6, 1993

Deloitte Touche Tohmatsu International

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UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH – BALANCE SHEETS, SEPTEMBER 30, 1992 AND 1991
(in Thousands)

	1992							
	Restricted Contract Funds					Corporate Funds		
ASSETS	NCAR	INO	Other	Property Fund	Foundation Fund	Administration	General	Total
CURRENT ASSETS:								
Cash	$ 1,494	$ 445	$ 56	$ 51	$ 70			$ 2,116
Investments			2,298		52		$ 2,881	5,231
Receivables:								
National Science Foundation (Note 2)	29,349		123					29,472
Other government agencies	2,857	427	8,061					11,345
Other	2,909		1,573	898	130	$ 80	38	5,628
Inventory	160				6			166
Deferred bond charges - current (Note 4)				133				133
Prepaid expenses and other	168	13					1	182
Total current assets	36,937	885	12,111	1,082	258	80	2,920	54,273
PROPERTY (Notes 3, 4, and 5):								
Land and improvements				1,523				1,523
Building and building construction				24,542				24,542
Equipment				28,420				28,420
Total				54,485				54,485
Less accumulated depreciation				12,986				12,986
Total property - net				41,499				41,499
OTHER ASSETS:								
Investments (Note 4)				37,012				37,012
Deferred bond charges (Note 4)				1,252				1,252
Total other assets				38,264				38,264
TOTAL	$ 36,937	$ 885	$ 12,111	$ 80,845	$ 258	$ 80	$ 2,920	$ 134,036
LIABILITIES AND FUND BALANCES (DEFICITS)								
CURRENT LIABILITIES:								
Deferred revenue	$ 27,736	$ 59	$ 8,890		$ 11			$ 36,696
Bond interest payable (Note 4)				$ 1,977				1,977
Bonds payable - current (Note 4)				3,375				3,375
Accounts payable	2,982	201	1,804	227	18	$ 180		5,412
Accrued vacation liability (Note 2)	3,344		291			372		4,007
Salaries and employee benefits payable	507				3	102		612
Due to (from) other funds	2,349	625	(332)	349	23	(3,494)	$ 480	
Indirect cost variances						2,920		2,920
Other	19							19
Total current liabilities	36,937	885	10,653	5,928	55	80	480	55,018
OTHER LIABILITIES:								
Rebate payable (Note 4)				938				938
Bonds payable (Note 4)				78,260				78,260
Other			66		10			76
Total other liabilities			66	79,198	10			79,274
FUND BALANCES (DEFICITS):								
Restricted (Note 1.A.)			1,392	(4,785)	193			(3,200)
Unrestricted				504			2,440	2,944
Total fund balances (deficits)			1,392	(4,281)	193		2,440	(256)
TOTAL	$ 36,937	$ 885	$ 12,111	$ 80,845	$ 258	$ 80	$ 2,920	$ 134,036

