

UCAR

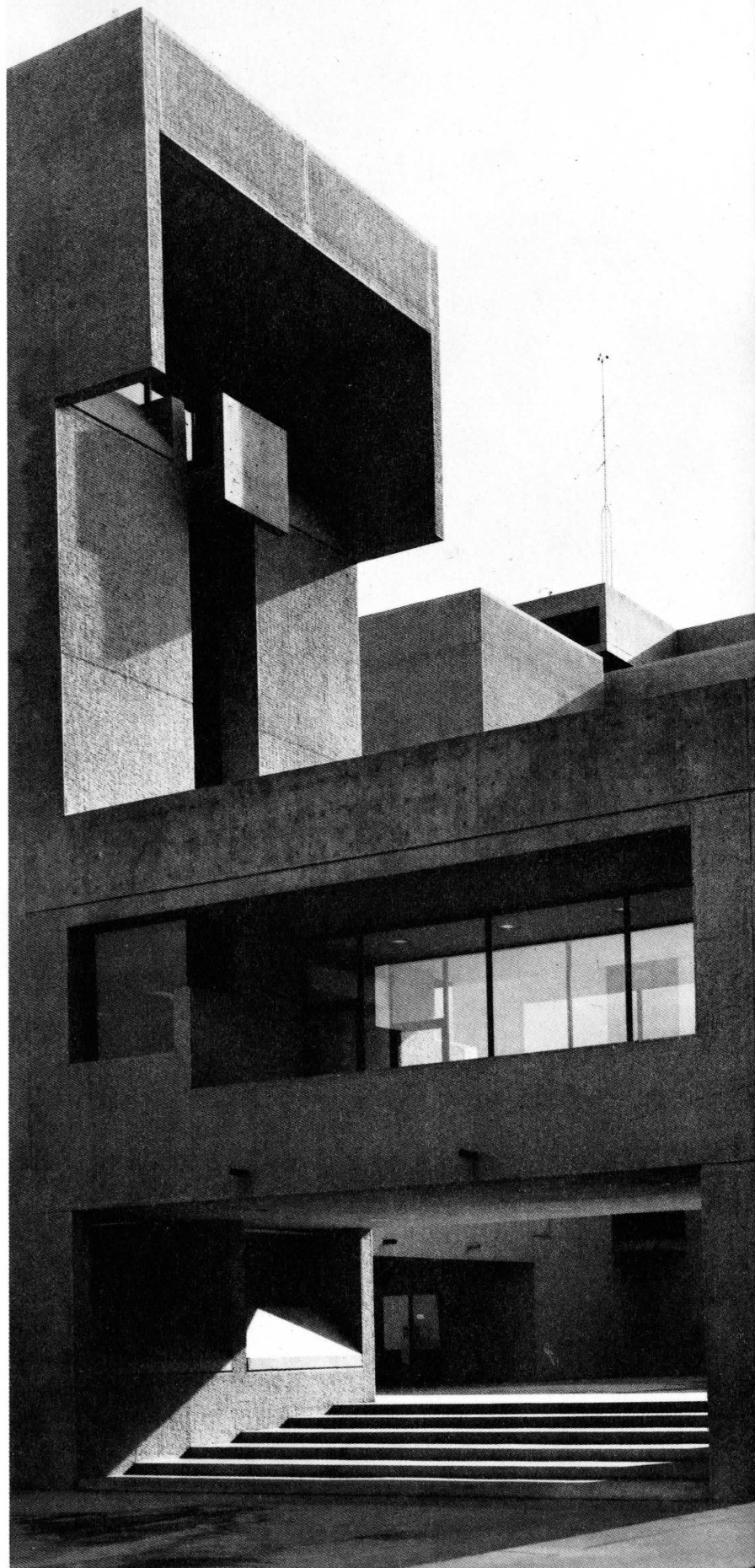
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Report for 1973

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Contents

President's Statement	4
NCAR Highlights	8
The National Hail Research Experiment	15
The Global Atmospheric Research Program	19
The Solar Corona –	
1973 Eclipse Expedition and Skylab.....	27
Small-Scale Analysis and Prediction	31
Environmental Assessment	37
Computing Facility Remote Access.....	40
Management and Financial Reports.....	42
UCAR Members' Representatives.....	43
UCAR Board of Trustees and	
Corporate Officers	48
NCAR Senior Management Staff.....	50
Corporate Financial Summary	51

PRESIDENT'S STATEMENT

The times are changing. The impact can be seen in the rising aspirations of most segments of humanity on this continent and throughout the world. The air is electric with the growing realization that we of Planet Earth have at long last attained the knowledge and the resources to bring about a world that assures equality, peace, and sufficiency to all of its inhabitants. Corollary to this is mounting impatience with social systems that do not speed the attainment of a better life. There is also an ever more widespread appreciation that the natural resources of earth are finite, and must be shared with restraint and wisdom if these rising aspirations are to be achieved.

The world's peoples, where they have the means of self-expression, have begun to demand that the spotlight of science and technology be focused on the needs of society rather than simply on the attainment of knowledge for its own sake. One can argue, of course, that it has always been so, or that pure science leads swiftly to practical uses. But there is little doubt that decision makers are looking more sharply for prompt and tangible benefits in return for public support to science.

Our great challenge is to respond to these pressures affirmatively, but without violence to the time-tested methods of science as a secure way to knowledge. The pressures are especially great in atmospheric research. Our science is still expanding rapidly in response to its prompt applicability to social purposes, and as a corrective to its earlier underdevelopment. The world's people have great stake in advancements in weather and climate forecasting, in air quality protection, and in deliberate and adventitious weather modification. In spite

of this, the atmospheric sciences are experiencing severe budget stringencies, as public funds for all areas of science shrink, and as many scientists in other fields look at the rapid growth of atmospheric research in recent years and wonder aloud about whether it is not time to hold this discipline down.

Faced with changing times and with budgetary constraints affecting the whole science, the University Corporation for Atmospheric Research carried out an intensive self-evaluation during the year. At the close of this analysis, UCAR affirmed its confidence in its prime purpose, the operation of the National Center for Atmospheric Research. Even in the face of the tight budgetary circumstances, the UCAR universities restated their conviction that the interests of the universities themselves, and the public more generally, are well served by UCAR's best efforts to operate a powerful and effective NCAR.

As a part of the same evaluation, UCAR reviewed its entire management and organization, and set new courses designed to bring to the operation of NCAR a sharpened focus on major research problems of importance to society. UCAR also took steps aimed at enhancing NCAR's partnership with and service to university research groups. The principal organizational outcome of this period of analysis has been a restructuring of the scientific division of NCAR along problem-oriented lines as distinct from the prior disciplinary management structure. Since this reorganization was carried out primarily by the Director of NCAR and his staff, I have asked the NCAR Director, John W. Firor, to discuss its implications in his portion of this annual report, below.

UCAR faces the coming year with a new sense of dedication to serve society and to do so in close alliance with the

member universities and other research organizations. Without their full and voluntary participation our ambitious goals are unattainable. The very nature of the atmosphere of our planet forces our thinking to transcend conventionally defined discipline, and imposes upon us broadly transnational perspectives; thus, we must not shrink from innovation, organizationally and in our science. We share a deep conviction that society urgently needs our ultimate product, knowledge of our atmospheric environment. Therefore we will not lower our sights even in times of stress. We must invent new ways to join forces with others in our society whose stakes in success equal our own. With their help we will be able to marshal the immense human and material resources needed to achieve our aim of "enabling the world's people to live in long-term harmony with their atmospheric environment."*

Walter Orr Roberts
President
University Corporation
for Atmospheric Research

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

NCAR HIGHLIGHTS

President Roberts, in his introduction to this report, has referred to the period of evaluation that UCAR and NCAR have just completed, and to the reorganization we have undertaken to direct NCAR, with the best precision that human judgment and group consensus will allow, toward its optimum role in the atmospheric science of today. Many people have taken part in NCAR's reorganization—NCAR staff, UCAR member university faculties, faculties and staffs of other universities and institutions, and representatives from the National Science Foundation. Everyone has approached the task with interest and seriousness, and NCAR is indebted to them for their help.

NCAR's mission was thoroughly reviewed and discussed, and two parallel but complementary roles emerged as the most critical for NCAR to undertake:

- NCAR, in cooperation with universities and other research groups, will identify, develop, and make accessible major research services and facilities required by the universities and NCAR.

- NCAR, in cooperation with universities and other research groups, will plan and carry out research programs of highest quality on selected scientific problems of national and international scope.

The main effects of this revised mission are to intensify the service function of NCAR to the university community, and to sharpen NCAR's internal research focus on problem areas, with increased participation at all stages by university researchers. The portion of this report that describes NCAR research highlights for 1973 contains many indications of important and integral participation by university representatives; we build on a firm base of experience as we move to increase the involvement of university scientists in planning and carrying out research programs.

