Department of Atmospheric Science

Annual Report
1986-1987

Colorado State University

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DEPARTMENTAL PERSPECTIVE

The Atmospheric Science Department has continued to flourish during the past year. Our staff of fourteen academic faculty has guided the department to a highly productive year. Our overall staffing has remained steady with 84 graduate students, 32 research faculty, and 20 state classified employees. The training of graduate students and scholarly research are the foci of the department program.

More effort has been devoted during the past few years to attract the most qualified graduate students available to the department. We all recognize that the quality of our graduate students has a major impact on the quality of our entire program and in the ultimate impact that the CSU department of Atmospheric Science has on our science. In the fall of 1986 a total of 19 new students entered the department. These new students arrived with an average GRE quantitative score at the 82 percentile. Twenty percent of our graduate students are foreign; twenty-two percent are women. A recent review of our students indicate that 50% came from meteorology or atmospheric science backgrounds. The other half obtained their undergraduate degrees in physics, mathematics, or engineering. The diversity of our student body in terms of experience and background contributes to a healthy graduate program. The department of Atmospheric Sciences granted seven Doctor of Philosophy degrees and thirteen Master of Science degrees in 1986.

The research program in the department which reflects the efforts of all faculty exceeded $3 million again this year. A strong indication of the vitality of the research activity lies in the publications from faculty and students. A total of 53 articles in the reviewed literature have been published or accepted for publication during the past year. The Atmospheric Science Department's report series for research reports has also increased by thirteen. The active research programs have led to a rapid increase in the utilization of a wide array of computers. Communications has become one of the primary services which the department now provides for department personnel. All students and staff now have access to personal computers or terminals which allow them to work on a personal computer, minicomputer (VAX 750), mainframe computer (CSU CYBER), or supercomputer (NCAR CRAY or CSU-205) by simple selection from their work site. Students are increasingly learning to use word processing software and several programming languages. The department has a clear need to develop better communication systems within and to the external world. The ability to take advantage of the increased computer capacity also requires easy access to accessible digital storage devices. We plan to be in the forefront of adapting these new, rapidly evolving, technologies to our atmospheric science research requirements.

Thomas B. McKee
Department Head

FACULTY AND STAFF

Professors

W. R. Cotton, Ph.D., Pennsylvania State University
Numerical modeling, cloud physics and dynamics, mesoscale meteorology

S. K. Cox, Ph.D., University of Wisconsin
Radiation physics, general circulation

L. O. Grant, M.S., California Institute of Technology
Precipitation physics, weather modification, mountain weather, hydrometeorology

W. M. Gray, Ph.D., University of Chicago
Tropical meteorology, atmospheric vortices, cumulus convection

R. H. Johnson, Ph.D., University of Washington
Atmospheric convection, boundary-layer meteorology, synoptic and mesoscale meteorology

T. B. McKee, Department Head, Ph.D., Colorado State University
Climatology, atmospheric physics

R. A. Pielke, Ph.D., Pennsylvania State University
Mesoscale modeling, weather forecasting, air-quality modeling

E. R. Reiter, Ph.D. Dozent, University of Innsbruck, Austria
General circulation, high-altitude winds, aerospace science, turbulence

W. H. Schubert, Ph.D., University of California, Los Angeles
Dynamic and theoretical meteorology, parameterization of cumulus convection, planetary circulations

D. E. Stevens, Ph.D., Harvard University
Earth and planetary physics; applied mathematics, numerical modeling, geophysical fluid dynamics, applied physics

T. H. Vonder Haar, Ph.D., University of Wisconsin
Satellite meteorology, radiation physics, global climate

Associate Professors

P. C. Sinclair, Ph.D., University of Arizona
Severe storms, cumulus dynamics, thunderstorm modification, meteorological instrumentation

G. L. Stephens, Ph.D., University of Melbourne, Australia
Radiation theory, radiative parameterization, cloud/climate studies

Research Staff

Ron Avissar, Research Associate
Jan Behunek, Research Associate
James Bresh, Research Associate
Glen Brier, Research Scientist
Doug Castle, Research Coordinator
Paul Ciesielski, Research Associate
Paul DeMott, Research Associate
Nolan Doesken, Research Associate
Bei-Fen Fan, Visiting Scientist
Rudy Garcia, Research Coordinator
Tom Greenwald, Research Associate
Marion Haurwitz, Research Associate
Paul Hein, Research Associate
Ed Hindman, Research Associate
Xinyuan Jia, Visiting Scientist
Chris Johnson-Pasqua, Research Associate
John Kleist, Research Coordinator
Marjorie Klitch, Research Associate
Bruce MacDonald, Research Associate
Jennifer Martin, Research Coordinator
Ray McAnnelly, Research Associate
Richard Pearson, Research Scientist
Dave Rogers, Research Associate
Mordecay Segal, Research Associate
John Sheaffer, Research Associate
Jenn-Luen Song, Research Associate
William Thorson, Research Coordinator
Craig Tremback, Research Associate
Si Chee Tsay, Research Associate
Robert Walko, Research Associate
Yungyu Xi, Visiting Scientist
Jiadong Ye, Visiting Research Associate
Zhoujia Ye, Visiting Scientist

Support Staff

Becky Armstrong, Administrative Clerk
Odelia Bliss, Secretary
Fredi Boston, Library Assistant
Barbara Brumit, Staff Assistant II
Cindy Carrick, Typist B
Gail Cordova, Senior Word Processor Operator
Jan Davis, Senior Administrative Clerk
Verna Dunn, Senior Secretary
Judith Gueswel, Senior Administrative Clerk
Brian Jesse, Lab Assistant IB
Susan Lini, Senior Secretary
Lucy McCall, Engineering Aide C
Dallas McDonald, Senior Administrative Clerk
Sally McLeland, Staff Assistant I
Walt Naylor, Department Manager
Jennifer Pollard, Word Processor Operator A
Brenda Thompson, Senior Secretary

Melissa Tucker, Senior Secretary
Juanita Veen, Staff Assistant I
Charles Wilkins, Instrumentation/Maker Fabricator II

RESEARCH

W. R. COTTON

NUMERICAL SIMULATION AND OBSERVATIONAL ANALYSIS OF MID-LATITUDE CONTINENTAL CUMULONIMBI AND MESOSCALE CONVECTIVE SYSTEMS

(1) Both individual case studies and composite analysis of the precipitation life cycle of MCC's reveal a well-behaved rainfall pattern that is normally distributed in time with its peak coincident with the maximum areal extent and intensity of the system. A parallel composite analysis of the MCC lifecycle of dynamic and thermodynamic properties has also completed which reveals that MCC's evolve into initially stable convective systems exhibiting a cyclone in the middle troposphere and anticyclone in the upper troposphere. It has been also found that approximately 30% of all MCC's produce severe linear winds sometime during their life cycle.