	1991							
	Restricted Contract Funds			Property	Foundation	Corporate Funds		
ASSETS	NCAR	INO	Other	Fund	Fund	Administration	General	Total
CURRENT ASSETS:								
Cash	$ 19	$ 271	$ 51	$ 292	$ 16		$ 144	$ 793
Investments			2,402		188		3,690	6,280
Receivables:								
National Science Foundation (Note 2)	28,287		271					28,558
Other government agencies	3,480	1,446	5,079					10,005
Other	2,794		39	410	102	$ 5	43	3,393
Inventory	209		8					217
Deferred bond charges - current (Note 4)				118				118
Prepaid expenses and other	158	79					2	239
Total current assets	34,947	1,796	7,850	820	306	5	3,879	49,603
PROPERTY (Notes 3, 4, and 5):								
Land and improvements				1,523				1,523
Building and building construction				16,621				16,621
Equipment				26,340				26,340
Total				44,484				44,484
Less accumulated depreciation				8,383				8,383
Total property - net				36,101				36,101
OTHER ASSETS:								
Investments (Note 4)			878	18,279				19,157
Deferred bond charges (Note 4)				957				957
Total other assets			878	19,236				20,114
TOTAL	$ 34,947	$ 1,796	$ 8,728	$ 56,157	$ 306	$ 5	$ 3,879	$ 105,818
LIABILITIES AND FUND BALANCES (DEFICITS)								
CURRENT LIABILITIES:								
Deferred revenue	$ 28,770	$ 1,263	$ 5,966					$ 35,999
Bond interest payable (Note 4)				$ 1,369				1,369
Bonds payable - current (Note 4)				3,900				3,900
Accounts payable	3,318	195	787	978	$ 15	$ 99		5,392
Accrued vacation liability (Note 2)	3,009	128	244			250		3,631
Salaries and employee benefits payable	1,547							1,547
Due to (from) other funds	(2,669)	209	202	1,971		(1,498)	$ 1,785	
Indirect cost variances						1,154		1,154
Other	972	1						973
Total current liabilities	34,947	1,796	7,199	8,218	15	5	1,785	53,965
OTHER LIABILITIES:								
Rebate payable (Note 4)				514				514
Bonds payable (Note 4)				51,500				51,500
Other			65					65
Total other liabilities			65	52,014				52,079
FUND BALANCES (DEFICITS):								
Restricted (Note 1.A.)			1,464	(4,810)	291			(3,055)
Unrestricted				735			2,094	2,829
Total fund balances (deficits)			1,464	(4,075)	291		2,094	(226)
TOTAL	$ 34,947	$ 1,796	$ 8,728	$ 56,157	$ 306	$ 5	$ 3,879	$ 105,818

See notes to financial statements.

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH – STATEMENTS OF REVENUES, EXPENDITURES, AND CHANGES IN FUND BALANCES (DEFICITS) – YEARS ENDED SEPTEMBER 30, 1992 AND 1991
(In Thousands)

	1992							
	Restricted Contract Funds			Property	Foundation	Corporate Funds		
	NCAR	INO	Other	Fund	Fund	Administration	General	Total
REVENUES:								
National Science Foundation Contracts:								
National Science Foundation funds	$ 54,860		$ 6,744				$ 70	$ 61,674
Other government agency funds	21,769		2,383				70	24,222
Other government contracts	3,809	$ 3,355	5,025				324	12,513
Other contracts	6,975		4,082				32	11,089
Dues and user fees							31	31
License fees and royalties					295			295
Interest on investments			84	$ 2,555	6		225	2,870
Total	87,413	3,355	18,318	2,555	301		752	112,694
EXPENDITURES:								
(Notes 3, 4, 5, and 6):								
Scientific programs	29,464	2,065	15,463	368				47,360
Scientific facilities	37,684	263		5,062	141			43,150
Other:								
Central administration	6,323	267	1,272		22	$ (6,673)		1,211
Direct administration	1,063	611	608	72	189	6,384	150	9,077
Research and project support	2,098							2,098
Plant operations and maintenance	4,894	149	532	4,449	2	289		10,315
Loss on disposal of assets				12				12
Total	81,526	3,355	17,875	9,963	354		150	113,223
Revenues over (under) expenditures before capital additions	5,887		443	(7,408)	(53)		602	(529)
Add capital additions				499				499
REVENUES OVER (UNDER) EXPENDITURES	5,887		443	(6,909)	(53)		602	(30)
FUND BALANCES (DEFICITS), BEGINNING OF YEAR			1,464	(4,075)	291		2,094	(226)
TRANSFERS:								
Property additions (Note 4)	(30)		(560)	796	(22)		(184)	
Bond debt service	(5,907)			5,907				
Other	50		45		(23)		(72)	
FUND BALANCES (DEFICITS), END OF YEAR	$	$	$ 1,392	$ (4,281)	$ 193	$	$ 2,440	$ (256)