NCAR's revised mission is also reflected in the redefinition of NCAR's research programs into problem areas, instead of into disciplines as previously. Research in the High Altitude Observatory, already project-oriented toward studies of the solar corona and solar-terrestrial relations, remains under its previous organizational structure. The Advanced Study Program has been left versatile; at present much of the attention of this group is directed toward making NCAR research work a valuable stage in the educational process of many atmospheric scientists. But all research efforts which previously were carried out in the Laboratory of Atmospheric Science's discipline-organized departments (Atmospheric Chemistry, Atmospheric Physics and Microphysics, and Atmospheric Dynamics) are now classified into broad project groups and placed in two new divisions, Atmospheric Analysis and Prediction, and Atmospheric Quality and Modification.

The new organizational scheme became fully effective on 1 July, with new or acting leaders appointed earlier for the divisions and project groups. Research has been progressing for several months within six groups: the Global Atmospheric Research Program (GARP), Small-Scale Analysis and Prediction, Climate, the National Hail Research Experiment (NHRE), Urban and Global Pollution, and Upper Atmosphere. GARP and NHRE were previously special project-oriented NCAR activities; they are now continuing as formal subdivisions in the new structure. The remaining four projects are new in their formulation of goals and research strategy, but in each case they are built on ongoing research programs that will contribute to the project. Preliminary goals for the six project groups are outlined below, and reviews follow of selected research work of these groups.

National Hail Research Experiment

This cooperative experiment has as its goals:

- To gain an increased understanding, by observation and analysis, of all aspects of the cloud dynamics and microphysics governing the severe convective storms that produce damaging hailfall at the ground.

- Equipped with this increased knowledge, to develop, if possible, a practicable method for suppressing the occurrence of damaging hail.

Global Atmospheric Research Program

The objectives of this program have been spelled out by international planning bodies: "To study the physical processes essential to an understanding of the large-scale fluctuations that control changes of the weather, leading to an improvement of weather prediction over periods of one day to several weeks." NCAR's activities will be to support these objectives, in close conjunction with participating universities and United States agencies.

Project on Small-Scale Analysis and Prediction

The present goals of this project are fourfold:

- To study small- and mesoscale atmospheric processes (processes in the size range measured in tens and hundreds of kilometers, respectively) and to determine how they contribute to the general circulation.
- To develop methods for short-range prediction of severe downslope winds and clear air turbulence.
- To improve short-range weather prediction through development of new types of models, particularly models based on potential temperature gradients rather than pressure.
- To improve theoretical understanding of boundary layer processes.

Climate Project

The ultimate goal of this project is to develop methods for predicting natural and possible man-made climatic changes from a few weeks to a century in advance. More immediate targets are:

- To adapt NCAR's Global Circulation Model to climatic studies.
- To design simple numerical models to study dominant climatic factors such as ice caps, ocean circulations, aerosols, and the hydrologic cycle.
- To apply statistical-dynamical techniques to climate modeling.
- To carry out a joint university/NCAR field program on the role of aerosols in the radiation balance.

Urban and Global Pollution Project

The goals of this project are to determine the distribution, seasonal variations, and long-term trends of natural and man-made constituents in relatively unpolluted air and in urban and near-urban regions, in an attempt to assess man's effects on atmospheric quality and the increasing load of trace constituents carried by the global atmosphere.

Upper Atmosphere Project

The goals of this project are to develop global-scale models of the atmosphere above the tropopause, incorporating chemical, physical, and dynamical processes. Such models will be applied to climatic studies and to questions of man's impact on the upper atmosphere (above about ten kilometers), as in NCAR's current study of the potential impact of supersonic transports.

Ravaged crops near Julesburg, Colorado, exemplify the destruction caused by hail. Atmospheric scientists feel that it may be possible and practical to allay such damage by seeding potential hail clouds, producing many small hailstones instead of large ones. Small hailstones often melt before reaching the ground; failing to melt, they are nevertheless not as destructive as the large ones.



National Hail Research Experiment

The yearly crop loss in the United States that is caused by hail damage is about 300 million dollars; damage to real property is thought to be about 30 to 60 million dollars. Economic incentive, combined with reports of progress in other countries, therefore led to the establishment of a collaborative national experiment aimed toward research into mechanisms of hail formation and development of techniques for suppressing hail. In 1968, at the request of the National Science Foundation, NCAR began planning the National Hail Research Experiment (NHRE), now one of NCAR's established projects. This experiment coordinates, under NCAR direction, a five-year venture into various areas of hail research, with participation by universities, government agencies, and other groups.

Combined field study of hailstorms in northeast Colorado began in 1968 as the Joint Hail Research Project, a cooperative endeavor involving NCAR, the National Oceanic and Atmospheric Administration (NOAA), and Colorado State University. This early study provided useful background knowledge and experience for the broader experiment which was to follow. As now constituted, NHRE has a twofold purpose:

- To gain an increased understanding of severe thunderstorms and the processes within them that lead to hail production, and
- To develop, if possible, a practical method for suppressing damaging hail.

A 900,000-hectare (3,500-square-mile) study area, mainly in northeast Colorado but extending into Wyoming and Nebraska, was selected as appropriate to the study. Hailstorms occur there frequently in summer, and the area is conveniently close to NCAR and several suitable airfields. The region is one of scattered farms and ranches, and includes the Pawnee National Grasslands. Population density is low; farmers and

ranchers in the area have been approached and are cooperative in this study, which offers ultimately to benefit them.

In the summer of 1971, the field effort was devoted to testing of equipment and development of operational procedures. The summer of 1972 was the first season of the project proper, when effort was shared equally between the research and suppression phases of the project.

The suppression portion of the experiment involves the placement of silver iodide in suspected hail-forming regions of clouds. It is hypothesized that the silver iodide "seeds" the clouds and produces more, and hence smaller, hailstones, which usually melt while falling to the ground. At the same time, evaluation of the impact of hail suppression on the environment—both natural and socioeconomic—was resumed; studies were begun on the effects of silver iodide on soil, crops, and natural vegetation in the target area.

In 1973 further studies were made of single-cell storms, and statistical studies of the effects of hail suppression were continued. Environmental assessment phases of the project continued also, with emphasis on cost-benefit evaluation and a study of the effects of hail suppression on downwind regions.

The program now involves participating scientists, aircraft, equipment, and crews from NCAR, the Universities of Chicago, Wyoming, and Oklahoma, the Illinois State Water Survey, the Desert Research Institute, NOAA, the South Dakota School of Mines and Technology, and Colorado State University. The observing system in 1973 included five radars, a sailplane, six powered aircraft, eight mobile survey crews, two mobile meteorological crews, 22 surface meteorological stations, 420 precipitation stations, and a scientific group at NCAR studying hailstone samples. A number of students from Metropolitan State College (Denver) participated in the program

as field observers, and farmers and ranchers in the region were asked to continue their services as on-the-spot observers.

With Federal Aviation Administration (FAA) cooperation, special use airspace has been established in the study area; the states of Colorado, Nebraska, and Wyoming issued permits to allow the use of weather modification procedures. FAA air traffic control supports the scientific observation and seeding programs. Private pilots and airport managers in the vicinity have been briefed on the program and the area is now marked on aeronautical charts.

During a typical "hail day"—identified on the basis of storm speed, direction, and intensity as indicated by radar reflectivity—a large thunderstorm within the special use airspace is surveyed by instrumented aircraft, circumnavigating the cloud at several levels to define its dimensions and to obtain data on the moisture, temperature, and motion of air peripheral to the cloud. NCAR's Sabreliner releases dropsondes above the cloud on a limited number of occasions; the sondes fall through the cloud and radio information on vertical winds within the cloud. An armored T-28 aircraft from the South Dakota School of Mines and Technology flies directly through the cloud, often repeatedly and at several levels, to obtain measurements of the liquid water content and updrafts in regions where hail is forming. Aircraft also release chaff for radar measurements of in-cloud winds. The sailplane penetrates the cloud in its early growth stage to measure vertical velocity, temperature, humidity, cloud droplet and ice particle distribution, and electrical effects.