(2) Analysis of squall line observed during the 1981 CCOPE revealed its low-level inflow of high θ_e air advected some distance over the downdraft outflow from an earlier supercell storm. Detailed multiple Doppler analysis revealed a complex flow structure and organization to the storm system including a mid-level jet that responded to the development of severe surface outflow. Also, the leading edge of convective elements was found to be very transient with older cells falling behind the squall front and periodically being replaced by new convective cells.

(3) A two-dimensional model extending from the Utah border to central Kansas has been designed to study the interaction among mountain slope flows, mountain waves, and deep convective systems on the propagation of mesoscale convective systems eastward from the Rocky Mountains onto the High Plains. A system with MCC-like features was simulated which exhibits a cyclone at low levels and anticyclone aloft, and maximum heating and vertical motion in the upper troposphere. The two-dimensionality of the Rocky Mountain barrier appears to be instrumental in establishing a regional-scale circulation that is favorable for the genesis of MCC's.

(4) The predictability of MCC's is being addressed with a nested grid version of the CSU Regional Atmospheric Modelling System (RAMS). It is found that it is possible to crudely simulate the genesis and lifecycle of individual MCC events. The model, however, is extremely sensitive to details in the initial, objectively analyzed, large-scale fields, soil moisture mappings, explicitly-resolved ice-phase physics, and the details of convective parameterization schemes. The extreme sensitivity of the model to these factors severely limits the overall predictability of MCC's in a general sense.

W. R. Cotton

National Science Foundation

CLOUD/MESOSCALE MODEL DEVELOPMENT AND APPLICATION STUDIES

The Colorado State University Regional Atmospheric Modeling System (RAMS) is being applied to the simulation and prediction of: (1) extreme wind shear and turbulence generated by severe thunderstorms; (2) the liquid water, areal coverage, and radiative properties of middle and high clouds; and (3) potential aircraft icing conditions. Research involves testing the model predictions of liquid water, the development of new parameterizations for calculating solar and terrestrial radiation through middle and high-level clouds, and the development of improved yet simplified turbulence models for calculating the properties of middle and high clouds on the mesoscale.

W. R. Cotton

Air Force Geophysics Laboratory

LARGE-EDDY SIMULATIONS OF PLUME TRANSPORT AND DISPERSION OVER FLAT AND HILLY TERRAIN

Research involves the adaptation of Colorado State University RAMS to the simulation of boundary layer eddies and the associated transports and dispersion of plumes from power plans. The approach is referred to as large eddy simulations (LES). Particularly unique is the LES of boundary layer eddies and transports over hilly terrain and over flat terrain with inhomogeneous heating in the horizontal. New model developments involve the implementation of two-way nested grid meshes and the use of multigrid techniques for inverting the elliptic equation of pressure. A Monte Carlo dispersion model has also been developed as a diagnostic routine for dispersion calculations. Recently, the interactive-nested grid approach has been applied to the simulation of buoyant plume dispersion.

W. R. Cotton

Electric Power Research Institute

S. K. COX

ANALYSIS OF MONEX RADIATION BUDGET FIELDS

Satellite, aircraft and surface data obtained from the MONEX (Monsoon Experiment) project conducted in and around the Indian subcontinent in 1979 have been analyzed. The Indian summer monsoon is a fundamental atmospheric response to the changing seasonal solar and infrared radiation patterns over the subcontinent and adjacent oceanic regions. The MONEX data have been used to construct these seasonal radiation patterns from January 1979 to August 1979. These radiation patterns are used in large scale atmospheric models to simulate and study the summer monsoon and its relationship to the surface and atmospheric radiation energy budgets.

S. K. Cox

National Science Foundation

OBSERVATIONS OF UPPER AND MIDDLE TROPOSPHERIC CLOUDS

Instrumentation for measurements of cirrus (ice) clouds found between 30,000 and 45,000 feet altitude are being developed. These ice clouds play a very important role through their radiative properties in determining the climate at the earth's surface. Depending upon the ice clouds' radiative properties, they can either warm or cool the earth's surface. Recognition of the importance of these clouds has led to the design of a field experiment during the fall of 1986. This experiment will consist of satellite, aircraft, lidar, and remote sensing measurements of cirrus clouds by government laboratory and university scientists. The experiment will be located in central Wisconsin and last from approximately 10 October to 2 November 1986.

S. K. Cox

National Science Foundation
National Aeronautics and Space Administration

A CIRRUS CLOUD MODEL

In addition to understanding the radiative properties of ice clouds, we must gain an understanding of why and when these clouds appear in the upper atmosphere. We have developed a two-dimensional numerical model which simulates the most important processes involved in the formation, maintenance and dissipation of cirrus clouds. This model is the most complete cirrus cloud model reported in the scientific literature to date. Using this model we have been able to ascertain the conditions under which cirrus clouds will form and persist. This model has served as the framework around which the cirrus observational program planned for fall 1986 will be conducted.

S. K. Cox

National Science Foundation

THEORETICAL AND OBSERVATIONAL MARINE BOUNDARY LAYER STUDIES

A tethered balloon instrument package will be designed, fabricated and deployed in a marine boundary layer environment for marine boundary layer studies.

The instrument package will be designed for the NASA Wallops Flight facility tethered balloon or (in a reduced configuration) on the NRL balloon. The instrumentation may include measurements of meteorological dynamic and thermodynamic variables, radiation, cloud microphysics and photography. Data acquisition will be accomplished by an onboard microprocessor based computer system. This system will be very similar to an aircraft package previously designed by the principal investigators. The instrument package will be deployed at San Nicolas Island from 29 June to 20 July 1987 in support of the FIRE Marine Boundary Layer Experiment. Data from the FIRE Experiment will be analyzed to determine the thermodynamic and the moisture structures of the Marine Boundary Layer.

S. K. Cox — Office of Naval Research

VISIBLE AND INFRARED SPECTRAL RADIANCES/SURFACE ENERGY BUDGET

The surface energy budget drives the boundary layer during the diurnal cycle. This research is to investigate the sensible heat and radiation components of the surface energy budget locally and areally integrated over mesoscale regions. The research is a combination of analysis and observation. An important aspect is the development of new methods to estimate areal values for energy budget components.