	1991							
	Restricted Contract Funds			Property Fund	Foundation Fund	Corporate Funds		Total
	NCAR	INO	Other			Administration	General	
REVENUES:								
National Science Foundation Contracts:								
National Science Foundation funds	$ 47,622		$ 3,494				$ 99	$ 51,215
Other government agency funds	19,973		2,203				59	22,235
Other government contracts	1,769	$ 3,091	3,939				195	8,994
Other contracts	3,827		1,411		$ 107		90	5,435
Dues and user fees							20	20
License fees and royalties					78			78
Interest on investments			138	$ 1,835	28		160	2,161
Total	73,191	3,091	11,185	1,835	213		623	90,138
EXPENDITURES:								
(Notes 3, 4, 5, and 6):								
Scientific programs	23,609	1,368	8,722	224	73			33,996
Scientific facilities	31,782	538		5,535	38			37,893
Other:								
Central administration	5,819	245	851		25	$ (5,780)	(93)	1,067
Direct administration	1,492	808	549	50	192	5,229	98	8,418
Research and project support	1,788							1,788
Plant operations and maintenance	4,780	132	288	1,971	5	239		7,415
Loss on disposal of assets				62				62
Total	69,270	3,091	10,410	7,842	333	(312)	5	90,639
Revenues over (under) expenditures before capital additions	3,921		775	(6,007)	(120)	312	618	(501)
Add capital additions				521				521
REVENUES OVER (UNDER) EXPENDITURES	3,921		775	(5,486)	(120)	312	618	20
FUND BALANCES (DEFICITS), BEGINNING OF YEAR			990	(2,897)	424	(312)	1,549	(246)
TRANSFERS:								
Property additions (Note 4)	(127)		(301)	514	(3)		(83)	
Bond debt service	(3,974)			3,974				
Other	180			(180)	(10)		10	
FUND BALANCES (DEFICITS), END OF YEAR	$	$	$ 1,464	$ (4,075)	$ 291	$	$ 2,094	$ (226)

See notes to financial statements.

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH – STATEMENTS OF CHANGES IN FINANCIAL POSITION
YEARS ENDED SEPTEMBER 30, 1992 AND 1991
(In Thousands)

	1992							
	Restricted Contract Funds			Property	Foundation	Corporate Funds		
	NCAR	INO	Other	Fund	Fund	Administration	General	Total
WORKING CAPITAL PROVIDED:								
Operations:								
Revenues over (under) expenditures before capital additions	$ 5,887		$ 443	$ (7,408)	$ (53)		$ 602	$ (529)
Add expenditures not requiring outlay of working capital:								
Depreciation and amortization				4,752				4,752
Loss on disposal of assets				12				12
Other transfers	(5,857)		45	5,907	(23)		(72)	
Working capital provided by operations	30		488	3,263	(76)		530	4,235
Decrease in noncurrent investments			878					878
Increase in bonds payable				26,760				26,760
Increase in rebate payable				424				424
Increase in other liabilities					10			10
Transfer of property additions	(30)		(560)	1,295	(22)		(184)	499
Total			806	31,742	(88)		346	32,806
WORKING CAPITAL APPLIED:								
Decrease in other liabilities			(1)					(1)
Decrease in deferred charges				434				434
Increase in noncurrent investments				18,733				18,733
Additions to property				10,023				10,023
Total			(1)	29,190				29,189
INCREASE (DECREASE) IN WORKING CAPITAL	$	$	$ 807	$ 2,552	$ (88)	$	$ 346	$ 3,617
INCREASE (DECREASE) IN COMPONENTS OF WORKING CAPITAL:								
Increase (decrease) in current assets:								
Cash	$ 1,475	$ 174	$ 5	$ (241)	$ 54		$ (144)	$ 1,323
Investments			(104)		(136)		(809)	(1,049)
Receivables	554	(1,019)	4,368	488	28	$ 75	(5)	4,489
Inventory	(49)		(8)		6			(51)
Deferred bond charges - current				15				15
Prepaid expenses and other	10	(66)					(1)	(57)
Total	1,990	(911)	4,261	262	(48)	75	(959)	4,670
Decrease (increase) in current liabilities:								
Deferred revenue	1,034	1,204	(2,924)		(11)			(697)
Bond interest payable				(608)				(608)
Bonds payable - current				525				525
Accounts payable	336	(6)	(1,017)	751	(3)	(81)		(20)
Accrued vacation liability	(335)	128	(47)		(3)	(122)		(379)
Salaries and employee benefits payable	1,040					(102)		938
Due to (from) other funds	(5,018)	(416)	534	1,622	(23)	1,996	1,305	
Indirect cost variances and other	953	1				(1,766)		(812)
Total	(1,990)	911	(3,454)	2,290	(40)	(75)	1,305	(1,053)
INCREASE (DECREASE) IN WORKING CAPITAL	$	$	$ 807	$ 2,552	$ (88)	$	$ 346	$ 3,617