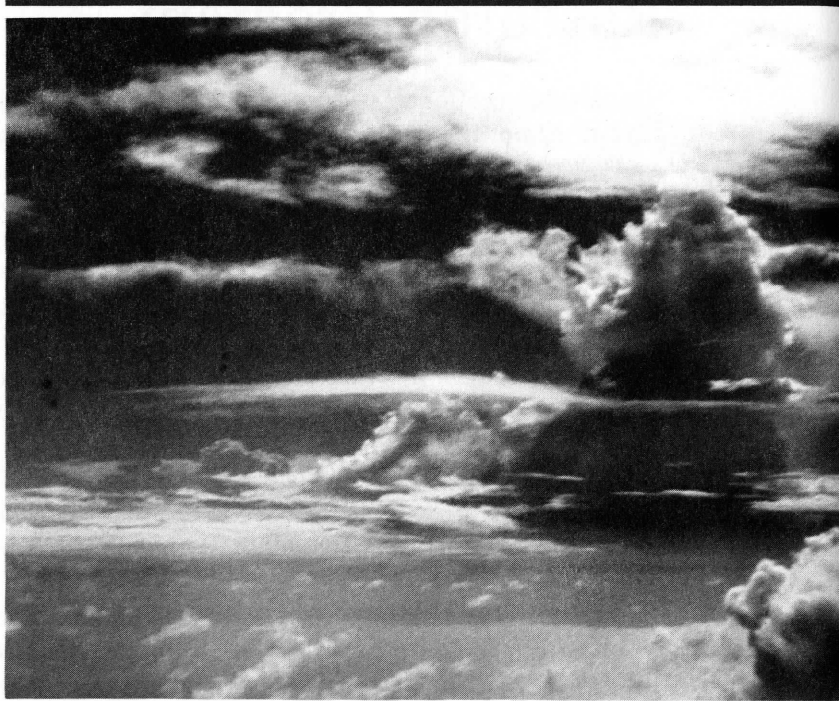
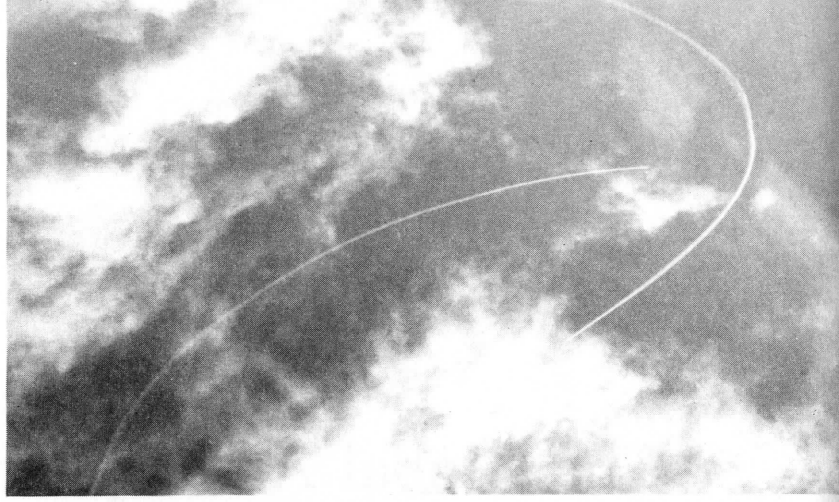
On the ground, precipitation networks gather data on both rain and hail, and ground crews and automatic sampling devices collect hail samples for further study. Large numbers of simultaneous hail and rain samples, and of simultaneously

collected air and ground samples, are obtained on both "seed" and "no-seed" days, selected by a random process. These samples are of special interest for studies of the origin of hail and the effectiveness of seeding. Seeding in 1972 was by silver iodide flares carried to cloud base by small aircraft; in 1973 seeding was by airborne rockets as well as flares.

The Global Atmospheric Research Program

An international program of atmospheric studies, the Global Atmospheric Research Program (GARP) is aimed at understanding both short-term changes in atmospheric behavior and the causes and nature of climatic fluctuations. For the present, NCAR's GARP group is placing greatest emphasis on the first of these objectives: it is devoting itself to studies of short-term atmospheric patterns manifested by changes in weather. Throughout the decade of the 1970s, NCAR scientists, joining colleagues in other institutions here and abroad, will carry out field and laboratory programs built around the following goals:

- Development of realistic numerical models of the atmosphere which will permit increasingly precise simulation of atmospheric behavior and the physical processes involved.
- Design and operation of field programs to observe and measure atmospheric features. These programs, which often involve design of new instrument systems, will provide the data necessary to the development and use of numerical models.
- Development of analysis techniques for atmospheric data obtained from field programs, including objective techniques for assimilation of global data by the model.
- Design of various numerical experiments using atmospheric models, such as simulation experiments testing the effectiveness of proposed observing systems.
- Assistance to university scientists in joint projects related to GARP, particularly in the areas of modeling the global circulation, experimenting with the NCAR Global Circulation Model, and participating in field programs.



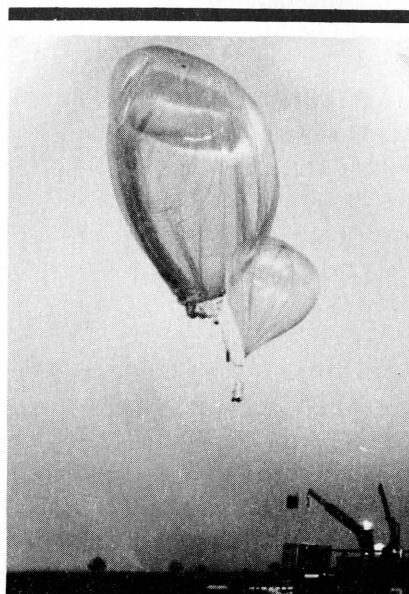
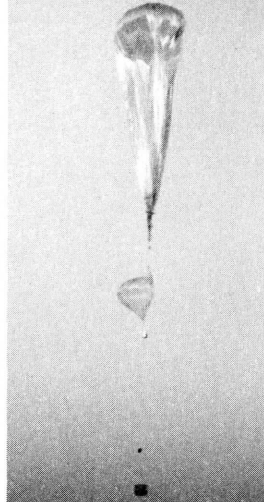
In a pre-GATE experiment in the Caribbean area, an NCAR team measured low-level wind speeds from the highly instrumented NCAR Buffalo aircraft while photo-reconnaissance planes from NASA and the U.S. Air Force circled above for precision photography and radiation measurements. The main purposes of the experiment were to test the agreement between direct observations of wind profiles and satellite-derived cloud motion data, to study the turbulent structure of the boundary layer in the tropics under different cumulus cloud conditions, and to observe reactions between the cloud and subcloud layers. The experiment also served as a test of the Buffalo gust probe and inertial system in an oceanic tropical environment.



Although most GARP programs are still in the planning stage, several GARP-related studies have advanced to the testing stage or beyond. NCAR's Global Circulation Model (GCM), developed over the last nine years, will play a vital role in many phases of GARP. Every effort is being made to make it as realistic as possible, and to enable it to assimilate real data as they become available from field programs. A version of the model based on a $2\frac{1}{2}^\circ$ horizontal mesh is now in use. As the GCM becomes more and more sophisticated, details of climatic simulation become more and more realistic, but every increase in sophistication is accompanied by an increase in computer time requirements. An advanced version of the model is being designed to run on a next-generation array processing computer which NCAR plans to acquire in 1976.

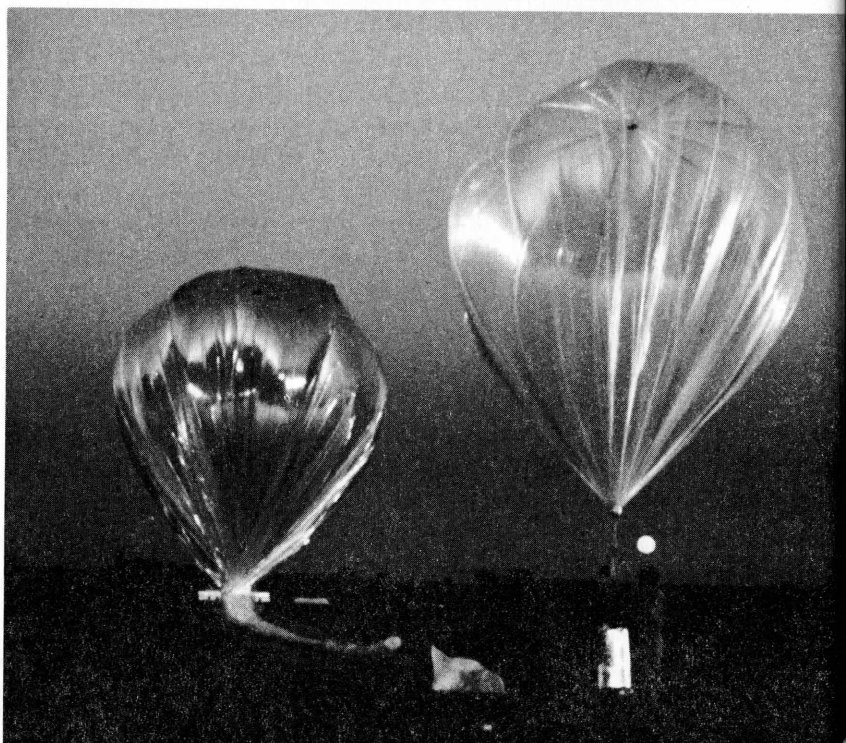
A limited-area $1\frac{1}{4}^\circ$ version of the GCM has been developed to study in detail medium-scale weather phenomena. It fits into the global model and takes its boundary conditions from the global representation. The limited-area model promises to play an important role in experiments designed to test data from GARP field experiments in which mesoscale features of limited parts of the globe are of primary concern.

