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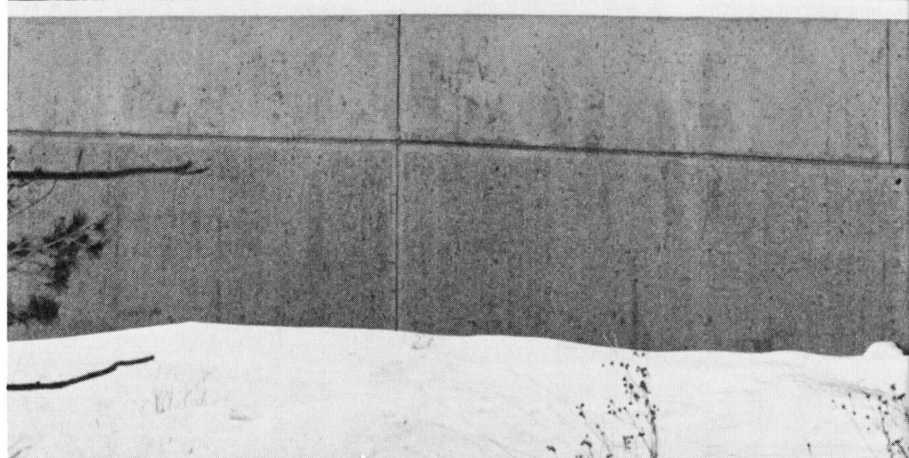
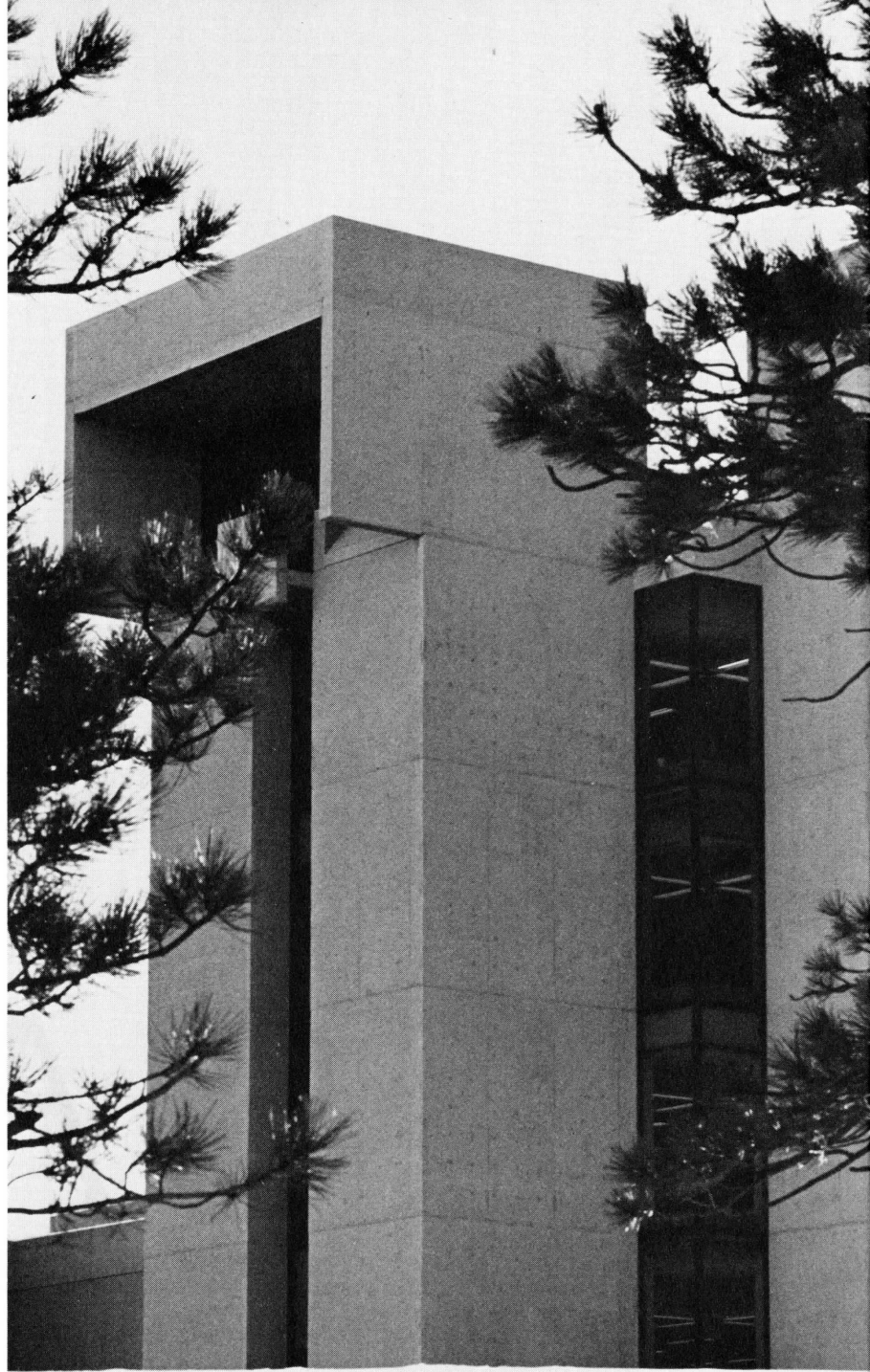
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Report for 1972

UCAR

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PRESIDENT'S STATEMENT

Deep in space, perhaps on a minor planet of an unnamed star among the hundred billion of our Milky Way, there must be a civilization wiser than ours. Its "people" have, I imagine, ended war, hunger, and pollution. They have probably found the touchstone of liberty, the secret of happiness. I would love to hear their music, read their poetry! But I doubt that I shall ever do so. Thousands of light years separate us, and space is an alien environment for the human body and spirit.

Nearly within grasp of our human aspirations, however, is the attainment of what a wiser civilization must long ago have achieved—the good life, not just for the few but for the vast majority. To win such a quality of human life has neared top priority among the tasks before us here on earth. Even considering the natural bounties of our planet, it will take more effort to achieve than simply dreaming of how it may have come about in other worlds.

No lesser goal will, I am convinced, satisfy those who felt the warmth of the torch that guided men and women from all over the world to Stockholm last June for the United Nations Conference on Problems of the Human Environment. From this rallying point the nations of the earth will, I believe, join to dedicate the last quarter of the twentieth century to attainment, for all future time, of a harmonious equilibrium between mankind and the natural riches and beauties of our planet. This equilibrium must include equitable access to the resources of the earth by all of its peoples; the benefits of development must come to the less developed nations without the curse of uncontrolled environmental exploitation. This is a resolve not to be entered upon casually!

For the universities joined together in the University Corporation for Atmospheric Research, this resolve will bring serious

new commitments. As the boundaries of our atmosphere are global, so also must be the scope of these commitments. UCAR, more than a year ago, formally recorded its obligation to "marshal the wisdom and capabilities of atmospheric scientists in the Member Universities and at the National Center for Atmospheric Research so that they can most effectively contribute to the advancement of man's knowledge of the atmosphere, with the aim of enabling the world's people to live in long-term harmony with their atmospheric environment."* Thus, UCAR's commitment was unambiguous even before the Stockholm Conference.

What the Stockholm Conference has done is to give to people of all races and all geographic origins a formal expression of their fervent hope to enhance the quality of human life by broadly applying the powers of science and technology; what the Conference has not done is to give any clear indication of how to do this. The principal responsibilities, after Stockholm, must fall to research groups, governmental agencies, and individual scientists within the world's nations. But unless organizations like UCAR and the universities move promptly to assume specific, constructive initiatives, the momentum provided by the Stockholm Conference may well be lost.

One of UCAR's strongest initiatives related to the Stockholm goals is support of the Global Atmospheric Research Program (GARP). Because GARP is attaining heightened attention at NCAR and in the UCAR Member Universities, I will speak of it in some detail here. The overall aim of this international cooperative program is to advance our understanding of the large-scale circulation of the atmosphere, and its central goal is to establish just how far in advance it is possible to make detailed weather forecasts. But many participants are equally concerned that the resources

***Concepts in Atmospheric Research for the 1970s**, UCAR, Boulder, Colorado, 23 February 1972, p. 25.

being assembled for GARP be used also to advance our understanding of climatic change and to assess the possibilities and dangers of inadvertent or deliberate modification of large-scale features of weather or climate.