T. B. McKee
S. K. Cox

U.S. Army Center
for Geosciences

L. O. GRANT

WEATHER MODIFICATION RELATED PHYSICAL STUDIES OF ROCKY MOUNTAIN CLOUD SYSTEMS

This research involves the collection and interpretation of focused, direct, and remotely sensed measurements of a wide variety of Rocky Mountain cloud systems. These measurements are now possible because of new instrument systems that have removed many earlier observational limitations. Measurements can be made with instruments such as radiometers to remotely and continuously detect cloud liquid and ice water, and airborne laser probes to measure cloud particles. Analyses of recent field observations will make significant advances possible in understanding the characteristics of cloud liquid and ice water regions and the precipitation efficiencies for different types of cloud systems. Analyses utilize case studies and data compositing approaches for different storms. The studies include conceptual and numerical model development and testing to describe cloud and cloud modification processes.

L. O. Grant
E. E. Hindman
W. R. Cotton
R. L. Graw
P. J. DeMott
R. Osterberg
T. Peterson

National Science Foundation

SUPERCOOLED WATER AND PRECIPITATION TRAJECTORIES IN THE WINTER OROGRAPHIC STORMS OVER TUSHAR MOUNTAINS DURING JANUARY-MARCH 1985

This study involves the analysis of cloud measurements made by the state of Utah and its contractors over the mountains of southwest Utah. These analyses focus on specific studies of the spatial and temporal distribution of supercooled water, hydrometeor trajectories, and precipitation processes. These analyses provide information on the weather modification potential of different weather systems and portions of weather systems passing through that area.

L. O. Grant
D. C. Rogers

Utah Department of Water Resources

ATMOSPHERIC WATERS TO AUGMENT AND SUSTAIN THE WATER REQUIREMENTS OF AGRICULTURE

The basic objective of this research is to assess the technical and economic feasibility and methodology for beneficially utilizing and conserving water supplies from the atmospheric water source. Specific objectives include improving assessments of precipitation augmentation potential and methodology, improving atmospheric water supply augmentation potential from management of snow cover in alpine areas.

L. O. Grant

State of Colorado

EVALUATION DESIGN FOR THE MOROCCOAN WEATHER MODIFICATION PROGRAM

This program involves the development of the design procedures for the evaluation and testing of cloud seeding effects on the streamflow and precipitation in Morocco. The research involves the utilization of evaluation procedures developed for Colorado. The refined statistical procedures will be based on nonparametric techniques such as multi-response permutation procedures and least absolute deviation regression. Specific control variables being tested include streamflow, precipitation, and numerical model estimated precipitation. In an effort to facilitate the research and its utilization in the field, attempts are being made to adapt the application procedures to a mini-computer.

P. W. Mielke, Jr. — Bureau of Reclamation
L. O. Grant — National Science Foundation

TESTING AND DESCRIPTION OF THE ICE NUCLEATING CHARACTERISTICS OF AgI AEROSOLS GENERATED USING NEWLY DEVELOPED GROUND-BASED SOLUTION COMBUSTION GENERATORS

This testing program provided a laboratory characterization of the ice nucleating ability of aerosols produced from the burning of silver iodide in two prototype ground-based generators. The characterization included descriptions of the effectivity, rates, and mechanisms of the nucleants produced.

P. J. DeMott — Colorado International Corporation
L. O. Grant

LABORATORY AND NUMERICAL MODEL STUDIES OF ICE FORMATION IN CLOUDS

This research is studying the formation of ice crystals by silver aerosols in supercooled clouds. The approach includes laboratory experiments, performed primarily in the CSU dynamic cloud chamber, and simulations with a detailed cloud microphysics computer model. The laboratory experiments measure the contributions to ice nucleating activity from four separate mechanisms and provides a description of expected activity as a function of the variables: temperature, water vapor concentration, aerosol and cloud droplet size and concentration, aerosol chemistry, time and environmental path preceding nucleation. The cloud model follows the same thermodynamic path as the cloud chamber experiments, and the model predictions of ice formation are compared for both the current descriptions of nucleation and for the new ones from this research. These results can be incorporated into cloud models, they will provide guidance for weather modification programs, and they will be useful in planning future field studies to assess the transferability of simulation results to real atmospheric situations.

D. C. Rogers
P. J. DeMott
L. O. Grant

W. M. GRAY

CLIMATOLOGICAL FACTORS INFLUENCING SEASONAL AND MULTI-WEEK VARIATIONS IN TROPICAL CYCLONE FREQUENCY

1) Analysis of 25-30 year period of alternating high and low Atlantic Hurricane Destruction Potential (HDP) for the period of 1886 to the present.

2) Analysis of physical reasons for the strong association of the phases of the east vs. west QBO stratospheric winds and Atlantic seasonal hurricane activity.

3) Statistical analysis of global and regional parameters associated with seasonal and monthly hurricane variability. An extensive statistical analysis of the author's Atlantic seasonal hurricane prediction scheme has been accomplished.

W. M. Gray
C. Collimore

National Science
Foundation

ANALYSIS AND CLASSIFICATION OF DIFFERENT TYPES OF TROPICAL CYCLONE INNER REGIONAL CIRCULATIONS FOR BOGUSING

Recent tropical cyclone research results are being obtained which may be useful as background information to forecasters. Findings and speculations are: (1) various climatological characteristics of tropical cyclones, (2) tropical cyclone formation processes, (3) tropical cyclone structure and structure change, (4) tropical cyclone intensity change, and (5) tropical cyclone outer radius wind strength variations.

W. M. Gray
C. S. Lee
R. Zehr
J. Martin
C. Collimore

Navy Environmental
Prediction Research
Facility

OBSERVATIONAL ANALYSIS OF PROCESSES INFLUENCING TROPICAL CYCLONE MOTION IN THE NORTHWEST PACIFIC

We will examine the following tropical cyclone (TC) motion questions:

1) TC recurvature as measured by composite rawinsonde data;

2) TC recurvature as measured by the Guam AF reconnaissance data;

3) Systematic cyclone motion deviations from steering flow as may be due to:

   a) Beta-influence,
   b) differences in cyclone strength (or 1-3° radius mean tangential wind),
   c) differences in cyclone intensity,
   d) differences in eye wall convection as measured by radar from aircraft penetration, and
   e) differences in cyclone speed and direction of motion;

4) Right versus left quadrant wind asymmetry beyond that specified by tropical cyclone motion;

5) How tropical cyclones are steered in an environment current with vertical and horizontal wind shear; and

6) Factors responsible for tropical cyclone oscillating and looping motion.