One such early field study will be the GARP Atlantic Tropical Experiment (GATE) scheduled for the summer of 1974. During the past year the GARP group has continued to plan actively for GATE, for training and participation of scientific personnel, and for operational participation. At the request of the GATE Project Office at NOAA, NCAR has assumed responsibility for developing a coordinated aircraft plan for GATE and for organizing the management of aircraft data. A preliminary aircraft operational plan has been presented to members of the GATE International Scientific and



A carrier balloon is launched near Toowoomba, Australia. Releasing dropsondes on radio command, such balloons will help to collect data from oceanic and tropical areas.

The small tow balloon (right) aids in controlling the rate of ascent to the float altitude of about 24,000 meters.



Management Group and to representatives of other countries—Brazil, France, United Kingdom, and USSR—that will assign aircraft to GATE.

Even as final plans are being laid for GATE, NCAR scientists are helping with preliminary plans for programs to follow GATE, such as the Monsoon Experiment (MONEX) proposed by India, the Antarctic Current Experiment (ACE), and the Air Mass Transformation Experiment (AMTEX)—a Japanese-sponsored study of changes that take place in cold, dry Siberian air masses as they sweep over warm seas south of Japan. GARP group members are also active in planning for the First GARP Global Experiment (FGGE), projected for 1977.

Special techniques are being developed for many of these large-scale experiments. Several members of NCAR's GARP group have been involved in development of a satellite-balloon system for the Tropical Wind, Energy Conversion, and Reference Level Experiment (TWERLE). The full-scale TWERLE experiment will be conducted synchronously with GATE, but migration patterns of balloons launched in the tropics have been tested this year. Balloons used for TWERLE are variations of NCAR's Global Horizontal Sounding Technique (GHOST) balloons, inexpensive, long-lived constant-level balloons which have demonstrated their usefulness in measuring meteorological variables over the wide oceanic expanses of the southern hemisphere.

Another variant of the GHOST system, the Carrier Balloon/Omegasonde system (CBO), will provide upper air data during 1974 in areas where such data are not available by other means. The CBO system involves large superpressure balloons carrying cargoes of miniature dropsondes. The sondes will be released on radio command, and their reports relayed by the carrier balloon to a satellite and then to earth. This system

is being developed at NCAR to provide a means of obtaining wind profiles in equatorial regions to meet the goals of FGGE.

NCAR is testing a data management system that is directed toward global analysis and is compatible with the GCM. Studies are being made now of methods for initializing and assimilating data, adjusting them to fit the GCM without disturbing the functioning of the model. (The problem can be likened to dropping a stone into a pond: techniques must be developed to prevent the generation of unwanted waves, in this case short-period gravity waves in the numerical model.) In 1974 NCAR will take part in the Data Systems Test (DST), a "dress-rehearsal" for United States participation in FGGE. DST will provide, every 24 hours, global meteorological information with a horizontal resolution of about 400 kilometers — a data set better by far than any yet in existence. Preparations are being made now for coordination of DST data acquisition, for quality control and data processing programs, and for data assimilation tests with the GCM.

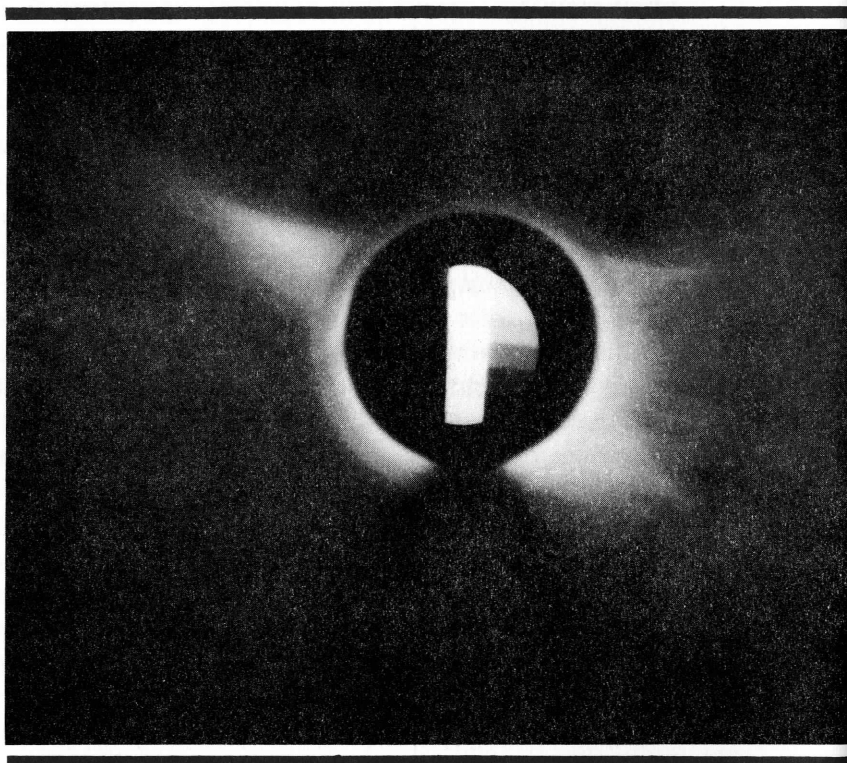
To check the performance of the GCM, climatic statistics compiled at NCAR are being analyzed and their variances examined. In particular, studies have been initiated of seasonal variations in tropical circulation, of waves in the equatorial troposphere and stratosphere, and of monsoonal circulation. The GCM is being tested against available real-data sets to examine the model's ability to forecast for periods up to two weeks. Such tests will have greater meaning, of course, when the more complete global data from the DST and FGGE become available.

NCAR's Facilities Laboratory is also "tooling up" in preparation for GARP field programs. In particular, the Research Aviation Facility this year completed engineering studies and directed modification of a Lockheed Electra ob-

tained specifically for GARP-related studies. The instrumentation includes a new data-handling system designed by the Research Systems Facility. Special instruments will be added to other NCAR aircraft, and the Research Systems Facility is also developing an aircraft-released wind-finding dropsonde for use in GATE. The Computing Facility plans to extend NCAR's computer resources to handle the increased computing load expected during and after GARP; they are now preparing the necessary software.

NCAR is working closely with the Lamont Observatory of Columbia University and the National Data Buoy Center of NOAA on development of buoys for the Antarctic Current Experiment; with scientists from Colorado State University, Florida State University, and the University of Virginia on a proposal for a land-based experiment in Africa in support of GATE; and with NASA's Goddard Space Flight Center and the University of Wisconsin on TWERLE. The GARP group, in cooperation with the UCAR GARP Council, has actively sought participation of university scientists in GARP by distributing information about GARP, notifying potential participants of projects in their fields of interest, and seeking to involve university scientists in joint programs. The GCM is being used for numerical experiments by a number of university scientists; their studies include analyses of the effects of Atlantic sea-surface temperature anomalies on European weather and of Pacific sea-surface temperature anomalies on global circulation patterns, and simulation of the climate during the last major glacial advance.

This photograph of the solar corona was made by a coronagraph on board NASA's Skylab orbiting laboratory during the first manned Skylab mission. It is one of more than 4,000 coronal photographs brought back by the astronauts for study and analysis. The White Light Coronagraph Experiment on Skylab was designed by scientists at HAO and built by Ball Brothers Research Corporation in Boulder, under NASA sponsorship.



The Solar Corona- 1973 Eclipse Expedition and Skylab

The High Altitude Observatory's continuing work in solar and solar-terrestrial physics has been highlighted this year by the longest duration eclipse of this century and by the launch of Skylab with its Apollo Telescope Mount.

For the total eclipse on 30 June, HAO and the Field Observing Facility had personnel in the field at three locations in Africa, where NCAR managed the entire U.S.-NSF 1973 Solar Eclipse Expedition. This eclipse is more than usually interesting to solar astronomers because of its seven minutes of totality and the location of the eclipse path across the deserts and savannahs of Africa. NCAR undertook a meteorological planning study of the eclipse path area as early as 1971. On the basis of this study and the accessibility of various portions of the eclipse path, NSF chose two major sites: a desert site near Chinguetti in the Islamic Republic of Mauritania, and one in the semi-desert highlands of northeast Kenya, at Loiyengalani.