The means being brought to bear on GARP are enormous. They range from expanded networks for conventional meteorological measurements over data-sparse regions of the earth, to the deployment of orbiting artificial satellites and drifting ocean buoys and free-flying globe-circling balloons; from concentrations of ships equipped for oceanographic studies and with supporting airplanes and radars, to the use of next-generation digital electronic computers to carry out highly sophisticated modeling experiments of the world's weather. No previous geophysical program of this scale or complexity has ever been attempted; its execution will occupy the major part of this decade.

UCAR and NCAR have been deeply involved in past and present aspects of the United States portion of the GARP international program. To bring more focus and coherence to university participation in GARP, and to mesh university participation with that of NCAR, the Corporation has established the UCAR GARP Council to serve information and coordination functions for the UCAR consortium, and NCAR has created a special group to coordinate NCAR's GARP work and supply a clearly identified staff backup capability for the Council. UCAR has laid before the Council and the NCAR staff the responsibility of bringing to GARP research efforts the best possible participation of the most highly qualified individuals and groups in NCAR and the universities. The main purpose of the GARP Council is to involve the universities of the United States and Canada more deeply and effectively in planning and executing GARP programs, which vitally depend on

university contributions. The GARP Council efforts have gained endorsement and cooperation from the National Science Foundation, from the National Academy of Sciences, and from the National Oceanic and Atmospheric Administration (NOAA), in whose hands lie the ultimate responsibilities for United States participation in GARP. The UCAR GARP Council is chaired by Edward N. Lorenz of the Massachusetts Institute of Technology, and has the full-time services of Philip E. Merilees, on a two-year leave from Canada's McGill University, as Executive Director. Each UCAR Member University is represented on the Council, which meets annually at NCAR and carries out its other information and coordination functions on a continuing basis.

National environmental initiatives, as well as international ones, are gaining increasing attention by atmospheric scientists. For example, a major effort is being planned by a number of groups (including NCAR) for urban air pollution research, using Saint Louis as a test city. And in northeastern Colorado an NCAR-directed, multi-university, multi-agency study of hail, possibly leading to knowledge of how to suppress damaging hail, is now under way.

The atmospheric sciences, as we enter 1973, face challenges of global scale. Never before has it been so evident that the welfare of mankind depends delicately upon weather and climate, and upon the changeable, complex processes that cleanse natural and man-made pollutants from the life-supporting atmosphere. Yet the resources for atmospheric research, in common with those for all of the sciences, are slowly being reduced. In neither of the two countries involved in UCAR have we found leadership with the inspiration and ability to enlist selective and adequate financial support for the atmospheric sciences. If we do not obtain such

support, our strategies for the future must change, and we must suffer setbacks in our collective hopes for "advancement of man's knowledge of the atmosphere, with the aim of enabling the world's people to live in long-term harmony with their atmospheric environment."

As in prior years, NCAR's activities are UCAR's principal responsibility. I am pleased, therefore, to introduce in the following pages Director John W. Firor's report on NCAR. The corporate financial summary and audit report for the fiscal year that ended 30 June 1972 follow his report.

Walter Orr Roberts
President
University Corporation for
Atmospheric Research

NCAR RESEARCH HIGHLIGHTS

The highlights of NCAR activities presented here illustrate the range and character of work undertaken at NCAR. These activities range from studies of particular phenomena in the atmosphere, which although isolated for study may have application or influence reaching far beyond the location or time at which they occur, to studies of the broad structure of atmospheric systems.

Examples of the first kind of studies described here are the investigations of mountain lee waves and the National Hail Research Experiment (NHRE). Mountain-induced waves are easily studied as a local phenomenon from our laboratory in Boulder, Colorado, but the results of our preliminary work placed the study in a much larger context, for they showed that the horizontal momentum transferred vertically through the atmosphere by these waves is sufficiently large to affect the global circulation of the atmosphere. The hail project, while aimed at the clearly defined, practical goal of ascertaining whether damaging hail can be artificially reduced, will undoubtedly also contribute to an understanding of the role of large convective storms in influencing, and in turn being influenced by, the larger scale atmospheric environment.

At the other end of the spectrum of NCAR research, mention is made in this report of the study of southern hemisphere climatology, of increasing awareness of the details of the even larger context of the atmosphere in its relations to the solar wind, and of the three-dimensional nature of the solar corona.

While these studies illustrate the breadth and complexity of atmospheric science, they also illustrate the variety of techniques which must be employed by NCAR in its interactions with the university community in the process of undertaking studies of the

large and difficult problems in the atmosphere. NHRE is a straightforward joint project, with a number of universities and government agencies cooperating with NCAR in conducting the field phases of the experiment, analyzing the results of each field phase, planning the following year's research emphasis, and designing the final construction of models to confirm our understanding of such storms. In other areas—the development of a wind-finding dropsonde and the instrumentation of a four-engine turboprop aircraft—NCAR is responding to needs developed on the international scene by the Global Atmospheric Research Program (GARP), one of the largest cooperative projects ever undertaken. Here, the interaction with universities is twofold: one, close and direct, with those groups who choose to participate in the measurements made on board the four-engine aircraft, and two, with other groups much more distant and difficult to trace in that the data set collected in the GARP Atlantic Tropical Experiment (GATE) will be a basic input for all those attempting either to understand the tropics per se, or to allow for the tropical input in mid-latitude numerical simulation of the atmosphere. Similarly, the maps of southern hemisphere climatology, although produced by cooperative endeavor, are basically a service undertaken for the benefit of the atmospheric science community as a whole.

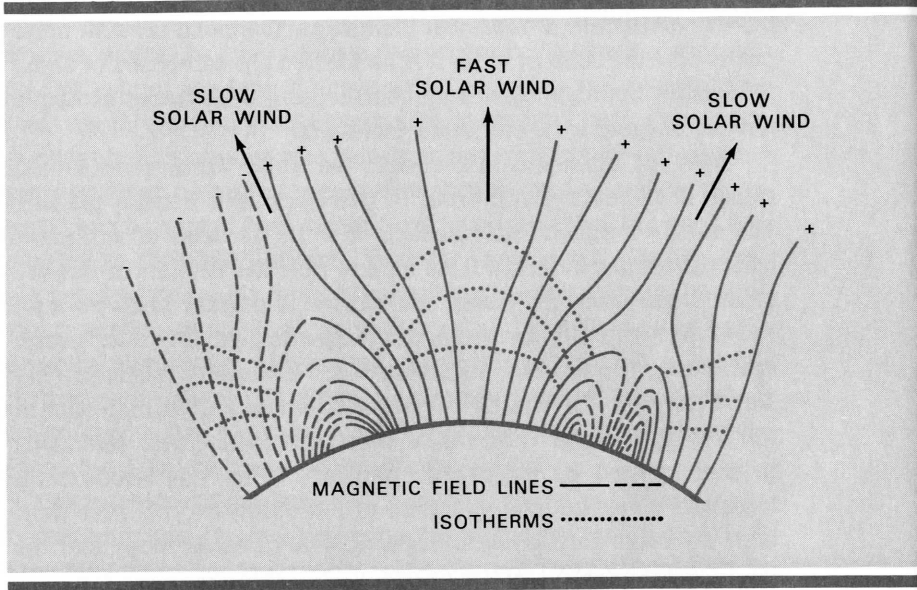
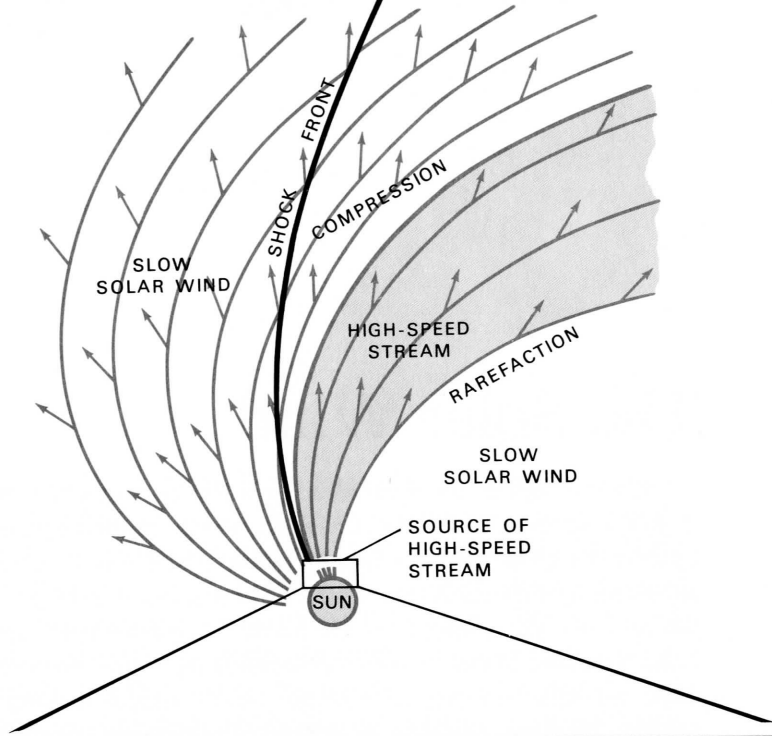
Such services flow both ways. In the case of our developing attempt to create a useful three-dimensional numerical simulation of the flow of matter and energy in the space between the sun and the earth, we find that expertise relating to the essential facets of such a model resides in the universities and in government laboratories. The program for the model development, therefore, envisions visits to NCAR by experts from other institutions as essential steps in the creation of this tool.