W. M. Gray
C. Weatherford
S. Hodanish

Office of Naval Research

OBSERVATIONAL STUDIES IN SUPPORT OF TROPICAL CYCLONE AND FGGE RESEARCH ACTIVITIES

This program is studying tropical cyclones in all its phases of climatological setting, genesis, structure, intensity change, motion, and influence on the general circulation. To properly understand these storm topic areas, we need to employ a large number of the meteorological observations collected through the recent special tropical experiments of GATE, FGGE, and MONEX, together with many years of conventional rawinsonde data sources.

This past year, activity has included utilization of FGGE data as supplied on magnetic tape and in map form from the ECMWF Center in Reading, England. Rawinsonde composite analysis was also utilized in the three ocean basins of the Northwest Atlantic, Northwest Pacific, and the South Pacific - Australian region.

Research has been conducted on the association of Atlantic seasonal hurricane frequency as related to the El Nino, stratospheric QBO, and springtime Caribbean Basin sea-level pressure. Surprisingly good associations have been found. A scheme to forecast seasonal hurricane activity at the beginnings of the hurricane season has been devised.

Development of a 20-25 year Australian/South Pacific region rawinsonde data set has continued for tropical cyclone and other tropical meteorology studies. Also, development continues of our western North Pacific rawinsonde data set from 10 (1961-1970) to 21 (1957-1977) years with the inclusion of Mainland China data and also 3 Taiwan upper-air stations for 15-20 years.

The European Center (ECMWF) FGGE year data set available on magnetic tape at NCAR was obtained and reduced. We are now beginning to make individual case analysis of all 60-70 tropical cyclones occurring during the FGGE year.

W. M. Gray
C. S. Lee
C. Weatherford
R. Zehr
J. Martin

National Science Foundation

DEVELOPMENT AND SCIENTIFIC ANALYSIS OF TROPICAL CYCLONE AIRCRAFT RECONNAISSANCE DATA SETS

All military reconnaissance aircraft flights into and out of typhoons during the last seven years are being processed and analyzed for new research insights into the behavior of these storm systems. Data sets on tropical cyclones are being developed and used for this purpose.

These new tropical cyclone data sets are allowing us much more extensive insights into the behavior characteristics of tropical cyclones than has previously been possible. We are documenting the large structural differences in tropical cyclones and how minimum central pressure and maximum sustained wind speeds are often quite misleading parameters in specifying a cyclone's net angular momentum, kinetic energy, moisture budget, and general damage potential.

W. M. Gray
C. Weatherford
P. Lunney
J. Martin
S. Hodanish

National Science Foundation

R. H. JOHNSON

A PROGRAM OF ENHANCEMENT OF THE COLORADO STATE UNIVERSITY DEPARTMENT OF ATMOSPHERIC SCIENCE SYNOPTIC/MESOSCALE METEOROLOGY LABORATORY

This project has involved the development of the Colorado State University Department of Atmospheric Science classroom weather laboratory. With the support of this grant, two computer workstations for processing and displaying of current weather data have been acquired for use in the weather laboratory. Processing software has been obtained from NASA for the analysis of realtime weather data and this capability has been implemented in the classroom. Data sources include both conventional observations and National Meteorological Center model output data. The classroom facility at CSU has benefited considerably from student involvement both in class and through research activities. Plans are to continue to develop the weather lab capabilities and coordinate this development with the University Corporation for Atmospheric Research UNIDATA program.

R. H. Johnson — National Science Foundation

MESOSCALE CONVECTION AND THE ATMOSPHERIC BOUNDARY LAYER

This research is directed toward an improved understanding of mesoscale convection, that is, moist convective weather phenomena having horizontal dimensions on the order of 100 km, that is observed in both the tropical atmosphere and at midlatitudes. Processes which initiate, maintain and modulate mesoscale convection, as well as effects of convection on the boundary layer of the atmosphere and treatment of their effects in large-scale numerical weather prediction models, will be investigated. Both analysis of observations and mathematical/physical models will be employed in this research effort. Additionally, characteristics of the atmospheric boundary layer in the region of the summer monsoon of Southeast Asia will be studied.

The primary observational sources for this research project are: (1) the Taiwan Area Mesoscale Experiment (TAMEX; May-June 1985) and (2) PRE-STORM (Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central).

R. H. Johnson — National Science Foundation

T. B. MCKEE

EVOLUTION OF TEMPERATURE INVERSIONS IN REGIONS OF COMPLEX TERRAIN

Temperature inversions in complex terrain vary considerably from those over flat terrain. Temperature inversions are a key ingredient in air pollution problems. This investigation includes observational and numerical model studies of inversion evolution in several valleys in western Colorado. Studies have included valleys which drain and those which do not drain at night. Research interest has also expanded to include regional as well as valley problems.

T. B. McKee
W. R. Cotton

National Science Foundation

CLIMATE DATA INFORMATION SERVICE FOR COLORADO

This is a diverse project involved in all aspects of Colorado climate. This broad research activity uses extensive available current and historic climatic data resources to study the complex local and regional climate system and its effects on agriculture, water resources, energy, and the natural and human-effected environment. Central to the project is a consistent, on-going program of acquisition, archival, utilization, and dissemination of climate information collected in Colorado. Current climatic conditions are monitored each month and compiled in detailed, widely-disseminated summary reports used to keep officials, researchers and educators throughout the state informed. Climatic data, data summaries, research results, and basic climate expertise are made widely available through publications, direct computer access, news media and personal contact.

T. B. McKee
N. J. Doesken

CSU Agricultural Experiment Station

METEOROLOGICAL OBSERVATIONS

The main campus weather station has been operated continuously since 1887. Measurements of temperature, precipitation, snowfall, humidity, pressure, wind, cloud cover, solar radiation, visibility, soil temperature and evaporation are taken daily in an effort to thoroughly monitor and document the climate of this area. Data is archived, summarized and disseminated to widely diverse users both on and off campus and are used by literally dozens of separate research projects. Observations are also taken every two hours around the clock in support of aviation operations and National Weather Service forecasting and warning activities. Data collected at the weather station are publicly accessible through a phone answering system, computer data files and climate publications.

T. B. McKee
N. J. Doesken

CSU Agricultural Experiment Station

BOUNDARY LAYER, SURFACE RADIATION AND ENERGY BUDGETS

The surface energy budget drives the boundary layer during the diurnal cycle. This research is to investigate the sensible heat and radiation components of the surface energy budget locally and areally integrated over mesoscale regions. The research is a combination of analysis and observation. An important aspect is the development of new methods to estimate areal values for energy budget components.