The main site in Kenya, near the southern end of Lake Rudolf, was close to the center of the path of totality. Here about 70 scientists and technicians gathered from many participating organizations to conduct eleven experiments. In Mauritania, about 25 scientists operated eight experiments. Among the participating organizations were, in addition to NCAR's High Altitude Observatory, the Naval Research Laboratory, Kitt Peak National Observatory, Sacramento Peak Observatory, Aerospace Corporation, and 16 universities and colleges—many of them UCAR members. The sum of observations obtained by the many groups at this eclipse will probably provide the greatest reservoir of information ever to come from a single eclipse.

NCAR's support role at the eclipse was carried out by the Field Observing Facility. In April, 45 tons of scientific and support equipment were shipped by chartered aircraft, escorted to Nairobi and Dakar by members of the FOF. From there they were transported to the field sites. Between April and early June, FOF crews set up camps, organized transportation, communication, and electrical systems to facilitate smooth functioning of the many experiments, and built platforms for telescopes and other instruments. All arrangements for housing and feeding field parties were made in advance of their arrival. Darkroom facilities, storerooms, and stocks of tools and mechanical equipment were prepared at each site so that individual research teams would not have to carry their own support equipment. A doctor was in residence at each site and a scientific translator served the Mauritania site. Shelters to protect equipment from blowing desert sand were established in Mauritania, and all participants were warned in advance of the problems to be encountered in living, working, and maintaining delicate instruments in portions of Africa where temperature fluctuations are extreme.

Eight members of the HAO staff conducted experiments at Kenya eclipse sites. At Loiyengalani, they obtained photographs of the inner corona with the white light coronal telescope previously used successfully in 1966 and 1970. The unique asset of this telescope is its radially graded filter, which varies in density to equalize the ten-thousandfold decrease in brightness over the portion of the corona being photographed: from the edge, or limb, of the sun out to $4\frac{1}{2}$ solar radii. An HAO team also used a new coronal camera equipped with an occulting disk large enough to blot out most of the brilliant inner corona, and recorded the very faint outer portions of coronal streamers, from $2\frac{1}{2}$ to 20 solar radii. Both telescopes were

equipped with polarizing filters, and documented both brightness (approximately proportional to density), and direction and magnitude of polarization in the tenuous gases of the corona. Photographs from the two telescopes thus complement each other; combined with calculations of the surface magnetic field made at observatories outside the eclipse area, they will help solar physicists form a coherent picture of large-scale coronal structures and how they are influenced by solar magnetic fields. Observers at Lake Rudolf were able to study the eclipse under fairly favorable conditions, with skies clearing moments before the eclipse and only some high cirrus interference.

A three-man HAO group also established an outpost about 110 kilometers north of the main Kenya camp to photograph solar spicules, spikes of luminescent gas that protrude above the edge of the sun's disk and are best visible from points near the margin of the eclipse path. Unfortunately, skies over this observing site were cloudy at eclipse time. At Chinguetti, skies were cloudless but observations were somewhat hampered by wind-blown sand and dust. At the date of this writing, eclipse photographs are being processed by Aerospace Corporation laboratories in California.

* * *

The Skylab manned orbital laboratory, launched by NASA on 14 May, is giving solar astronomers their first opportunity to record and photograph the sun's surface and corona on a regular basis from a vantage point in space, above the light scattering and filtering effects of the earth's atmosphere. HAO scientists have been heavily involved in preparation of the white light coronagraph experiment, one of the six solar instruments on the Apollo Telescope Mount on Skylab. The

HAO coronagraph creates an artificial eclipse by blocking, or occulting, the disk of the sun, enabling observations to be made of the solar corona and transient coronal phenomena. High-resolution photographs brought back to earth by the astronauts from the first Skylab mission, a 28-day mission ending 10 June, reveal that this instrument operated successfully; the pictures show the rotational and evolutionary changes that took place in the corona over most of the period of the mission (including several of the transient coronal phenomena that have previously been observed from earth-bound observatories and satellites). During the second and third missions, beginning on 28 July and around 15 November, astronauts living and working in the space laboratory for 56 days at a time will undoubtedly be able to obtain even longer records of changes in the corona. Priorities planned for the three missions place solar studies with the Apollo Telescope Mount second for the first mission (after medical experiments to analyze man's physiological adjustment to prolonged periods in space), first during the second mission, and second (after earth resources studies) during the third mission.

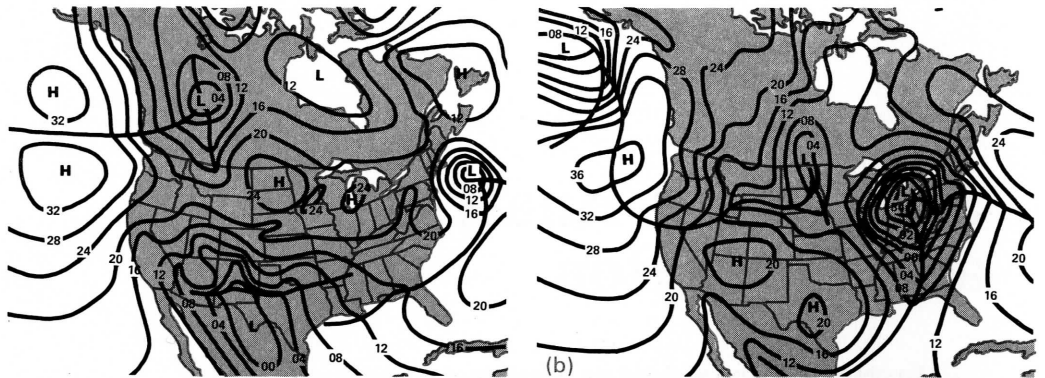
A unique and unexpected opportunity for an entirely different type of observation will be afforded by the passage of comet Kohoutek close to the sun late in December. ATM experiments will be directed to this object to determine its chemical composition, dust content, and response to changes in the solar wind.

Small-Scale Analysis and Prediction

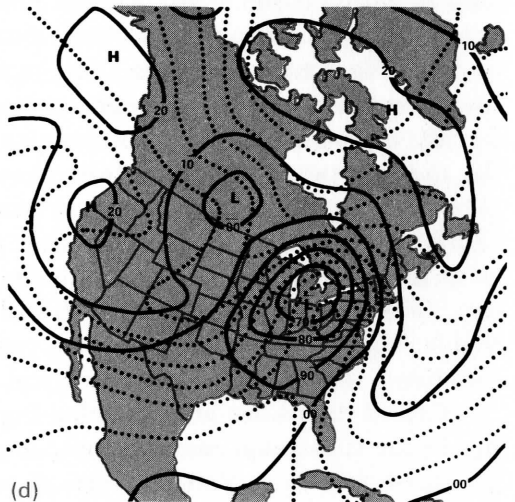
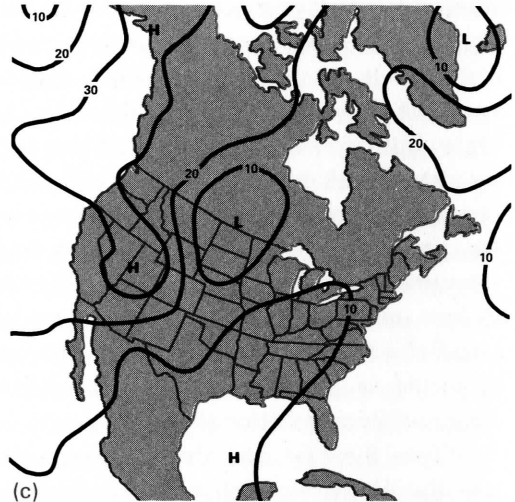
Present techniques used in weather forecasting rely on numerical analyses and models based on pressure levels. Early in the development of meteorological analysis of upper air flow it was recognized that analysis along surfaces of constant potential temperature had definite theoretical advantages, but certain practical problems caused this technique to be virtually abandoned. Two NCAR scientists, aided by members of the Computing Facility, have now developed a computer program for analyzing frontal regions along potential temperature (isentropic) surfaces. Isentropic surfaces seem to define material atmospheric layers, and therefore closely parallel air-mass boundaries, so the new technique can be expected to give more realistic input for forecasting than that obtained from traditional analyses.

Two forecast models have been developed at NCAR to use the isentropic analyses in prediction; one of these has already been found to outperform conventional models in predicting spontaneous explosive development of several mid-latitude cyclonic storms. The models are particularly useful in middle latitudes, where cyclonic storms and well-defined air masses are prevalent features of the weather. Since the predictions also show regions of strong horizontal temperature gradients and strong vertical wind shear, an additional benefit can be derived from them: they can be used to define areas where dangerous clear air turbulence may occur, and so may be useful in producing operational forecasts for aircraft flights. Their accuracy is now being compared with clear air turbulence data gathered by commercial airlines.