The Solar Wind

The concept of the solar wind as a constant flow of particles from the sun was formulated by Eugene Parker at the University of Chicago in 1958. Parker's theory replaced the older concept of solar corpuscular radiation, which had been developed to explain the auroras, the changes in the earth's magnetic field, and the radio interference that are often associated with solar events. Since 1960, satellites orbiting above the earth's magnetic field have verified the presence of the solar wind in interplanetary space and have revealed that it is almost identical in composition with inner portions of the solar corona: it is an ionized gas composed of about 95 percent hydrogen and 5 percent helium, with traces of highly ionized oxygen, iron, and other elements.

Moving at supersonic speed, the solar wind reaches the region of the earth's orbit four or five days after leaving the sun. The earth's magnetic field deflects it so its particles do not penetrate the atmosphere, but from time to time the velocity or density of the solar wind increases and causes important changes near the earth by modifying the earth's magnetic field. It is now known that during the eruption of a solar flare a mass of particles may shoot out from the sun at a velocity so much higher than that of the rest of the solar wind that a shock front is formed, analogous to that created by supersonic aircraft. When this shock front impinges upon the magnetic field of the earth, two or three days after the solar flare, the geomagnetic field changes shape and the flow speeds recorded by satellites increase sharply.

Solar flare eruptions carry with them into space tremendous quantities of energy: in a few hours one solar flare expends many times as much energy as is normally given off by the entire solar corona over several days. Some of this energy is doubtless transferred to the earth's magnetic field, but the mechanisms of the



The solar wind, spiraling outward from the sun, is now thought to be derived from relatively inactive areas on the sun. In active areas, strong magnetic fields guide ionized particles along loop-like paths, returning them to the solar surface and preventing their escape into interplanetary space. Persistent high-velocity streams emanate from areas distant from such strong magnetic fields.



transfer are not fully understood.

In addition to the sudden-onset variations caused by solar flares, more gradual changes in the solar wind occur almost constantly. Some changes seem to recur at regular intervals of about 27 days, and so are thought to relate to the rotation rate of the sun, about 27 days as seen from the earth. However, NCAR studies of satellite observations show that less than 10 percent of the velocity changes recur on successive rotations; most velocity structures evolve on a shorter time scale. Two features of the earth-sun relationship make precision studies unusually difficult: various latitudes of the sun rotate at different rates, and the plane of the sun's rotation is inclined slightly relative to the plane of the earth's orbit, so that from the earth we never view exactly the same part of the sun during successive 27-day periods.

Because of the sun's rotation, persistent high-velocity streams leaving the sun take on a spiral configuration, somewhat like streams of water droplets leaving a rotating sprinkler. Although the stream forms a spiral, the solar wind particles travel radially, as do the drops from a sprinkler. Material on the convex leading edge of each high-speed spiral should, theoretically, compress the ambient solar wind in front of it, while that along the concave side should become rarefied. Satellite data analyzed by NCAR scientists verify this relationship, but show that although compression along the leading edge is very great, shock waves predicted by theoretical models do not appear to form there.

There have been two schools of thought concerning the source of persistent streams in the solar wind. One school believed they must derive from active regions on the sun; the other claimed they originated in less active portions of the solar surface. During just the last few months, announcements by a number of solar phys-

icists, including NCAR scientists, have lent weight to the latter concept. When the magnetic polarities of successive streams are charted, the data show that individual streams carry either a predominantly negative or a predominantly positive polarity. Hence they must derive from fairly extensive solar areas characterized by having one or the other polarity, as do the inactive regions. Several preliminary attempts to trace solar wind streams back toward the sun suggest that their origin is in relatively inactive areas of the sun's surface, as predicted by theory.

Two NCAR physicists have found also that the average velocity and energy flow of the solar wind remain surprisingly constant through the 11-year solar activity cycle, even when increased energy is apparent in many parts of the sun's surface and corona. This finding supports the belief that most of the solar wind originates in the less active, but more extensive, portions of the solar corona.

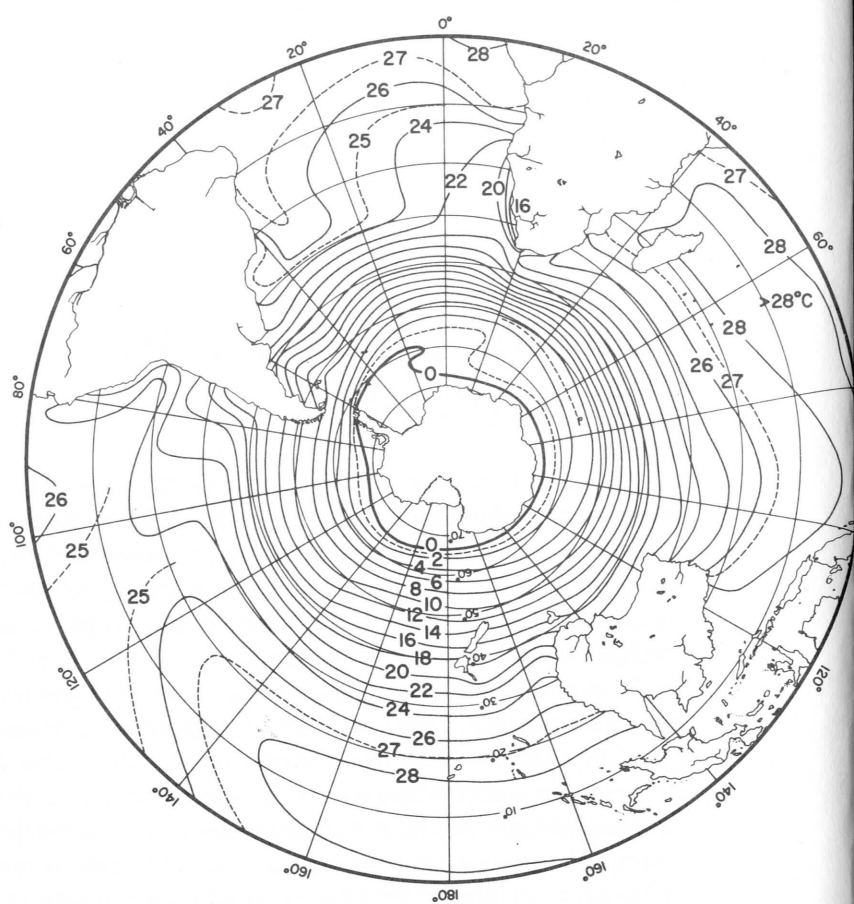
If this is the case, we are faced with another problem: Why should the geomagnetic field respond at all to the solar cycle? NCAR solar physicists studying the abundant data now coming in from satellites hope soon to be able to answer this question, as well as many others concerning the mechanisms by which the solar wind influences the geomagnetic field and the earth's upper atmosphere.