T. B. McKee
S. K. Cox

U.S. Army Center
for Geosciences

CLIMATE AND STREAMFLOW VARIABILITY IN THE WESTERN UNITED STATES

Surface water supplies in the Rocky Mountain west are a precious commodity continuously affecting and limiting economic growth and development in the region. Management of this natural resource is made difficult by its large and unpredictable year-to-year variability which has been particularly extreme during the past ten years. This research is intended to increase our understanding of regional variations and their relationship to larger scale atmospheric phenomena. Available precipitation, temperature, snowpack, and streamflow data in selected river basins from Montana to New Mexico will be used in this study. The relative variability to each component will be analyzed and correlated and related to aspects of the large scale atmospheric circulation.

T. B. McKee
N. J. Doesken

U.S. Geological Survey

R. PEARSON

FLUX AND BUDGET OF TROPOSPHERIC OZONE III; MEASUREMENTS OF BUDGETS AND ENTRAINMENT IN THE MARINE BOUNDARY LAYER

We propose to continue our studies of the vertical flux and first moment budget of O_3, concentrating first on the analysis of the data from the DYnamics and Chemistry Of Marine Stratocumulus experiment (DYCOMS) which took place in July and August 1985. The construction of most of the instrument and acquisition of data were done under NSF/ATM-83-11405. The stratocumulus (SC)-capped marine boundary layer (MBL) is thought to provide a relatively clean and steady state environment which is among the best suited for measuring fluxes and budgets of trace gases in the troposphere. In addition to measuring the surface deposition and budget for O_3, we will use our data to calculate the velocity at which air is entrained into this MBL thereby enabling investigators with sensor which are too slow for eddy-correlation flux measurements to obtain both fluxes and budgets from their data. Gases measured by others include NO, NO_2, HNO_3, OCS, S_2O, DMS, CO, PAN, halocarbon and hydrocarbons. We also propose to use our O_3 data to study the mechanism of entrainment in SC which ultimately should improve the skill of the meteorologist to forecast SC conditions, and to piggy-back on two new field studies over the Pacific Ocean. The results should be a major part of one of the most complete experimental studies of tropospheric chemistry and photochemistry ever undertaken.

R. Pearson, Jr.

National Science Foundation

R. A. PIELKE

INFLUENCE OF TERRAIN FORCED-MESOSCALE SYSTEMS IN LONG-RANGE TRANSPORT OF AIRBORNE GASES

There are two major facets of our investigation of the role of terrain-forced mesoscale circulations on long-range transport in the northeast United States. These are:

(a) to estimate the frequency of occurrence of the different types of terrain-forced mesoscale systems within subregions of the northeast quarter of the United States, and

(b) to perform finer resolution mesoscale numerical model calculations for specific subregions using selected simulation results from the NCAR/Penn State model.

The synoptic classification of daily surface weather patterns has been completed on a 5 x 7 grid of eastern North America for the five-year period 1975-79. We are now using this data set to prepare a mesoscale climatology for this region.

We have used a coupled mesoscale meteorological model and a Lagrangian particle model to study several aspects of mesoscale pollutant dispersion, including the interaction of mountain-valley winds with pollutant being transported across a mountain range, the interaction of lake and land breezes with pollutant being transported across a large lake, and the influence of diurnal and inertial atmospheric cycles on mesoscale plume dispersion. We are presently implementing time-dependent lateral boundary conditions in the mesoscale meteorological model to permit one-way nesting of this model with the NCAR/Penn State model.

R. A. Pielke
M. Segal

Electric Power Research Institute, Inc.

MESOSCALE MODELING

Studies of mesoscale meteorology and its relation to air quality are being applied to National Park Service managed lands. A combined mesoscale meteorological model and Lagrangian pollutant dispersion model are used to evaluate case study days from the WHITEX 1987 and the 1985 Grand Canyon Field Experiment. This will aid in the evaluation of model performance and will also enable the assessment of the contribution of local sources relative to long-range transport for the winter stagnation episodes during WHITEX. The models are also being used (along with climatological data) to help determine the level of model complexity needed for source attributions in the western United States. Model enhancements are also under development. Those include the coupling of the Lagrangian particle model with a chemical kinetics mechanism, and development of more efficient methods of assessing pollutant concentrations.

R. A. Pielke
M. Segal
R. W. Arritt

National Oceanic and
Atmospheric
Administration
National Park Service

A QUANTITATIVE STUDY OF FLORIDA DEEP CONVECTION IN SEA BREEZE ENERGETICS

Mesoscale modeling studies of the sea breeze-deep convection interactions over the Florida Peninsula. The last report (August, 1986) described the derivation of a cumulus parameterization and its application to the study of the Florida mesoscale-convection interactions (see detailed discussions in Song and Pielke, 1987a and b). To evaluate cumulus parameterization, we have developed a systematic methodology utilizing a state-of-the-art numerical tool (as described in Song, Cotton, and Pielke, 1987) for the summertime Florida environment. Two-dimensional preliminary results of the Mesoscale Cumulus Eddy Simulation (MCES) are briefly described.

R. A. Pielke
M. Segal
J.-L. Song

National Aeronautics and
Space Administration
No. NAG5-359

EVALUATION OF SURFACE THERMAL AND MOISTURE CHARACTERISTICS, AND TERRAIN CONFIGURATION ON THE INITIATION AND DEVELOPMENT OF CONVECTIVE CLOUDS

We propose a continuation and extension of our previous numerical modeling research on terrain-forced mesoscale circulations in which the interaction of these circulations with moist processes will be considered. Particular emphasis will be placed on the role of these circulations on the initiation and growth of convective storms. The completion of the ongoing merger of our numerical model with that developed by W. R. Cotton and colleagues into a new modeling system referred to as the Regional Atmospheric Modeling System (RAMS) provides a refined tool for achieving the objectives of this project. The RAMS system will include the boundary layer and surface parameterizations developed by our group (e.g., parameterizations of soil physics and vegetative cover) with the representations of moist processes developed by the Cotton group. The fully integrated system will be available by the beginning of the proposed research.

Case studies will focus on the Colorado Front Range area and the Great Plains, due both to the high density of observational data in this region and the extensive past research studies in this area. We plan to utilize, among other sources, data from the Convective Initiation and Downdraft Experiment (CINDE) to be conducted in northeast Colorado in 1987, along with additional data available for this area. These data will be used for model verification and to describe and interpret the observed atmospheric behavior using numerical simulations.