One of the values of forecasting from isentropic analyses lies in the substantial reduction of computer time needed for preparing forecasts. Variable vertical resolution is inherent



Observed surface pressures for 1 April 1970 (a) show no sign of impending storm development. However, after 36 hours a large cyclonic storm developed in eastern United States (b). The 36-hour Weather Service forecast (c) failed to predict this storm, but a 36-hour isentropic forecast (d) shows the storm's development.

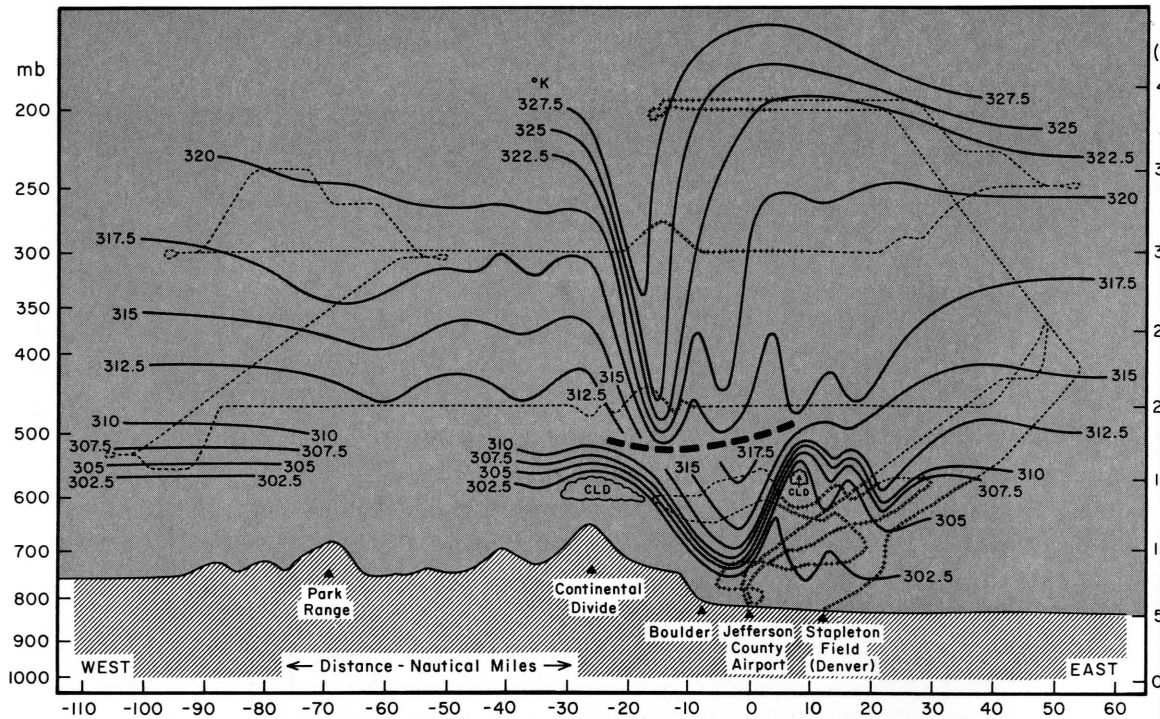


in the models because of the variable spacing of potential temperature surfaces: data points are automatically closely spaced in frontal zones where fine resolution is desirable and widely spaced across large, featureless areas.

* * *

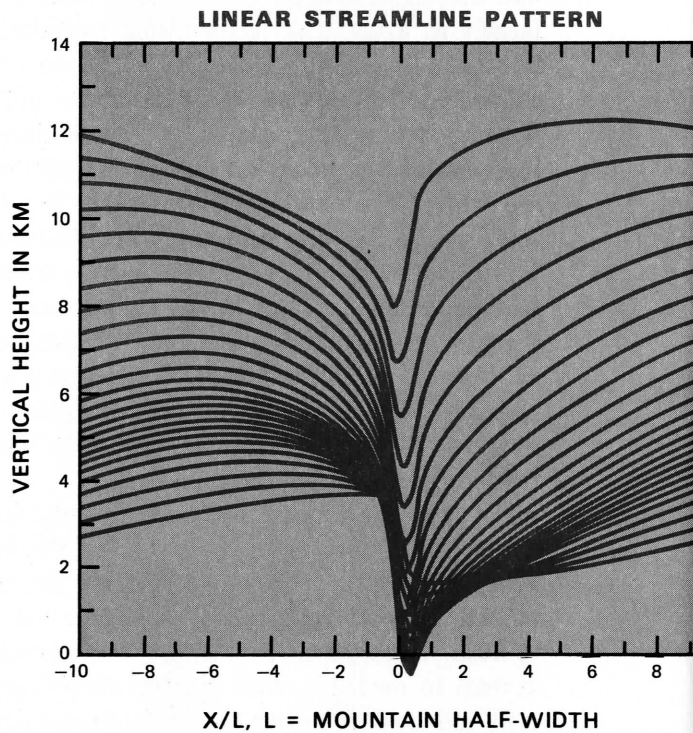
A second important advance in techniques for predicting small-scale atmospheric features is the discovery of a method for forecasting violent and damaging "chinook" winds in the area just east of the Rocky Mountains. NCAR scientists believe that they have identified the mechanism of these windstorms, largely as a result of unique data collected by NCAR during two periods of severe winds in 1971 and 1972. As had been suspected, the storms are manifestations of powerful mountain wave systems, with a large-amplitude standing wave located just east of the mountain divide. Whenever strong westerlies are present and a stable air layer exists just above mountaintop level on the western, upwind side of the mountains, with less stable layers above and beneath it (a condition known as a temperature inversion), heavy winds may develop near the surface on the downwind side of the Continental Divide. Windstorm forecasts of useful accuracy can apparently be obtained by inserting observed upstream conditions into a numerical model, which then predicts locations and amplitudes of surface wind maxima.

These findings open the way to short-range (4- to 24-hour) warning of the severe winds in the Boulder-Denver region. Working jointly with NCAR on this project, NOAA has installed an acoustical sounding system just west of the Divide to detect temperature inversions. In conjunction with a doppler system to measure wind profiles above mountaintop level, it will collect data to test the prediction method. If the tests are



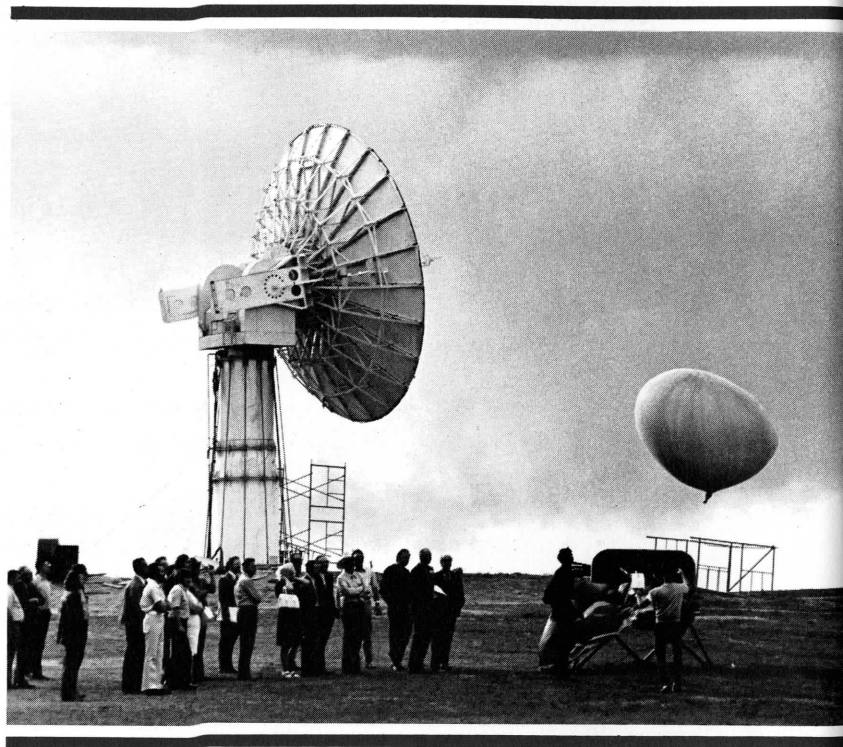
The upper diagram shows observed wind flow patterns over the Colorado Rockies on 11 January 1972. Fine dashed lines are aircraft flight paths, with crosses indicating areas of increased turbulence. Measurements below 500 millibars were made during the early afternoon with NCAR's Queen Air aircraft; those above 500 millibars were obtained several hours later from the Sabreliner. Note that the large standing wave moved upstream during the afternoon. Wave clouds formed at the crests of two low-level waves, and high-velocity winds struck the Boulder region.

The lower diagram is a computer-drawn forecast derived from upstream data on 11 January. Heavy surface winds are predicted for the area where the wave trough touches the surface.



favorable, the new prediction technique should be similarly applicable to other areas where winds of the chinook type occur—in Nevada, trans-Alpine Europe, Argentina, Japan, New Zealand, China, and parts of the USSR.