Southern Hemisphere Climatology

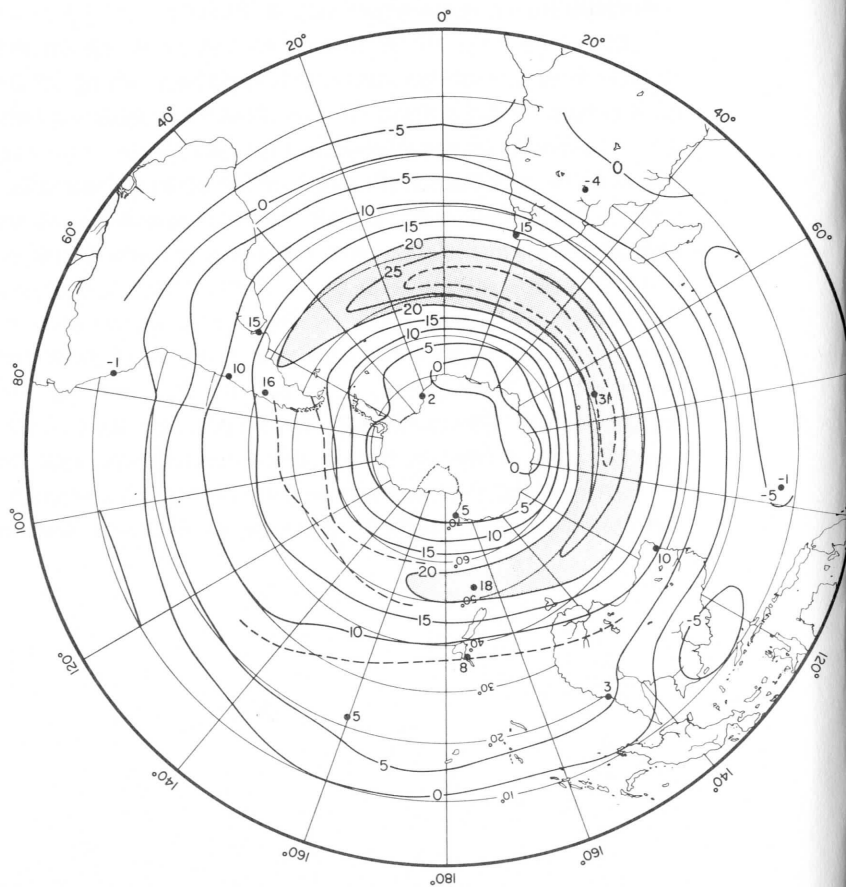
Patterns of weather and climate in the southern hemisphere differ substantially from those of the northern hemisphere, largely because of the much lesser extent of land areas and the much greater extent of ocean areas south of the equator. The ice-covered continental mass of Antarctica, too, must play a role in creating and maintaining climatic differences.

In the northern hemisphere the availability of extensive observational networks has provided opportunities to describe and study the atmosphere in considerable detail; the meteorology of the southern half of the world has remained, by comparison, relatively unexplored. Nevertheless, some data are available from island and continental weather stations and from cooperating "ships of opportunity." When considered over a period of years, they are complete enough to allow derivation of climatic means and definition of many weather features.

For some time NCAR has conducted research on the atmospheric structure of the southern hemisphere. Using all available data, scientists and computer specialists from NCAR, collaborating with members of the National Climatic Center and the South African Weather Bureau, have compiled charts of monthly means and incorporated them into a four-volume **Atlas of Southern Hemisphere Climatology**. This work was published between 1969 and 1972 cooperatively with the National Climatic Center and the Department of Defense. The southern hemisphere studies culminated this year with completion of a monograph, **Meteorology of the Southern Hemisphere**, published by the American Meteorological Society. This landmark volume presents an overall look at synoptic climatology in the southern hemisphere, and describes the nature of the southern hemisphere atmosphere—characteristic weather systems, average structure at different seasons, and



Maps of climatological means are significant components of the work done at NCAR on the southern hemisphere. The upper chart shows mean sea-surface temperature distribution (given in centigrade degrees) in midsummer; the lower chart shows the velocity of upper level westerly winds (at 500 millibars, expressed in meters per second) in summer. Note that upper level winds are strongest (shaded area) where the sea-surface temperature gradient is greatest.



features of the radiation, momentum, and energy budgets. Comparisons are drawn with related features in the northern hemisphere. For example, in the southern hemisphere the large heat storage capacity of the oceans moderates seasonal temperature changes so that they are not nearly as pronounced as in the northern hemisphere, where weather and climate reflect the summer heating and winter cooling of large continental masses. The total transfer of energy from the warm tropics toward the cold poles is similar in both hemispheres; however, differences in land coverage cause differences in the proportions of this energy carried by water vapor as latent heat, by other atmospheric mechanisms, and by ocean currents.

The charts of climatological averages and related statistics will be useful for comparison with calculations produced by numerical models of the global circulation, and as background material for GARP and for other studies of climatic change.

This Lockheed Electra, carrying an NCAR-designed instrumentation system, will be used in studies of cumulus development, mesoscale phenomena, and other features of the lower atmosphere. With a range of 6,400 kilometers, the aircraft is particularly suited to GARP programs, many of which will require long over-water flights. The Electra's flight speed ranges from 213 to 713 kilometers (130 to 440 miles) per hour, and its ceiling is 8,700 meters (28,400 feet).



Lockheed Electra Aircraft for GARP

NCAR research capabilities were greatly increased this year when the Research Aviation Facility acquired a Lockheed Electra four-engine turboprop aircraft. This large, long-range (6,400 kilometers or 3,460 nautical miles) aircraft was obtained specifically for use on long-distance over-water flights in support of GARP studies. It will be used initially during GATE and the Air Mass Transformation Experiment initiated by Japan.

The Electra has been sent to California for engineering studies and modifications necessary for instrument installation. The modifications include adding a nose boom and sensors for obtaining basic meteorological measurements, so that the aircraft can be used in studies of cloud development, organized mesoscale disturbances, and the planetary boundary layer. When complete, the Electra will carry a dual computer data system designed by NCAR scientists and engineers to generate both computer-compatible magnetic tape and in-flight displays of aircraft and meteorological information. One computer will sample and format incoming data for recording on magnetic tape; the other will perform the necessary derivative computations and data-display operations. The data system will be self-monitoring to insure data integrity; the dual system is so designed that if one computer fails the other will continue to log incoming data.

The Electra will also be equipped with an inertial navigation system, mounted at the base of the instrumented nose boom, which will provide accurate measurements of aircraft attitude (roll, pitch, and yaw) and vertical and horizontal acceleration. In addition to providing information on aircraft heading, ground speed, and position, the inertial navigation system will permit aircraft motions to be separated from small-scale wind variations measured by instruments on the nose-boom tip.

Other instruments being installed in the aircraft include several types of thermometers, hygrometers, instruments to measure total liquid water content in the air and the size distribution of water particles, pressure transducers to measure air speed and atmospheric pressure at flight level, a radio altimeter, radiometers and pyranometers to record incoming and reflected solar radiation, cameras, and storm-avoidance radar.

The Electra will also serve as a launching and data-gathering platform for the wind-finding dropsonde developed this year at NCAR. According to present schedules, the Electra data and instrumentation systems will be ready for in-flight testing during the fall of 1973.

Mountain-Induced Atmospheric Waves

When strong winds blow across mountains, standing waves develop in the atmosphere. This phenomenon has been recognized for some time. The presence of the waves is often indicated by linear arrays of stationary, lens-like clouds parallel to the mountain ridges and at right angles to the wind direction.

Recent research at NCAR shows that these waves are of more than regional significance. They are now believed to act as drag elements, slowing down prevailing high-level winds over extensive areas. On several occasions, NCAR's instrumented aircraft and cooperating aircraft from other institutions have flown traverses across the Front Range of the Rocky Mountains during periods of particularly vigorous westerly winds. They have recorded intense wave structures at levels up to 17 kilometers (55,000 feet)—well into the stratosphere—increasing in amplitude upward with the decreasing density of the atmosphere. Associated areas of clear air turbulence show that the waves, although stationary in their mean structure, may be breaking, removing momentum from the westerly flow and transferring it to the earth by producing a pressure difference across the mountains.