	1991							
	Restricted Contract Funds			Property	Foundation	Corporate Funds		
	NCAR	INO	Other	Fund	Fund	Administration	General	Total
WORKING CAPITAL PROVIDED:								
Operations:								
Revenues over (under) expenditures before capital additions	$ 3,921		$ 775	$ (6,007)	$ (120)	$ 312	$ 618	$ (501)
Add expenditures not requiring outlay of working capital:								
Depreciation and amortization				4,443				4,443
Loss on disposal of assets				62				62
Other transfers	(3,794)			3,794	(10)		10	
Working capital provided from operations	127		775	2,292	(130)	312	628	4,004
Decrease in noncurrent investments			(814)	5,134				4,320
Increase in rebate payable				46				46
Transfer of property additions	(127)		(301)	514	(3)		(83)	
Total			(340)	7,986	(133)	312	545	8,370
WORKING CAPITAL APPLIED:								
Decrease in other liabilities			(1)					(1)
Decrease in bonds payable				3,900				3,900
Additions to property				6,240				6,240
Total			(1)	10,140				10,139
INCREASE (DECREASE) IN WORKING CAPITAL	$	$	$ (339)	$ (2,154)	$ (133)	$ 312	$ 545	$ (1,769)
INCREASE (DECREASE) IN COMPONENTS OF WORKING CAPITAL:								
Increase (decrease) in current assets:								
Cash	$ (2,228)	$ 93	$ (19)	$ 291	$ 16		$ 143	$ (1,704)
Investments			401		(164)		2,495	2,732
Receivables	13,375	21	1,703	(80)	30	$ 5	36	15,090
Inventory	(83)							(83)
Prepaid expenses and other	6	51						57
Total	11,070	165	2,085	211	(118)	5	2,674	16,092
Decrease (increase) in current liabilities:								
Deferred revenue	(10,571)	18	(1,876)					(12,429)
Bond interest payable				61				61
Bonds payable - current				(970)				(970)
Accounts payable	(1,079)	(86)	(237)	(978)	(15)	(58)		(2,453)
Accrued vacation liability	(22)	(35)	(40)			(136)		(233)
Salaries and employee benefits payable	(132)							(132)
Due to (from) other funds	1,302	(79)	(271)	(478)		1,655	(2,129)	
Indirect cost variances and other	(568)	17				(1,154)		(1,705)
Total	(11,070)	(165)	(2,424)	(2,365)	(15)	307	(2,129)	(17,861)
INCREASE (DECREASE) IN WORKING CAPITAL	$	$	$ (339)	$ (2,154)	$ (133)	$ 312	$ 545	$ (1,769)

See notes to financial statements.

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH
NOTES TO FINANCIAL STATEMENTS
YEARS ENDED SEPTEMBER 30, 1992 AND 1991

The University Corporation for Atmospheric Research (UCAR) is a nonprofit membership corporation engaged in scientific and educational activities in atmospheric research and related fields. UCAR operates the National Center for Atmospheric Research (NCAR) under contract with the National Science Foundation (NSF), which includes direct funding from NSF and funding by other United States Government agencies through interagency transfer to NSF. UCAR also operates the Institute for Naval Oceanography (INO) under contract with the Office of Naval Research (ONR) and other scientific projects principally funded by other United States Government agencies.