Members of the Citizens' Council on Hail Research view an Air Force launching of a radiosonde balloon near NHRE headquarters in Grover, Colorado.



Environmental Assessment

NCAR's interest in the environmental consequences of deliberate atmospheric alteration began in 1968 as a result of the Joint Hail Research Project, the forerunner of the National Hail Research Experiment (NHRE). Since that time NCAR has given increased attention to the possible environmental impact of weather modification, and this involvement led to the formation of the Environmental Assessments Group (EAG) in the Advanced Study Program in 1971. Studies of ecological, social, economic, and legal/political aspects of modification—especially of cloud seeding and hail suppression—accompanied development of NHRE itself; baseline data were collected in northeast Colorado before NHRE received nationwide publicity and before any seeding was undertaken.

EAG's study is a five-year investigation (corresponding to the five-year NHRE program) of the societal impacts of hail suppression. The study involves:

- Estimation of direct and indirect economic effects (benefits and disbenefits) of an operational hail suppression program.
- Estimation of the direct costs of such a program.
- Assessment of the environmental costs and benefits.
- Appraisal of social and psychological effects.
- Evaluation of legal and political alternatives and constraints.

A core study, involving the development and application of a decision analysis model (see schematic diagram) and the assessment of the economic effects and suppression program costs, is being conducted by the EAG staff. They will investigate the direct effects of cloud seeding on crop damage and

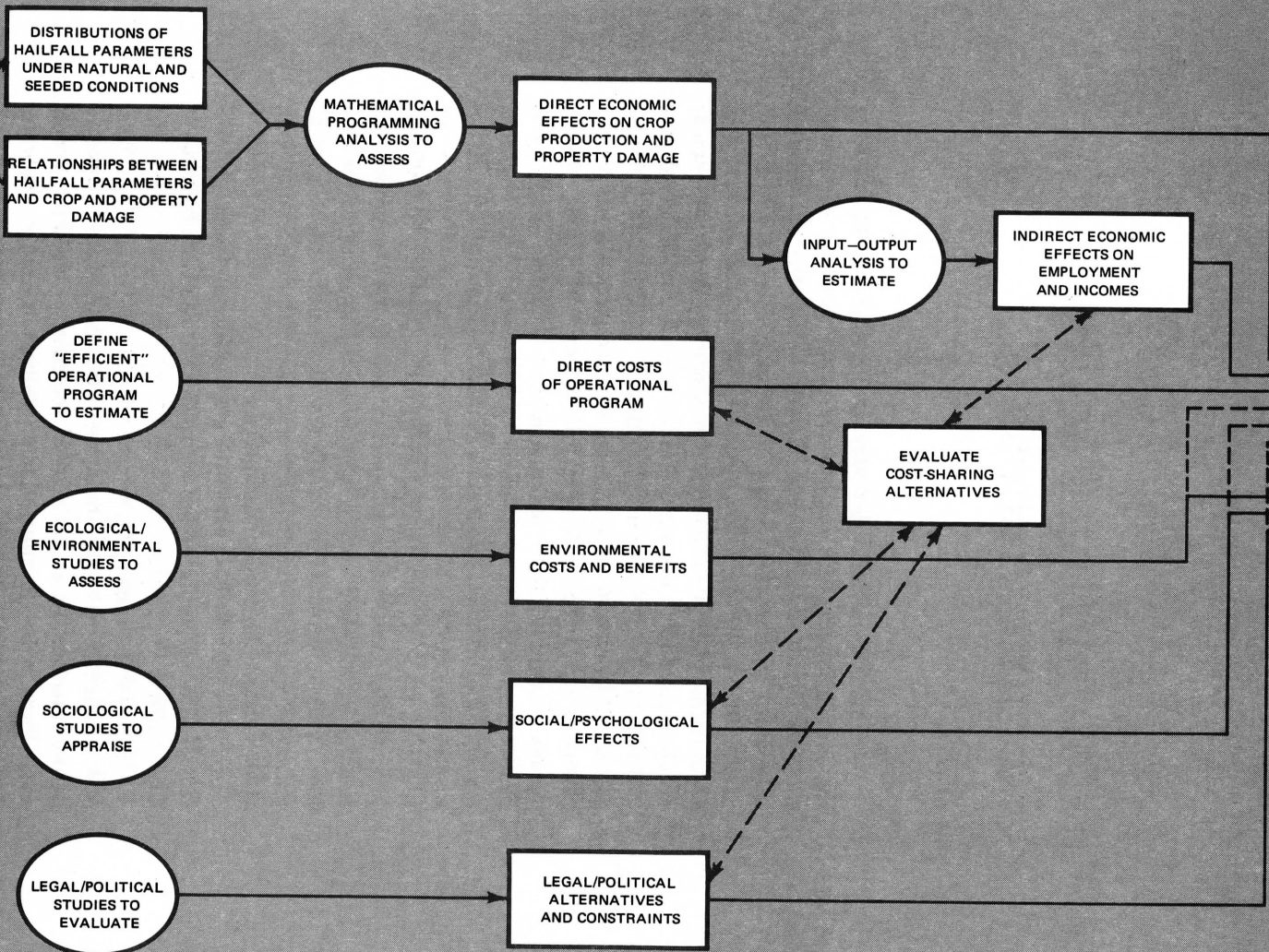
crop production due to possible increases or decreases in hail and precipitation, and the indirect effects on employment, incomes, and land values.

Supplementing the core study, university groups are studying the effects of silver iodide on plants, animals, and soil, and the downwind effects of seeding to suppress hail—such as possible changes in precipitation outside the NHRE experimental area. Other university groups are monitoring public opinion and attitudes toward hail suppression in the experimental area, and studying legislation bearing on weather modification in Colorado and other states.

NCAR has organized a Citizens' Council on Hail Research, made up of community leaders in the NHRE experimental area in northeast Colorado and southwest Nebraska. The Council is proving to be a highly effective mechanism for exchange of information between NCAR scientific staff and the residents of the area affected by the field operations.

In another vein, EAG is now looking into the possibility of making detailed studies of the economic and social value of weather forecasts. Estimates of the potential benefits of various atmospheric research programs would be useful in identifying the directions research should take to provide maximum benefits from forecast improvements, and in establishing research priorities. Such a forecast value study will relate directly to GARP, for this program has been assigned high-priority funding in the United States and elsewhere in the expectation that it will lead to improved forecasts.

On the small-scale prediction level, EAG is now investigating the benefits to be derived from improved forecasts of severe local windstorms in the Boulder area. Progress in developing a technique to make such forecasts is described in an earlier section of this report.



Program Elements of the Hail Suppression Study

Computing Facility Remote Access

NCAR is now seeking a way to develop remote access to its Computing Facility for university atmospheric scientists, particularly for those who are engaged in atmospheric studies that merit resources of larger computers than are available at their own campuses. A survey of university plans concerning such studies has revealed that considerable interest for remote services does exist among university groups, as well as among NCAR/university collaborating teams. Because of teaching responsibilities and other university commitments, university scientists often find it impractical to travel to NCAR; remote access terminals could make available to them the present NCAR Control Data Corporation 7600/6600 computer complex and the planned next-generation Advanced Computer for Array Processing (ACAP).

The goal of our remote computer operation will be to provide the most broadly based access that is economically feasible to as many university scientists as possible. The system must be versatile, allowing universities to select from a variety of types of terminals. It must also include connections with varying degrees of complexity.

The remote access system now being planned will include installation of the following equipment at the NCAR Computing Facility:

- A buffer computer to receive and store incoming data. This computer will handle both input and direct two-way communication from the remote terminals. Its capacity will vary from voice frequency bandwidth circuits to the relatively wide-band circuit of the ARPA (Advanced Research Projects Agency) network. The buffer computer also should be

able to operate with improved data transmission systems of the future.

- A mass storage subsystem for effective remote use of present NCAR computers and the ACAP. Mass storage is already needed for large programs and the quantities of data now assembled at NCAR; the availability of remote access to the computers will increase this need greatly.

- Hard-copy graphics and interactive graphics. These features can be provided by combining the capabilities of the buffer computer and the present 7600/6600 hardware and software systems.

- Provisions for accommodating a variety of university-based remote terminal facilities and differing communication lines.

NCAR now plans to acquire a buffer computer in late 1973 and a mass storage device during FY 1975. Remote-use service will begin in early 1974. Initial phases of remote service will provide a shakedown period during which NCAR and its university terminal users can identify needed improvements in communication lines and data transmission capacity. NCAR hopes to be able to provide suitable communication modes to satisfy most university atmospheric science department needs, and will set up a process to develop software in accord with those needs. Present plans call for the remote systems to be completed by mid-1975 so that university scientists will have direct access to the ACAP as soon as it is installed.