R. A. Pielke
M. Segal
R. W. Arritt
R. Avissar

National Science Foundation

E. REITER

ENERGY BUDGET IN COMPLEX TERRAIN

We have measured the complete surface radiation, sensible, and latent heat budgets at a measurement site in the Gobi Desert of western Gansu Province, People's Republic of China, and at several sites in the Rocky Mountains of Colorado. Data from these field experiments are presently being analyzed. A similar, but larger field experiment was performed during June/July 1986 in Tibet (TIPMEX-86). Two fully equipped radiation and energy budget stations were installed near Lhasa (ca. 3500 m a.m.s.l.), and near Nagqu (ca. 4500 m), and operated for 6 weeks. Solar photometer and radiosonde measurements (2 or 3 sondes/day) were also made during the same time frame.

Our analyses of these data have yielded alternative parameterizations for the exchange coefficients assigned to these mountainous regions. The new estimates have significant impact on numerical modeling and forecasting of weather events in mountainous terrain. Also, the detailed assessment of surface energy budgets and their relationships to surface radiation characteristics is of importance to the calibration of satellite data.

E. Reiter

National Science Foundation
National Aeronautics and Space Administration
U. S. Air Force Office of Scientific Research

MESOSCALE FLOW PATTERNS OVER MOUNTAINS

During July/August 1985 detailed measurements of wind and temperature conditions were carried out on nineteen mountain peaks between southern Wyoming and northern New Mexico. In addition, energy budgets were measured at four of these stations. The project was carried out in cooperation with the Los Alamos National Laboratory, the U. S. Forest Service, and with the management of local ski areas. Data from this experiment (ROMPEX-85) are presently being analyzed. They reveal the effects of the generation and dissipation of large convective systems over some of the main mountain ranges of Colorado. We also gained detailed insight into the formation of monsoonal and non-monsoonal weather systems over Colorado. Some of the details in flow patterns revealed by our study lend themselves to practical application for air safety in mountainous terrain. In addition to ongoing analyses of these (1985) data, we are also conducting a similar but smaller scale program during the present (1987) summer. This program includes special instrumentation at five sites (four on mountaintops) to gain additional insight into the forcing mechanisms for mesoscale circulation in mountainous areas.

E. Reiter

U.S. Department of Energy through Los Alamos National Laboratory

MESOSCALE FORECASTING OVER COMPLEX TERRAIN

We have developed a numerical prediction model for weather development over complex terrain. The model is run on an HP 9000 desktop computer. This model has been tested successfully over Tibet and over the western United States for severe weather events during summer. A nested-grid version of this model has been highly successful in simulating the time sequence of events surrounding the Big Thompson flood of 1976 and the Cheyenne flood of 1985. This model version has performed significantly better than the NMC LFM predictions issued for these events. Despite its commendable performance in forecasting precipitation, wind and pressure fields in a variety of cases, the model has been less than ideal in some instances (such as overpredicting precipitation in some cases, including cyclonic flow or producing erroneous cloud fields). By determining how these faulty forecasts evolved in the model, we are modifying some routines to improve the model's performance. Comparing model output with satellite data has revealed other aspects of the model we can improve, so that it may also eventually be used to forecast cloud fields. Also, the nontested model version has performed better than the LFM in predicting "explosive" cyclogenesis in the lee of the Rocky Mountains. A relocatable version of this model has been developed for application over Brazil and over the East Coast of the U.S.

E. Reiter

National Science
Foundation
Air Force Office
of Scientific Research

WEATHER AT SEA

We are investigating by means of diagnostic and modeling studies the meteorological and oceanographic factors which are most likely responsible for rapid and severe cyclogenesis over the oceans. Such cases of cyclogenetic "bomb" development pose a severe threat to naval operations. In the initial phase of this study, we have investigated a number of "bomb" developments over the contiguous United States where data are more abundant than over the ocean. So far, we have been successful in isolating the implications of a traveling short wave at tropopause level and its superposition over a low-tropospheric wind streak in the development of such cyclones. Both conditions appear to be necessary to provide tightly focused convergence with generation of vorticity in the lower troposphere and latent heating in the storm center. In nonexplosive cyclones, convergence takes place in the very lowest layers only, with a poorly defined level of nondivergence, and much less latent heating. We are presently exploring the applicability of satellite data to detect the signatures of these upper and lower tropospheric wind maxima over ocean areas. Our next step will be to design artificial intelligence-based procedures for the analysis and incorporation of appropriate satellite data into the prediction process for severe cyclogenesis at sea.

E. Reiter

Office of Naval Research

SURFACE HEAT BALANCE MEASUREMENTS FOR "FIFE"

In collaboration with personnel from Florida State University, two surface energy budget stations were modified to incorporate very accurate Bowen Ratio monitors and improved soil heat monitoring systems. These stations were then deployed at the First ISLSCP Field Experiment (FIFE) test site near Manhattan, Kansas during May 1987. These stations will continue functioning there through October 15, 1987. Field activity includes participation in the first, second and fourth intensive field campaigns.

E. Reiter Florida State University

W. H. SCHUBERT

DYNAMICS OF TROPICAL WEATHER SYSTEMS

There is a three year project to investigate the dynamics of tropical weather systems using both numerical modeling and analytical methods. The models are used as tools for studying the banded structure of tropical cyclones and the relative roles of convective heat and vorticity sources in cloud clusters.

W. H. Schubert — National Science Foundation

DEVELOPMENT AND APPLICATION OF MULTIGRID AND SPECTRAL METHODS IN NUMERICAL WEATHER PREDICTION

Over the past eight years multigrid methods and spectral methods have proven very useful in solving a variety of problems in physics and fluid dynamics. This project's goal is the further development and application of these methods to the problem of numerical weather prediction.

W. H. Schubert
G. Taylor — Office of Naval Research

THEORETICAL AND OBSERVATIONAL MARINE STRATOCUMULUS STUDIES IN SUPPORT OF FIRE

A four-year research project to investigate marine stratocumulus convection is proposed. This work is in support of the first ISCCP Regional Experiment (FIRE) and involves both numerical modeling and observations. The expertise of the investigators lies in the areas of dynamics (W. Schubert), cloud physics (E. Hindman) and radiation (G. Stephens). The modeling work involves explicit simulations of boundary layer convective elements using spectral techniques (both Fourier-Chebyshev and normal mode). The observational work involves thermodynamic and cloud microphysical measurements from a tethered balloon on San Nicolas Island in June 1987 and 1989.