UCAR's contract for the operation of NCAR, which was to expire September 30, 1992, was extended until September 30, 1993. Management believes that the contract will be subsequently renewed for an additional five-year period. UCAR's contract for the operation of INO expired on September 30, 1992 and will not be renewed.

Performance of work under government contracts may be terminated whenever the contracting agency shall determine that such termination is in the best interest of the United States Government. Funding under all United States government contracts is subject to availability of funding as determined by the United States Congress.

UCAR has incurred bond indebtedness for the purposes explained in Note 4. UCAR's ability to repay the bonds when due is dependent upon funding by NSF. NSF intends that funds to repay the bond indebtedness will be part of its annual budget allocation to UCAR and will be included in the annual NCAR program plan.

The University Corporation for Atmospheric Research Foundation (Foundation) was incorporated by UCAR for the purpose of engaging in technology transfer and other scientific, educational, and charitable activities in support of UCAR's mission. UCAR's Board of Trustees selects the members of the Board of Directors of the Foundation. The Foundation's primary source of revenues is license fees and royalties from transferred technology.

1. SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

A. Fund Accounting - To ensure observance of restrictions placed on the use of certain resources, the accounts of UCAR are maintained in accordance with the principles of fund accounting. Restricted resources are classified for accounting and reporting purposes into funds established for the specified activities or objectives. Separate accounts are maintained for each fund.

Restricted Contract Funds - NCAR and INO represent restricted contract Funds of UCAR since the respective resources are restricted by the funding source. Related expenditures are restricted to specific programs which are approved annually by the contracting agency.

Other Restricted Contract Funds represent resources restricted under terms of grants, contracts, or by management for certain research programs.

Property Fund - The Property Fund includes restricted and unrestricted real and personal property titled with UCAR and all obligations related thereto. The fund deficits in the restricted property fund at September 30, 1992 and 1991 are a result of expenditures exceeding revenues, primarily due to depreciation and interest expense exceeding contract revenues received for bond debt service. In subsequent years as the bond service payments are made in accordance with the maturity schedules outlined in Notes 4.A, 4.B and 4.C, a commensurate amount of revenues will be recognized. The revenue received in future years to meet bond debt service should exceed future years' expenditures related to depreciation and interest.

Foundation Fund - The Foundation Fund represents resources restricted to activities in support of the scientific, educational, charitable, and technology transfer purposes of UCAR. The Foundation Fund financial statement amounts include the balances of its majority-owned subsidiary, Weather Information Technologies Incorporated (WITI). WITI is a for-profit corporation incorporated in 1989 for the purpose of commercializing certain UCAR technologies. All significant intercompany transactions and balances have been eliminated in the consolidated Foundation Fund amounts.

Corporate Funds - Corporate Administration Funds primarily represent resources used to support general and administrative activities which are allocated to the respective restricted contracts through an NSF approved indirect cost rate.

Corporate General Funds represent unrestricted resources of UCAR. The principal sources of unrestricted revenues are UCAR management fees and interest on corporate investments.

B. **Investments** - Property Fund investments, consisting of amounts held by a bond trustee (see Note 4), are invested in United States Treasury Bills, Federal Home Loan Bank Notes, and Guaranteed Funding Agreements of an insurance company. All other Fund investments consist principally of United States Treasury and agency obligations.

Investments are recorded at amortized cost, which approximates market. Property Fund investments which are designated for expenditure in the acquisition or construction of noncurrent assets or for the liquidation of long-term bonds payable are classified as noncurrent. Other Fund investments which mature during the next fiscal year and are not expected to be reinvested are classified as current. Bond-trustee held investments are restricted for payment on the projects or to bond holders.

C. **Inventory** - Electronic parts inventory is valued at the lower of average cost or market.

D. **Property** - Property is recorded at purchase cost, except for equipment acquired from the United States Government and equipment received through donations, which are recorded at estimated fair market value at the time of acquisition. Property with title vested in the United States Government is not recorded in the financial statements (see Note 3). Depreciation on UCAR titled property is provided using the straight-line method over the estimated useful life of the property.