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Corporate Financial Summary

Fiscal Year 1973

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Balance Sheet, June 30, 1973 and 1972

	<u>1973</u>	<u>1972</u>
ASSETS		
CURRENT FUND:		
Cash (includes interest-bearing deposits: 1973, \$327,890; 1972, \$318,595).....	\$ 332,222	\$ 344,958
United States Government securities (at cost, which approximates market value)	19,875	20,000
Receivables	34,127	3,508
Prepaid expenses.....	4,397	8,553
Total current fund....	<u>390,621</u>	<u>377,019</u>
PLANT FUND—Property (Notes 1 and 2):		
Plant (net)	179,055	434,152
Equipment.....	587,033	620,245
Total plant fund.....	<u>766,088</u>	<u>1,054,397</u>
TOTAL.....	<u>\$1,156,709</u>	<u>\$1,431,416</u>
LIABILITIES AND FUND BALANCES		
CURRENT FUND:		
Accounts payable.....	\$ 17,065	\$ 13,050
Fund balance (restricted: 1973, \$34,628; 1972, \$35,204) (Note 3) .	373,556	363,969
Total current fund....	<u>390,621</u>	<u>377,019</u>
PLANT FUND—Balance (Notes 1 and 2) .		
	<u>766,088</u>	<u>1,054,397</u>
TOTAL.....	<u>\$1,156,709</u>	<u>\$1,431,416</u>

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Statement of Revenues, Expenditures, and Changes in Fund Balances for the Years Ended June 30, 1973 and 1972

	<u>1973</u>	<u>1972</u>
CURRENT FUND:		
Revenues:		
Fee for management of the National Center for Atmospheric Research	\$ 340,000	\$ 320,000
Interest	20,995	16,293
Other (principally dues and gifts)	9,253	15,722
TOTAL	370,248	352,015
Expenditures:		
Salaries and wages	136,650	74,638
Travel	91,360	46,132
Materials, supplies, and other	45,215	27,670
Services	35,690	39,805
Employee benefits	28,120	19,024
Fellowships	22,146	16,455
TOTAL	359,181	223,724
Revenues over expenditures	11,067	128,291
Current fund balance—Beginning	363,969	247,662
Transfer to plant fund for property additions	(1,480)	(11,984)
Current fund balance—Ending	\$ 373,556	\$ 363,969
PLANT FUND:		
Plant fund balance—Beginning	\$1,054,397	\$1,044,743
Transfer from current fund for property additions	1,480	11,984
Government excess, donations, etc.	2,500	7,196
Amortization	(8,526)	(8,526)
Disposals	(283,763)	(1,000)
Plant fund balance—Ending	\$ 766,088	\$1,054,397

UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

NOTES TO FINANCIAL STATEMENTS FOR THE YEAR ENDED JUNE 30, 1973

1. The University Corporation for Atmospheric Research is a non-profit 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 (see Note 4). Contract C-760 is in effect 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.

The more significant accounting policies followed by the Corporation are summarized below:

Property is recorded at cost except for property acquired from United States Government excess and donations which is recorded by management at appraised values at June 30 as follows: 1973, \$535,832; 1972, \$806,841.

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, annual amortiza-

tion of \$8,526 has been charged to the plant fund balance during the years ended June 30, 1973 and 1972. Building cost at June 30, 1973 is \$211,763 with accumulated amortization to that date of \$32,708.

2. During 1973 the land and buildings of the Climax Observatory Station with a carrying value of \$246,571 were transferred to American Metal Climax Company for use as a scientific research station.
3. At June 30, 1973 the Corporation is contingently liable for \$34,628 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.
4. Financial position and results of operations of the National Center (which are not included in the financial statements presented herewith) as of June 30, 1973 and 1972 and for the years then ended are included below:

**National Center for Atmospheric Research
Balance Sheet**

	<u>1973</u>	<u>1972</u>
ASSETS		
CURRENT FUND:		
Cash	\$ 19,167	\$ 45,691
Receivables:		
National Science Foundation	6,033,955	7,080,622
Other governmental agencies	114,592	311,130
Other	215,341	135,363
Balloon inventory (at identified cost) .	202,723	190,027
Prepayments and deposits	301,128	20,743
Total current fund	<u>6,886,906</u>	<u>7,783,576</u>
PLANT FUND—Property (Notes a and b):		
Plant	9,588,069	9,495,788
Equipment	21,120,272	18,500,701
Construction in progress	370,287	247,017
Total plant fund	<u>31,078,628</u>	<u>28,243,506</u>
TOTAL	<u>\$37,965,534</u>	<u>\$36,027,082</u>

LIABILITIES AND FUND BALANCES		
CURRENT FUND:		
Liabilities:		
Accounts payable	\$ 647,997	\$ 1,020,780
Salaries and wages payable	284,389	270,826
Payroll taxes	74,393	72,120
National Science Foundation	161,970	136,465
Other liabilities	269,723	266,783
Total	<u>1,438,472</u>	<u>1,766,974</u>
Commitments (Notes a and c):		
Fund balance:		
National Science Foundation	5,448,434	6,015,870
Other grant		732
Total	<u>5,448,434</u>	<u>6,016,602</u>
Total current fund	6,886,906	7,783,576
PLANT FUND—Balance (Notes a and b) .	31,078,628	28,243,506
TOTAL	<u>\$37,965,534</u>	<u>\$36,027,082</u>

National Center for Atmospheric Research
Statement of Revenues, Expenditures, and Changes in Fund Balances

	1973			
	NATIONAL SCIENCE FOUNDATION CONTRACT	OTHER GOVERNMENT CONTRACTS AND GRANT	TOTAL	1972 TOTAL
CURRENT FUND:				
Revenues (Note a):				
National Science				
Foundation funds	\$19,695,678		\$19,695,678	\$20,166,555
Other Government agency funds	2,009,655		2,009,655	986,600
Other contracts and grant		\$2,220,470	2,220,470	1,932,894
Total	21,705,333	2,220,470	23,925,803	23,086,049
Expenditures:				
Operating:				
Salaries and wages	9,396,086	81,778	9,477,864	8,621,331
Employee benefits	1,290,258	11,043	1,301,301	1,128,837
Materials and supplies	1,944,167	152,407	2,096,574	2,133,304
Services	5,664,752	1,599,467	7,264,219	5,639,056
Travel	699,250	64,076	763,326	603,287
Fixed fee (Note e)	340,000		340,000	320,000
Other	25,505		25,505	310,721
Total operating	19,360,018	1,908,771	21,268,789	18,756,536
Property (Note b)	2,912,751	312,431	3,225,182	2,866,030
Total	22,272,769	2,221,202	24,493,971	21,622,566
Revenues over (under) expenditures	(567,436)	(732)	(568,168)	1,463,483
Fund balance, beginning of year	6,015,870	732	6,016,602	4,553,119
Fund balance, end of year	\$ 5,448,434		\$ 5,448,434	\$ 6,016,602
PLANT FUND:				
Balance, beginning of year	\$28,023,335	\$ 220,171	\$28,243,506	\$25,893,436
Current year acquisitions:				
Current fund expenditures	2,912,751	312,431	3,225,182	2,866,030
Government excess, donations, etc.	85,438		85,438	271,366
Current year disposals	(468,121)	(7,377)	(475,498)	(787,326)
Balance, end of year	\$30,553,403	\$ 525,225	\$31,078,628	\$28,243,506

- (a) The more significant accounting policies followed by the National Center are summarized below:

Revenues from the continuing National Science Foundation Contract C-760 are recognized when amendments to the contract are received. Revenues from other government cost-reimbursable contracts are recognized as expenditures under those contracts are incurred.

Funds committed for a project are not recorded in the general books until the services are rendered or the goods received. At June 30, 1973 the National Center had unfilled purchase commitments of approximately \$4,700,000.

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 approximately \$4,200,000. Title to 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) The National Center has a five-year cancelable lease agreement with a major computer manufacturer for scientific computer equipment and services. The agreement, which contains a purchase provision, provides for annual payments of approximately \$1,700,000 through the year ended June 30, 1977. A portion (\$2,600,000) of the cumulative lease payments made by the Center, which represent this purchase provision, is included in the property accounts pending the Center's decision to purchase the equipment.
- (c) At June 30, 1973 the National Center had lease agreements requiring payments of approximately \$614,000 for the next fiscal year.
- (d) Expenditures charged to all Government contracts are subject to Government agency audit and adjustment.
- (e) The fixed-fee expenditure of the National Center is paid to University Corporation for Atmospheric Research for management of the National Center.

- (f) At June 30, 1973 the National Center has contingent liability not reflected in the foregoing financial statements of approximately \$972,000 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.
- (g) Certain reclassifications of the June 30, 1972 balances have been made for comparative purposes.

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, 1973 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, 1973 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.

August 15, 1973

Haskins + Sells