W. H. Schubert
E. Hindman
G. Stephens — Office of Naval Research

P. C. SINCLAIR

DEVELOPMENT AND APPLICATIONS OF ADVANCED TRACER TECHNIQUES TO VALIDATE MODEL FLOWS FOR COMPLEX TERRAIN AND LONG RANGE TRANSPORT

This research is designed to provide a basis from which transport and diffusion models can be validated by the development and application of advanced tracer techniques. In order to improve our understanding of circulation systems which provide the short- and long-range transport-diffusion pathways in the atmosphere, we are developing a new class of biological tracer materials and detectors that have absolute detection limits of 1-100 molecules. The new tracer system utilizes the detection of female insect pheromone compounds (mono- or dienic fatty alcohols, aldehydes, or acetates) with instrumented male (roach) antenna receptors. Each male antenna carries a dense array of approximately 17,000 sensory hair lumens, each of which lead to a receptor dendrite or cell, which can detect <u>one molecule</u> of a particular pheromone compound (i.e., a detection sensitivity of 1 ppv 10^{23}). The electrical impulse from the insect antenna can be recorded <u>continuously</u> in <u>real-time</u>. "Biological amplification" of the antenna signal can be achieved by using antenna arrays and binary pheromone mixtures. In addition, pheromone tracer concentrations can be measured directly from calibrated electroantennograms. Entomologists have had considerable success in the laboratory in developing these detection techniques. The tracer system is now under laboratory development and we feel that its detection sensitivity of approximately 1 ppv 10^{23}, which is 10^{5}-10^{6} greater than any known atmospheric tracer, is so significant that its development and testing will be of great importance to the field of atmospheric transport and diffusion. The research plan involves a strong interdisciplinary collaboration between scientists in the CSU Atmospheric Science and Entomology Departments.

In order to test the usefulness of the pheromone tracer system, a simple flow situation for a plain intersecting a sloping barrier (i.e., a Colorado Front Range location) would be employed to compare measured tracer material trajectories and concentrations with the Pielke (1983) numerical mesoscale model simulations. A previously developed cesium tracer system (Sinclair and Finnegan, 1981) will be used as a bench mark check on the plume transport and dispersion boundaries. Both winter and summer flow situations would be investigated with instrumented aircraft measurements of tracer location and concentration, winds (u, v, w), temperature, pressure and dew point. Inner-mountain, complex terrain tests would follow these initial tracer-model validation experiments.

P. C. Sinclair — Army
L. Bjostad
P. Scott
G. Edelen
R. Hill

G. L. STEPHENS

AN INVESTIGATION OF THE APPLICATION OF MONTE CARLO METHODS TO PROBLEMS IN VISIBILITY

The investigation conducted under this grant has focused on the physical aspect of visibility in the National Parks. A hierarchy of methods have and are being developed that are specific to the problem of light attenuation in an optically thin, polluted atmosphere. These methods range in sophistication from a Monte Carlo model to a very simple parametric description of the radiative processes that influence visibility. The work continues with investigation of the effects of: variable lighting conditions, spatially varying aerosol concentrations, non-uniform surface reflectances, and the optical properties of the particles on visibility.

G. L. Stephens
S. K. Cox
T. B. McKee
T. Greenwald

National Park Service

STUDIES OF THE RADIATION BUDGETS OF FAIR WEATHER CUMULUS & STRATOCUMULUS CLOUDS

The overall objective of this investigation is to provide a better understanding of the spatial variability of the optical properties of clouds and the impact of this variability on the radiation budgets of individual clouds and cloud ensembles. There are two components to the investigation. The first involves analysis of aircraft radiation and cloud physics data to study:

(i) the spatial variability of reflectivity, microphysical, and optical properties of cloud ensembles

(ii) the spectral variability of cloud reflectivity

(iii) the correlation of cloud reflectivity and cloud emissivity

(iv) statistics relevant to the definition of the radiation budgets of cloud ensembles

(v) validation (or lack of) theoretical calculations

(vi) measurements of the average broadband radiative heating fields of cloud fields.

The second, and complementary, component of the research involves development of appropriate multidimensional radiative transfer theories which have been used to provide a basis for the analysis of the data as well as an overall framework for the development of the parameterization of radiative transfer in spatially non-homogeneous optical media.

G. L. Stephens

National Science Foundation

THE EFFECT OF CIRRUS CLOUDS ON SATELLITE OBSERVED RADIANCES

We plan to investigate the interaction of radiation with cirrus clouds with some emphasis on the retrieval of cloud properties from satellite radiance data. In order to achieve the stated objectives of this research and for the purposes of future developments of cirrus cloud parameterization, we plan to develop a microphysical model of cirrus and to couple this model to a radiative transfer scheme that will allow a convenient way of treating the radiative heating term to the microphysical growth equation while at the same time provide simulated "satellite" radiance data. We also plan to be involved in the future FIRE cirrus cloud experiment and propose to develop an ice water content probe for use in these field experiments. Measurement of this parameter will be important in testing the cloud model simulations, radiation parameterizations and cloud retrieval schemes to be developed under this proposal.

G. L. Stephens
S. K. Cox

National Science Foundation

THE EQUATORIAL MESOSCALE EXPERIMENT: EMEX

The research here represents a component of a highly focused field experiment (The Equatorial Mesoscale Experiment: EMEX) and research plan aimed at investigating the heating mechanisms within tropical cloud clusters to define the effect of these cloud systems on the vertical profile of large-scale heating through the troposphere. The primary observing platforms for this experiment will be the NOAA WP-3D research aircraft, the CSIRO Fokker F-27 aircraft and the NCAR L-188 Electra which is under request. In addition, it is expected that a dedicated EMEX ship from the People's Republic of China will take part in the experiment.

The EMEX will be conducted from 1 January - 15 February 1987 out of Darwin, Australia, over Northern Australia and Southern Indonesia. It will coincide in space and time with two independent but complementary experiments: The Australian Monsoon Experiment (AMEX) aimed at defining the synoptic-scale structure of the northwest monsoon, and the NASA Stratospheric-Tropospheric Exchange Program (STEP) aimed at examining the mechanisms of stratospheric-tropospheric interchange and interaction.

The particular objective of the research to be conducted under this proposal concerns the analysis of aircraft radiation and cloud microphysical data in order to provide estimates of vertical radiative heating through the cloud system.

G. L. Stephens

National Science Foundation

THEORETICAL AND OBSERVATIONAL MARINE BOUNDARY LAYER STUDIES

This project will investigate marine stratocumulus convection. This work is in conjunction with the First ISCCP Regional Experiment (FIRE) and involves both numerical modeling and observations. The expertise of the investigators (S. Cox, W. Schubert, G. Stephens) lies in the areas of thermodynamics, dynamics, radiation and cloud physics. The modeling work involves explicit simulations of boundary layer convective elements using spectral techniques (both Fourier-Chebyshev and normal mode). The observational work involves thermodynamic, dynamic, radiation and cloud microphysical measurements from a tethered balloon on San Nicolas Island in July 1987 and 1989.