Included within recorded property is the Fleischmann Building. Under terms of a declaration of trust covering the Fleischmann Building, any sale of the building must be to the United States Government at a price not to exceed cost less depreciation. At the end of the depreciable period in 1994, title to the land and building must be conveyed to the United States Government without charge.

E. **Deferred Revenue, Revenue, and Expenditure Recognition** - Funds from restricted contracts are recorded as restricted deferred revenue as of the effective dates of amendments to the contract, upon receipt of correspondence from the contracting source approving such funding, or upon the receipt of proceeds. Restricted deferred revenues are recognized as revenues when expenditures under the contract are incurred. Contributions are recognized when received. Expenditures charged to all United States Government contracts are subject to government agency audit.

F. **Statement of Financial Accounting Standards No. 106 (SFAS 106)** - "Employers Accounting for Retirement Benefits Other Than Pensions" has been issued by the Financial Accounting Standards Board but has not yet been adopted by UCAR. SFAS 106 currently requires adoption by UCAR in fiscal year ending September 30, 1994. UCAR has not determined the effect that the adoption of SFAS 106 may have on its financial position.

G. **Reclassification** - Certain amounts in the 1991 financial statements have been reclassified to conform to the 1992 presentation.

2. ACCRUED VACATION

NSF has agreed that in the event of termination of the NSF-UCAR contract for the convenience of the United States Government, the liability for unused vacations of NSF-UCAR sponsored employees may be included as part of any termination claim by UCAR and will be paid, up to a maximum of $2,282,000. Accordingly, a receivable of $2,282,000 for anticipated future funding by NSF of such vacation liability has been recognized at both September 30, 1992 and 1991. The remaining balance of the NCAR accrued vacation liability and the total balance of the accrued vacation liability for Other Restricted Contract Funds and Corporate Administration Funds are provided through normal operations.

3. PROPERTY

Property purchased with title vested in UCAR, including property restricted as to a particular purpose, is recorded in the financial statements in the Property Fund. Restricted UCAR property is acquired with restricted funds and therefore is recorded in the Property Fund through a transfer from the originating restricted fund.

Restricted property with title vested in the United States Government is not recorded in the financial statements. Acquisitions of such property are recorded as expenditures. Property acquisitions with title vested in the United States Government were $7,869,000 for NCAR, $27,000 for INO, and $283,000 for other restricted funds in 1992; and $6,834,000 for NCAR, $255,000 for INO, and $73,000 for other restricted funds in 1991. UCAR has the responsibility of maintaining property records and reporting balances to the respective government agency. Government-owned property consisted of the following at September 30:

	1992 (in thousands)			
	NCAR	INO	Other Restricted	Total
Plant	$16,292			$16,292
Equipment	58,457	$1,109	$970	60,536
Total	$74,749	$1,109	$970	$76,828

	1991 (in thousands)			
	NCAR	INO	Other Restricted	Total
Plant	$15,900			$15,900
Equipment	53,786	$897	$737	55,420
Total	$69,686	$897	$737	$71,320

4. BONDS PAYABLE

A. Cray YMP Bonds - UCAR borrowed $25,120,000 on behalf of NCAR in 1989, through the issuance of County of Boulder, Colorado, Development Refunding and Revenue Bonds, Series 1989 (CRAY YMP Bonds) to assist in refunding County of Boulder, Colorado project revenue bonds, series 1986 (CRAY XMP Bonds), and financing the costs of a CRAY YMP8/664 computer system and related computer equipment and improvements (the Project).