In the Wave Momentum Flux Experiment NCAR is now attempting to measure accurately the momentum that is removed by mountain-induced waves. Preliminary estimates based on studies in Colorado indicate that decreases in wind speed as great as 8 meters per second (18 miles per hour) may be common in the immediate mountain area, and that around the world at the same latitude decreases may still be on the order of 4 meters per second. Since mountains occupy 15-20 percent of the land area of both hemispheres, the drag occasioned by atmospheric waves forming above them must have important effects on global weather and climate.

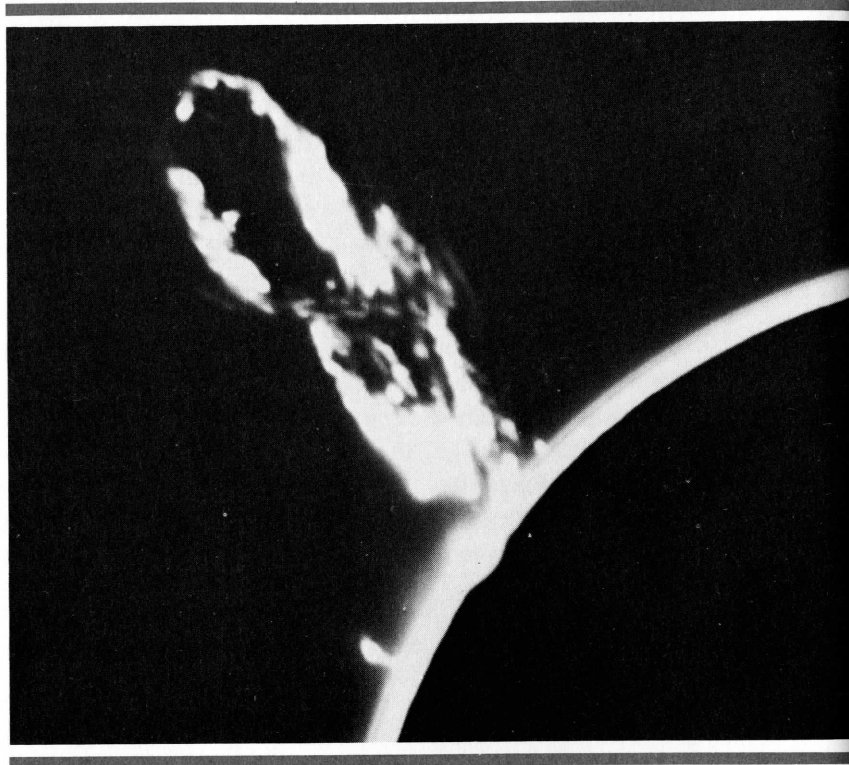
Standing atmospheric waves are marked by lines of lenticular clouds, shown here along the eastern edge of the Rocky Mountains. Although these clouds seem motionless, they are constantly replenished on their upwind side and continuously dissipated on their downwind side.



The findings at NCAR suggest the origin of a problem that has plagued atmospheric modelers. Most numerical models of the global circulation, such as NCAR's GCM, show an average westerly jet velocity about 5 meters per second greater than that found in the real atmosphere. When loss of momentum caused by mountain-induced waves is brought into the model, the discrepancy may be much reduced.

Atmospheric waves in the Rocky Mountain region are often associated with violent surface winds, damaging to the heavily settled areas along the lee of the mountains. As another new facet of its mountain wave studies, NCAR is attempting to develop a technique for predicting these dangerous winds. Research at the University of Colorado, using NCAR windstorm data, shows that conditions for lee-slope windstorms include a temperature inversion on the windward side of the mountains, with warm air overriding cooler air at mountaintop level. During the winter of 1972-73, NCAR and NOAA will test a monitoring system using acoustic soundings to locate such inversions west of the mountains, and employing surface and aircraft data and a numerical forecast model to predict wind conditions.

The great ascending solar prominence of 12 August 1972 was photographed in the light of hydrogen alpha at NCAR's field station on Mauna Loa, Hawaii. The prominence material moved radially from the sun with a speed of about 350 kilometers per second, in good agreement with the University of Colorado's interferometer measurements of a moving Type IV radio burst tracked to more than 4.5 radii from the center of the sun.



Three-Dimensional Structure of the Solar Corona

As seen at eclipse or with a coronagraph, the sun's corona appears flat against the plane of the sky, and one can readily overlook the fact that it is in reality a three-dimensional structure. Photographs of the corona, such as those obtained by NCAR at the 1966 and 1970 eclipses, do not reveal the true locations of streamers and other features: features in the line of sight overlap and blend together, making it difficult to distinguish one from another and to analyze the behavior of individual coronal components.

At NCAR's high altitude site on Mauna Loa, Hawaii, two instruments developed by HAO engineers, the K-coronameter and the Coronal Activity Monitor, measure coronal radiance electronically. They record the polarized K-component of the corona, the light scattered by free electrons in the sun's atmosphere. Both the K-coronameter and the Coronal Activity Monitor measure this radiation by making concentric small-aperture scans around the sun while the brilliant solar disk is occulted.

The wealth of observations now available from Mauna Loa facilitates studies of the evolution of individual coronal features. As the sun rotates, there are apparent changes in coronal features as projected against the sky, and from these changes the three-dimensional structure of the corona can be deduced. When active centers on the solar disk reach the edge of the sun, for instance, helmet-shaped structures appear at greater heights above the sun's surface and taper to narrow streamers. Comparing K-coronameter measurements with corresponding observations of the inner corona and the solar disk, NCAR solar astronomers have found that long-lived helmets develop in association with active centers near the sun's equator, and that they then drift toward the poles. Solar differential rotation distorts the active centers so that they become strung out and often break apart; the helmets broaden and sometimes divide correspondingly.

NCAR scientists have now developed a complex numerical technique which will enable them to identify and describe coronal structures by calculating their electron densities from K-coronameter data. Mapping the electron densities in terms of latitude, longitude, and distance above the edge of the sun, they are able to identify the boundaries of individual coronal streamers and resolve overlapping features.

Occasionally, Mauna Loa data show very abrupt, short-lived changes in localized regions of the corona. These usually occur at low latitudes and are associated with explosive solar prominences. Cooperative research with the Commonwealth Scientific and Industrial Research Organization in Australia has shown that these changes are sometimes associated with moving sources of radio noise—several coronal transients have now been recorded by instruments at Mauna Loa and by the radioheliograph at Culgoora, Australia. Recent satellite observations suggest that massive eruptions in the outer corona may cause such short-lived features. Careful study of K-coronameter, radioheliograph, and satellite information can reveal whether these eruptions occurred on the near or the far side of the sun.

Orbiting above the light-scattering atmosphere, satellites offer many advantages over ground-based solar observatories. A satellite coronagraph designed at NCAR will be mounted on NASA's Skylab manned orbiting observatory scheduled for launch in 1973. With colleagues from other observatories, NCAR scientists have also proposed that an improved satellite coronagraph, capable of recording events in the lower corona, be mounted on the Orbiting Solar Observatory OSO-K in 1976. Data from these instruments, coupled with continuing K-coronagraph and radioheliograph information, should further document the evolution of solar structures in three dimensions.

Wind-Finding Dropsonde

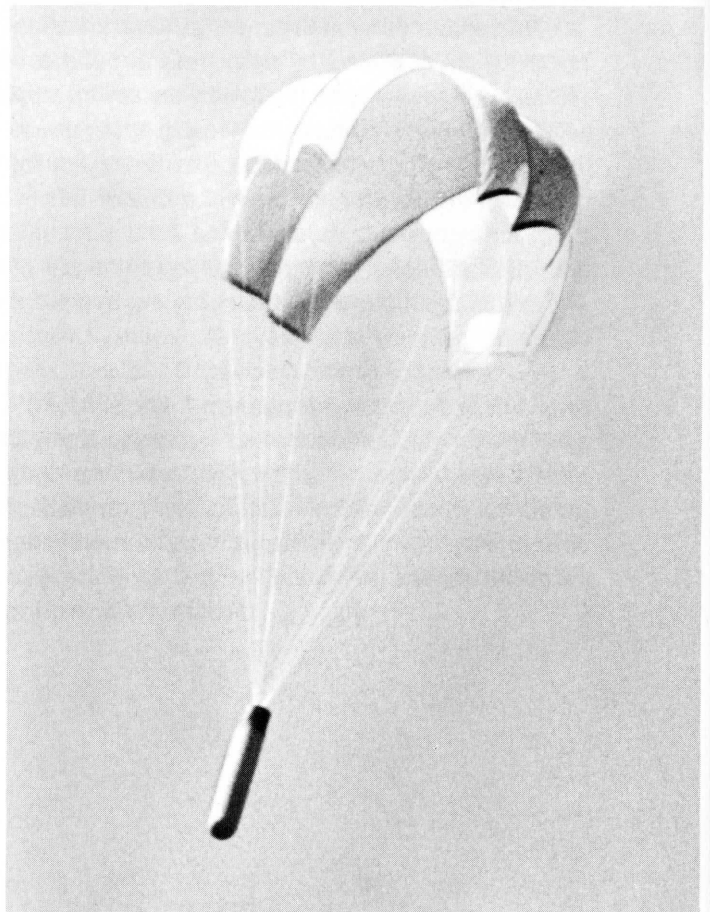
International programs planned for the mid-1970s need methods for obtaining accurate wind and meteorological data in the tropics. At the request of NCAR scientists involved in GARP and the U.S. GATE Project Office at NOAA, NCAR's Facilities Laboratory has designed a new dropsonde to fulfill this need. The dropsondes, which will be released from a special dispenser mounted inside an aircraft, can measure temperature, humidity, and barometric pressure, transmitting the data back to the parent aircraft through a telemetry link. By simultaneously receiving and relaying Omega international navigation signals, the dropsondes provide data from which their horizontal positions, and therefore the winds encountered during their fall, can be computed.

Dropsonde descent from an altitude of about 7.5 kilometers (24,600 feet) is slowed by parachute initially to about 10 meters (33 feet) per second. In the lower, denser atmosphere the rate of descent is only 5 meters per second. The descent of each sonde lasts about 20 minutes; during this time, data are reported continuously, giving profiles along the line of fall.

Each dropsonde is contained in a tube measuring 9 centimeters in diameter by 45 centimeters in length (3.5 by 18 inches)—a size compatible with launching equipment already available on many military and research planes. Current plans for the use of these dropsondes during GATE call for as many as 20 dropsondes deployed during each flight of NCAR's Electra aircraft over the tropical Atlantic. Omega navigation equipment carried aboard the aircraft will provide exact aircraft location data, giving an unambiguous starting point for each dropsonde track. Navigational and meteorological data will be processed and recorded aboard the plane.



A prototype wind-finding dropsonde is released from Colorado State University's research aircraft. The dropsonde, shown in the lower photograph, weighs only 1.75 kilograms (3.8 pounds). Since these sondes are to be used over ocean areas, they will be expendable, built of relatively inexpensive materials comparable to those used in conventional radiosondes.



Development work on the wind-finding dropsonde is nearly complete; prototype sondes are being flight-tested and, if the flight tests are satisfactory, the final model should be ready for production in early 1973.

NCAR-UNIVERSITY INTERACTIONS

A radar installation in northern Colorado is one of several field centers for the National Hail Research Experiment. The radar is operated by teams from the University of Illinois and the Illinois State Water Survey; the plastic dome protects its antenna.

CHICAGO



Major Field Programs

At NCAR, as elsewhere, exchange and collaboration have become more and more the style of science. NCAR provides scientific, research-support, and educational resources to which many universities contribute and on which they draw. The growing number of projects too large or too diverse to be undertaken by any single group has created tight cooperative bonds between NCAR and the universities: the National Hail Research Experiment (NHRE) and the programs associated with GARP are the most prominent examples of NCAR-university joint research efforts now under way. The developing Saint Louis study provides additional opportunity for future collaborative work.

NHRE, a five-year study, centers around two goals: to gain increased knowledge of the physics and dynamics of hailstorms, and to test the feasibility of cloud seeding as a tool for reducing damage from hail. Eight universities and several state and federal agencies are taking part in this experiment under NCAR leadership. The Saint Louis study will analyze the impact of a large city on the atmospheric environment. The leadership role in this study has been placed with the Environmental Protection Agency; NCAR chemists are participating in analyses of downwind pollutants. GARP programs have an international base; here NCAR is serving as a medium through which university scientists may become involved in supporting programs or in the First GARP Global Experiment. A major asset to NCAR and university GARP projects is the Lockheed Electra four-engine turboprop aircraft described above. The Electra's long flight range is essential for airborne investigations of many atmospheric phenomena. The aircraft is being equipped with special instruments and data systems and will be used in GATE in 1974 and in other GARP-related observing programs.

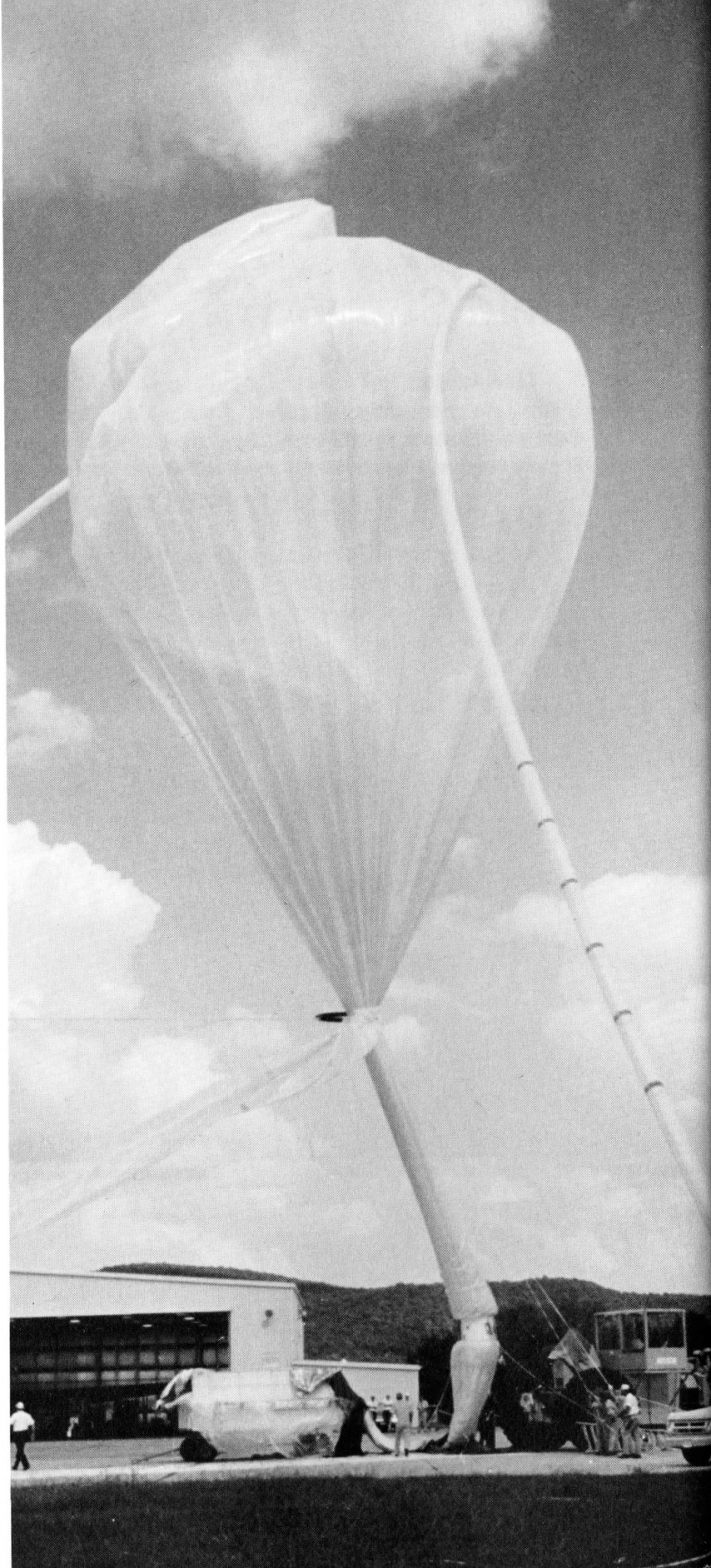
NCAR's Queen Air cruises off the Oregon coast during CUE. Equipped with an instrumentation system developed at NCAR, the Queen Air serves as a mobile platform for measuring and recording atmospheric conditions, sea-surface temperatures, and sea-surface chlorophyll content in the CUE area. (Photo courtesy of Oregon State University.)