As of September 30, 1992, the bond trustee held $2,500,000 in a reserve fund for payment of bond principal. The CRAY YMP Bonds bear interest and mature serially as follows:

	(in thousands)
6.10% maturing December 1, 1992	$ 2,865
6.20% maturing December 1, 1993	3,045
6.30% maturing December 1, 1994	3,235
6.40% maturing December 1, 1995	3,450
6.50% maturing December 1, 1996	6,610
Total	$19,205

CRAY YMP Bonds maturing after December 1, 1992 are subject to redemption prior to maturity, at the option of UCAR, at redemption prices ranging from 100.5% to 102% of the principal amount plus accrued interest to the redemption date. The CRAY YMP Bonds are collateralized by the Project. Certain costs incurred by UCAR in connection with the CRAY YMP Bonds were deferred and are being amortized over the period which the CRAY YMP Bonds are outstanding.

B. **1988 Building Bonds** - UCAR borrowed $33,210,000 in 1988 through the issuance of County of Boulder, Colorado revenue bonds, Series 1988 (1988 Building Bonds) to assist in financing the costs of constructing and equipping a building to house research and other scientific activities of NCAR and other activities of UCAR. During 1990, UCAR decided to purchase an existing 250,000 square foot building with the proceeds of the bonds.

As of September 30, 1992, the bond trustee held $3,150,000 in a reserve fund for payment of bond principal. The 1988 Building Bonds bear interest and mature serially as follows:

	(in thousands)
8.10% maturing December 1, 2005	$12,465
8.25% maturing December 1, 2013	19,830
Total	$32,295

UCAR is required to make annual payments to a sinking fund equal to the aggregate debt service payments required on the 1988 Building Bonds. In 1992 and 1991, UCAR deposited $915,000 and $440,000, respectively, into an escrow account designated for payment of the 1988 Building Bonds. Such deposits have been recorded as a reduction in bonds payable since the debt is considered to be extinguished for financial reporting purposes. Sinking fund requirements under the 1988 Building Bonds for the next five years are as follows:

Year ending September 30,	(in thousands)
1993	$ 510
1994	555
1995	595
1996	645
1997	700
Thereafter	29,290
Total	$32,295

The 1988 Building Bonds are subject to redemption between December 1, 1998, and November 14, 2000, at the option of UCAR, at redemption prices ranging from 100.5% to 101% of the principal amount plus any accrued interest. It is management's intention to exercise the redemption option on December 1, 1998 (see Note 4.C.). The 1988 Building Bonds are not collateralized. Certain costs incurred by UCAR in connection with these bonds were deferred and are being amortized over the period which the 1988 Building Bonds are outstanding.

C. **1991 Building Bonds** - UCAR borrowed $30,135,000 on November 5, 1991 through the issuance of County of Boulder, Colorado Development Revenue Refunding and Improvement Bonds, Series 1991 (1991 Building Bonds) to assist in refunding the 1988 Building Bonds, finance the costs of remodeling the Mesa Laboratory building, and acquire equipment to be used in research and other scientific activities of NCAR.

As of September 30, 1992 the bond trustee held $28,690,000 in escrow for the payment of the principal of and redemption premium on the 1988 Building Bonds as of December 1, 1998 and for payment of debt service on the 1991 Building Bonds through December 1, 1998.

At September 30, 1992, the 1991 Building Bonds bear interest and mature serially as follows:

	(in thousands)
6.25% maturing December 1, 1999	$ 1,085
6.35% maturing December 1, 2000	1,155
6.45% maturing December 1, 2001	1,230
6.50% maturing December 1, 2002	1,310
6.60% maturing December 1, 2003	1,395
6.90% maturing December 1, 2007	6,580
7.00% maturing December 1, 2013	17,380
Total	$30,135

The 1991 Building Bonds are subject to redemption between December 1, 2001 and December 2013, at the option of UCAR, at redemption prices ranging from 100% to 101% of the principal amount plus any accrued interest. The 1991 Building Bonds are not collateralized. Certain costs incurred by UCAR in connection with these bonds were deferred and are being amortized over the period during which the 1991 Building Bonds are outstanding.

D. **Bond Rebate** - The Internal Revenue Code (IRC), as amended, requires that cumulative income earned from investing bond proceeds in excess of the related bond interest expense (arbitrage) be rebated to the United States Government. As of September 30, 1992 and 1991, UCAR has recorded an estimated liability for cumulative arbitrage of approximately $938,000 and $514,000, respectively.