Field Support

Field support and often field management of large experiments are frequently requested from NCAR. This year the Facilities Laboratory (FAL) again provided field management, logistic support, equipment, and technical crews for Colorado State University's Venezuela International Meteorological and Hydrological Experiment, in which students, university researchers, and government scientists from the United States, England, Venezuela, and Germany took part. FAL also supported two university-based projects for the International Field Year for the Great Lakes, and participated in the Coastal Upwelling Experiment (CUE), a field study along the Oregon coast involving 20 organizations. NCAR conducted survey trips to Africa in 1971 and 1972 to evaluate sites for two expeditions to observe the solar eclipse of 30 June 1973. The National Science Foundation, which will sponsor the expeditions, has requested that NCAR manage the field program; about 100 university and government scientists will participate. Another survey trip to Africa evaluated sites for a proposed land-based program coordinated with GATE in 1974.

A 6-million-cubic-foot (170,000 cubic meter) balloon is inflated at Huntsville, Alabama, preparatory to the launch of the Stratoscope II astronomical telescope. Scientific Balloon Facility engineers have designed special equipment and procedures for launching such heavy, delicate instruments without swinging or jarring the payload as low-level winds tug the balloon to leeward.



Scientific Balloon Facility

NCAR's Scientific Balloon Facility, now consolidated at Palestine, Texas, continues to provide flight services for university investigators. The Palestine site is being improved by construction of a new paved surface for launch operations. A major achievement this year—perhaps one of the most difficult feats of modern day ballooning—was the successful flight of the 7-ton Stratoscope II telescope in a joint program with Princeton University and NASA. For the second consecutive year the Balloon Facility conducted a series of balloon launches from Argentina for flights in southern hemisphere skies.

Fellowships and Professorships

NCAR's educational activities attract outstanding students to graduate study in atmospheric science, and provide established scientists with opportunities to become a part of activities at NCAR. NCAR continues to offer postdoctoral fellowships to scientists from the United States and abroad and summer employment to predoctoral students. Through the Advanced Study Program, fifteen new postdoctoral appointments were awarded during the current fiscal year, three to scientists on sabbatical leave from university positions. Under the provisions of the Presidential Internship Program, seven unemployed scientists with doctor's or master's degrees were granted one-year appointments at NCAR. Some are applying previously acquired skills and others are learning new skills to replace skills no longer marketable.

NCAR scientists participate in university life through affiliate or adjoint professorships, as well as by participating in meetings and university field projects. At present, NCAR scientists hold appointments as affiliate and adjoint professors at Pennsylvania State University and at the Universities of Miami, Alaska, Missouri, and Washington.

Visitors and the Advanced Study Program

During the last year 80 doctoral scientists worked at NCAR as short- or long-term NCAR-sponsored visitors. An equal number visited NCAR to conduct research with funding from independent sources. Among these were 21 oceanographers who gathered for several weeks to discuss the Mid-Oceanic Dynamics Experiment, sponsored by the National Science Foundation and planned for the spring of 1973.

The Advanced Study Program initiated a series of visitors' seminars to familiarize both visitors and NCAR staff with atmospheric science topics. Lectures by NCAR scientists, reviewing many specialty areas, have focused on research opportunities in atmospheric dynamics, cloud physics, GARP, atmospheric chemistry, radiation, the upper atmosphere, solar-terrestrial physics, and problems relating to ecology. Emphasis on historical perspectives and problems for the future will, it is hoped, help young scientists formulate their research goals.

With NCAR scientists involved in GARP, the Advanced Study Program sponsored a nine-week summer colloquium on the dynamics of the tropical atmosphere, a topic chosen for its timeliness in relation to the planned GATE experiment. Participants came from 15 organizations in 10 countries. During one week the colloquium was interrupted to enable its members to attend a workshop on GATE, where they observed a scientific group debating a developing problem related to the topics dealt with in the colloquium.

Summer conferences and colloquia at NCAR bring young scientists in contact with experts in many fields related to the atmospheric sciences. Lectures, workshops, and informal discussion groups often lead to teamwork on special problems.



Conferences and Meetings

NCAR continues to gain importance as a center for conferences, symposia, planning meetings, and other formal or informal scientific gatherings involving university participants. NCAR was host for a conference on flare-produced shock waves in the solar corona and interplanetary space, at which 47 international authorities sought to assemble a coherent picture of eruptive flare events. In October, a symposium on human interactions with the atmosphere brought together physical, social, and political scientists, ecologists, economists, psychologists, and lawyers to exchange ideas on such topics as man-made atmospheric changes and their ecological consequences, the role of behavioral and social research in the management of atmospheric resources, political and social choices involved in weather modification, and scientific responsiveness to public issues.

NCAR'S cinematographer films the installation of radar hail-detection equipment at a field site in northern Colorado. NCAR has produced six short documentary films describing research programs in solar astronomy, atmospheric chemistry, and cloud physics.



Work-Study Programs

A cooperative work-study program was established this year to encourage undergraduate students who are interested in the atmospheric sciences by offering them opportunities for practical experience. Three students with three- to six-month appointments are now working on NCAR programs under the supervision of staff scientists. NCAR also reaches students (as well as university faculties and laymen) through its quarterly periodicals and documentary motion pictures geared to general or science-oriented audiences.

The Facilities Laboratory initiated a summer program to train students in planning and implementing field projects for atmospheric research support. The six participating students received on-the-job training in instrument design, field observation, and airborne research techniques. For the eighth consecutive year the Computing Facility awarded summer fellowships for training in scientific computer programming. A case study recently completed by the facility showed that participants in the programs from 1966 to 1971 maintained high interest in the use of computers in their academic and professional careers. All former participants commented favorably on the value of receiving training at a basic research center where they could observe and assist scientists pursuing tangible research problems. The students stated that the learning experience at NCAR was "different from the academic environment, but equally effective."

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CORPORATE FINANCIAL SUMMARY

Fiscal Year 1972

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Balance Sheet
June 30, 1972 and 1971

		ASSETS	
		<u>1972</u>	<u>1971</u>
CURRENT FUND:			
Cash (includes interest-bearing deposits: 1972, \$318,595; 1971, \$44,211)	\$	344,958	\$ 70,217
United States Government securities (at cost, which approximates market value)		20,000	169,579
Receivables		3,508	10,012
Prepaid expenses		8,553	7,837
Total current fund		<u>377,019</u>	<u>257,645</u>
PLANT FUND—Property (Note 2):			
Plant (net)		434,152	435,134
Equipment		620,245	609,609
Total plant fund		<u>1,054,397</u>	<u>1,044,743</u>
TOTAL		<u>\$1,431,416</u>	<u>\$1,302,388</u>

LIABILITIES AND FUND BALANCES

CURRENT FUND:			
Accounts payable	\$	13,050	\$ 9,983
Fund balance (restricted: 1972, \$35,204; 1971, \$35,662)		363,969	247,662
Total current fund		<u>377,019</u>	<u>257,645</u>
PLANT FUND—Balance (Note 2)		<u>1,054,397</u>	<u>1,044,743</u>
TOTAL		<u>\$1,431,416</u>	<u>\$1,302,388</u>

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Statement of Revenues, Expenditures, and Changes in Fund Balances
for the Years Ended June 30, 1972 and 1971

	<u>1972</u>	<u>1971</u>
CURRENT FUND:		
Revenues:		
Fee for management of the National Center for Atmospheric Research	\$ 320,000	\$ 140,000
Interest	16,293	16,910
Other (principally dues and gifts)....	15,722	12,974
TOTAL.....	<u>352,015</u>	<u>169,884</u>
Expenditures:		
Salaries and wages	74,638	69,055
Travel	46,132	59,111
Services	39,805	31,626
Materials, supplies, and other	27,670	18,423
Employee benefits	19,024	17,227
Fellowships	16,455	15,961
TOTAL.....	<u>223,724</u>	<u>211,403</u>
Revenues over (under) expenditures..	128,291	(41,519)
Current fund balance—Beginning	247,662	290,117
Transfer to plant fund for property additions	(11,984)	(936)
Current fund balance—Ending	<u>\$ 363,969</u>	<u>\$ 247,662</u>
PLANT FUND:		
Plant fund balance—Beginning	\$1,044,743	\$1,056,812
Transfer from current fund for property additions	11,984	936
Government excess, donations, etc.....	7,196	2,248
Amortization	(8,526)	(8,169)
Disposals	(1,000)	(7,084)
Plant fund balance—Ending	<u>\$1,054,397</u>	<u>\$1,044,743</u>

See Notes to Financial Statements.