E. **Interest Expense** - UCAR incurred interest expense totaling approximately $5,777,000 and $4,160,000 in 1992 and 1991, respectively, in connection with the bonds, of which $586,000 and $823,000, respectively, was capitalized related to the renovation of the purchased building (Note 4.B.).

5. COMMITMENTS

UCAR, on behalf of NCAR, INO and other activities, leases plant and equipment under operating leases. Total rental expenditures under all operating leases were approximately $2,827,000 and $2,175,000, respectively, for 1992 and 1991.

As of September 30, 1992, UCAR's future minimum rentals under operating leases, which may be terminated by UCAR in the event of insufficient funding, are as follows:

Years ending September 30,	
1993	$ 791,445
1994	186,797
1995	31,602
1996	10,200
1997	10,200
Total minimum lease payments required	$1,030,244

Commitments of restricted funds are not included in the financial statements until the services are rendered or the goods are received. At September 30, 1992 and 1991, UCAR had unfilled purchase order commitments of approximately $13,517,000 and $11,745,000, respectively.

6. PENSION PLAN

UCAR has a contributory plan available to all regular full-time and part-time employees. Participants are required to contribute 5% and may contribute an additional amount in accordance with IRC guidelines. UCAR is required to contribute 10% of annual gross salary. UCAR reserves the right to modify or discontinue the plan at any time. Pension expenditures were as follows for the years ended September 30:

	1992	1991
	(in thousands)	
NCAR	$3,151	$2,739
INO	124	114
Other restricted	451	301
Corporate administration	311	277
Foundation	2	
Total	$4,039	$3,431

7. LINE OF CREDIT

The Foundation has a $150,000 revolving line of credit with a bank, which bears interest at the bank's prime rate and expires on June 3, 1993. At September 30, 1992, there were no borrowings outstanding under this line of credit.

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UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH – SUPPLEMENTAL SCHEDULES OF EXPENDITURES BY OBJECT OF EXPENDITURE CLASSIFICATION – YEARS ENDED SEPTEMBER 30, 1992 AND 1991
(In Thousands)

	1992							
	Restricted Contract Funds			Property	Foundation	Corporate Funds		
	NCAR	INO	Other	Fund	Fund	Administration	General	Total
Salaries and employee benefits	$ 43,138	$ 1,696	$ 6,172		$ 32	$ 4,262	$ 3	$ 55,303
Central Administration	6,323	267	1,272		22	(6,673)		1,211
Purchased services	16,394	1,167	7,300		263	1,718	87	26,929
Plant additions	189			$ 8				197
Equipment additions	7,680	27	283					7,990
Materials and supplies	4,641	71	1,150		2	421	59	6,344
Travel	3,161	127	1,698		35	272	1	5,294
Depreciation and amortization				4,752				4,752
Interest				5,191				5,191
Loss on disposal of assets				12				12
Total	$ 81,526	$ 3,355	$ 17,875	$ 9,963	$ 354	$	$ 150	$ 113,223

	1991							
	Restricted Contract Funds			Property	Foundation	Corporate Funds		
	NCAR	INO	Other	Fund	Fund	Administration	General	Total
Salaries and employee benefits	$ 37,431	$ 1,555	$ 4,115		$ 5	$ 3,785		$ 46,891
Central Administration	5,819	245	851		25	(5,780)	$ (93)	1,067
Purchased services	12,698	824	3,815		285	1,143	90	18,855
Plant additions	209							209
Equipment additions	6,625	255	73					6,953
Materials and supplies	4,039	111	304			237	8	4,699
Travel	2,449	101	1,252		18	303		4,123
Depreciation and amortization				$ 4,443				4,443
Interest				3,337				3,337
Loss on disposal of assets				62				62
Total	$ 69,270	$ 3,091	$ 10,410	$ 7,842	$ 333	$ (312)	$ 5	$ 90,639