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

**NOTES TO FINANCIAL STATEMENTS
FOR THE YEAR ENDED JUNE 30, 1972**

1. The University Corporation for Atmospheric Research is a nonprofit membership corporation engaged in scientific and educational activities in atmospheric research and related fields. The Corporation operates the National Center for Atmospheric Research under contract with the National Science Foundation. Contract C-660 terminated on June 30, 1972 and was renegotiated under Contract C-760 for a five-year period ending June 30, 1977. The performance of work under Contract C-760 may be terminated by the Foundation whenever it shall determine that such termination is in the best interests of the Government. Other Government agencies also utilize the services of the National Center through contracts and grants.

Financial position and results of operations of the National Center (which are not included in the financial statements presented herewith) as of June 30, 1972 and 1971 and for the years then ended are included below:

National Center for Atmospheric Research Balance Sheet

ASSETS

	<u>1972</u>	<u>1971</u>
CURRENT FUND:		
Cash	\$ 45,691	\$ 34,954
Receivables:		
National Science Foundation.....	7,080,622	4,889,468
Other governmental agencies.....	311,130	259,734
Other	135,363	111,292
Balloon inventory, prepayments, etc...	210,770	247,069
Total current fund	<u>7,783,576</u>	<u>5,542,517</u>
PLANT FUND—Property (a):		
Plant	9,495,788	8,357,395
Equipment	18,500,701	16,547,676
Construction in progress	247,017	988,365
Total plant fund	<u>28,243,506</u>	<u>25,893,436</u>
TOTAL.....	<u>\$36,027,082</u>	<u>\$31,435,953</u>

LIABILITIES AND FUND BALANCES

CURRENT FUND:		
Liabilities (e):		
Accounts payable	\$ 1,020,780	\$ 496,485
Salaries and wages payable	270,826	241,666
Payroll taxes	72,120	52,919
National Science Foundation	136,465	106,722
Other liabilities	266,783	91,606
TOTAL	<u>1,766,974</u>	<u>989,398</u>
Commitments (b):		
Fund balance:		
National Science Foundation	6,015,870	4,553,119
Other grant	732	
TOTAL	<u>6,016,602</u>	<u>4,553,119</u>
Total current fund	7,783,576	5,542,517
PLANT FUND—Balance (a)	28,243,506	25,893,436
TOTAL.....	<u>\$36,027,082</u>	<u>\$31,435,953</u>

Statement of Revenues, Expenditures, and Changes in Fund Balances

	1972			
	NATIONAL SCIENCE FOUNDATION CONTRACT	OTHER GOVERNMENT CONTRACTS AND GRANT	TOTAL	1971 TOTAL
CURRENT FUND:				
Revenues:				
National Science				
Foundation funds	\$20,166,555		\$20,166,555	\$16,219,424
Other Government agency				
funds	986,600		986,600	531,500
Other contracts and grant..		\$ 1,932,894	1,932,894	2,235,216
TOTAL	21,153,155	1,932,894	23,086,049	18,986,140
Expenditures (c):				
Operating:				
Salaries and wages	8,574,168	47,163	8,621,331	7,547,354
Employee benefits	1,122,680	6,157	1,128,837	951,624
Materials and supplies	1,907,690	225,614	2,133,304	1,360,809
Services	4,029,856	1,609,200	5,639,056	4,113,391
Travel	561,077	42,210	603,287	383,244
Fixed fee (d)	320,000		320,000	140,000
Other	310,721		310,721	212,774
Total Operating...	16,826,192	1,930,344	18,756,536	14,709,196
Property	2,864,212	1,818	2,866,030	2,034,953
TOTAL	19,690,404	1,932,162	21,622,566	16,744,149
Revenues over expenditures	1,462,751	732	1,463,483	2,241,991
Fund balance, beginning of				
year	4,553,119		4,553,119	2,311,128
Fund balance, end of year	\$ 6,015,870	\$ 732	\$ 6,016,602	\$ 4,553,119
PLANT FUND:				
Balance, beginning of year	\$25,675,083	\$ 218,353	\$25,893,436	\$23,822,892
Current year acquisitions:				
Current fund expenditures	2,864,212	1,818	2,866,030	2,034,953
Government excess, dona-				
tions, etc.	271,366		271,366	370,933
Current year disposals	(787,326)		(787,326)	(335,342)
Balance, end of year	\$28,023,335	\$ 220,171	\$28,243,506	\$25,893,436

- (a) Property is recorded at cost except for property acquired from United States Government excess and donations which are recorded by management at an appraised value of \$4,200,788. Title to the National Center property is vested in the National Science Foundation and other Government agencies.

In accordance with practices generally followed by organizations similar to the National Center, no provision has been made for depreciation of property.

- (b) At June 30, 1972 the National Center had unfilled purchase order commitments of approximately \$4,400,000 and annual lease commitments for the year ending June 30, 1973 of approximately \$843,000.
- (c) Expenditures charged to all Government contracts are subject to Government agency audit and adjustment.
- (d) The fixed-fee expenditure of the National Center is paid to University Corporation for Atmospheric Research for management of the National Center.
- (e) At June 30, 1972 the National Center has a contingent liability not reflected in the foregoing financial statements of approximately \$866,000 for employee vacations earned but not taken. Vacations are recorded as taken or when the employee terminates. In the event of termination of Contract C-760 for the convenience of the Government, the liability at the time of termination for unused employee vacations would be satisfied by the National Science Foundation.

2. Property is recorded at cost except for property acquired from United States Government excess and donations which are recorded by management at appraised values as follows: 1972, \$806,841; 1971, \$799,645.

In accordance with practices generally followed by organizations similar to the Corporation, no provision has been made for depreciation of property except that under terms of a declaration of trust covering the Fleischmann Building, such building must be sold to the United States Government at a price not to exceed cost less amortization over a period of twenty-five years beginning with the date of occupancy. At the end of that period, in 1994, title to the building must be conveyed to the Government without charge. Accordingly, amortization of \$8,526 and \$8,169 has been charged to the plant fund balance during the years ended June 30, 1972 and 1971, respectively. Building cost at June 30, 1972 is \$211,763 with accumulated amortization to that date of \$24,183.

3. At June 30, 1972 the Corporation is contingently liable for \$35,204 pursuant to a deferred compensation contract with a corporate officer. The contract provides for total payments from corporate and insurance policy sources of \$72,000 in event of the officer's death or upon his retirement. It is estimated that the cash value of the life insurance policy at the officer's retirement will approximately equal the required compensation benefits.

HASKINS & SELLS

CERTIFIED PUBLIC ACCOUNTANTS

621 SEVENTEENTH STREET

DENVER 80202

ACCOUNTANTS' OPINION

Board of Trustees,
University Corporation for Atmospheric Research:

We have examined the balance sheet of the University Corporation for Atmospheric Research as of June 30, 1972 and the related statement of revenues, expenditures, and changes in fund balances for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying financial statements present fairly the financial position of the University Corporation for Atmospheric Research at June 30, 1972 and the results of its operations and changes in fund balances for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Haskins + Sells

September 1, 1972