S. K. Cox
W. Schubert
G. L. Stephens

Office of Naval Research
(ONR)

D. E. STEVENS

DYNAMIC INSTABILITIES OF ATMOSPHERIC MEAN FLOWS

The study of inertial/barotropic instability of a geophysical fluid is being expanded as we are investigating the more realistic case of a zonal jet with shear in the vertical direction as well as the latitudinal direction. We are developing a spectral, prognostic numerical model in order to accomplish this study. Most unstable modes are being calculated in regions of negative potential vorticity with our time integration model. This method will enable us to generalize more directly to non-linear dynamical flows.

D. E. Stevens
M. Ringerud

National Science
Foundation

DYNAMICS AND MODELING OF PLANETARY TO SYNOPTIC SCALE ATMOSPHERIC CIRCULATIONS

A global semi-spectral model for linearized perturbations has been developed. The model was used to investigate the Walker Circulation. Results indicate that when cumulus friction is included in the linear model calculations, a mean vertical velocity field should also be included. When the effects of the zonal mean winds and the Hadley Cell/cumulus friction terms are included, the model response resembles the observed tropical and subtropical responses to the El Nino ocean temperature anomaly.

The influence of pressure gradients on the parameterization of cloud momentum transports was also investigated. Results suggest that horizontal pressure gradients should be taken into account in modeling of convective lines.

Planetary wave propagation in the southern winter hemisphere was studied. An average or composite over several propagating cases reveals the wave structure and evolution, and suggests a source of planetary wave activity in the upper troposphere.

D. E. Stevens
M. Flatau
P. Ciesielski

National Science
Foundation

MODELING INVESTIGATIONS OF TWO SHORT TERM CLIMATE PHENOMENA

The first of two short term climate phenomena investigated in this study is the 40-50 day oscillation in the tropical troposphere. A linear model with a basic state consisting of a Hadley cell is found to give rise to a class of slow, wavelike motions which are in agreement with observations of the 40-50 day oscillation. These perturbations on a zonally symmetric Hadley cell basic state form a dynamical explanation for the time scale of the oscillation. Modeling efforts with zonally asymmetric basic states are also considered.

The second area of investigation is the blocking phenomena of mid-latitudes. Analysis of Ertel potential vorticity on isentropic surfaces is a fundamental diagnostic tool for large-scale dynamical processes. Therefore, a case study of a particular blocking event is considered with emphasis placed on an isentropic evaluation of its evolution and structure. Interactions with the higher frequency synoptic storms are considered by means of trajectory analysis and Eliassen-Palm fluxes.

D. E. Stevens
F. Crum

National Science
Foundation

DYNAMICS OF LARGE-SCALE ATMOSPHERIC CIRCULATIONS

Several specific lines of research are proposed in this three-year research program.

Preliminary calculations have shown that vertical shear of the basic state wind field plays a crucial role in the thermodynamic balance of tropical easterly waves, as well as in the qualitative structure of the atmosphere's response to convective heating. We use observed wind fields along with a consistent Hadley cell to study the response to convective heat and momentum sources in a linear framework, and then compare the model results with recent observations.

The zonal wind structure, Hadley cell advection, and cumulus momentum mixing also influence circulations over South America. The linear wave model will be used to study the response to both stationary and diurnal forcing located over Brazil.

The zonally symmetric linear response to the zonal average component of diabatic heating has proved difficult to obtain when using primitive equation models that do not reduce to shallow water systems. We suspect that the magnitude and parameterization scheme of dissipation strongly influence the response, and therefore propose to study the zonally symmetric problem. A time integration model may be required.

Further advances in understanding, simulation, and eventual prediction of middle latitude blocks require additional analysis of observations. We will complete a study, already begun, which focuses on the interaction of blocks with cyclones by analyzing isentropic potential vorticity fields and isentropic trajectories.

Barotropic instability is important as a dynamic mechanism in large-scale flows. The spatial and temporal structures of barotropically unstable modes will be investigated by analytic study of a functional of the wind field, complemented by a numerical eigensolution technique.

D. E. Stevens
M. Flatau
F. Crum

National Science Foundation

T. H. VONDER HAAR

SCIENTIFIC INVESTIGATION FOR THE EARTH RADIATION BUDGET EXPERIMENT

NASA has launched instrumental earth-orbiting satellites to monitor the earth's radiation budget by simultaneously measuring both the outgoing reflection of the sun's energy and the long-wave radiation emitted from the earth's surface and atmosphere. The purpose of this effort is to provide scientific support during instrument development and perform data use investigations with observations of the earth's radiation budget parameters as determined from the satellite measurements.

T. H. Vonder Haar
G. G. Campbell
D. Randel
L. Smith

National Aeronautics
and Space Administration

RAIN VOLUME ESTIMATION OVER AREAS USING SATELLITE AND RADAR DATA

The principal goal of the project is to investigate the feasibility of rain volume estimation over fixed and floating areas using rapid scan satellite data following a technique recently developed with radar data called the Area-Time-Integral (ATI) technique. To accomplish this task, continuous case studies were selected on the basis of existing radar and satellite data sets which match in space and time.

T. H. Vonder Haar
D. Reinke

National Aeronautics
and Space Administration

ANALYSIS OF NIMBUS-7 SOLAR AND EARTH RADIATION BUDGET

This research focuses upon intensive analysis of the long-term (>10 years) time series of Earth Radiation Budget (ERB) measurements obtained from NASA satellites NIMBUS-6 and NIMBUS-7. The satellite measurements are studied using correlative data describing atmospheric and oceanic circulation and cloudiness. The research strongly supports development and improvement of atmospheric-ocean coupled climate models.

T. H. Vonder Haar
G. G. Campbell
D. Randel
L. Smith

National Aeronautics
and Space Administration

SATELLITE REMOTE SENSING AND OBSERVATIONS OF AREAL PRECIPITATION

The primary objectives of this project are to explore new physical and statistical methods and approaches to the remote sensing of lower tropospheric moisture; to study the physical basis of detection of area precipitation; and to explore new (e.g., lidar) satellite remote sensing methods for aerosols, clouds, and related parameters. These new studies will take advantage of the rapidly expanding opportunities for remote sensing from civilian and DoD spacecraft.

T. H. Vonder Haar — Army Research Office
T. B. McKee

DEVELOPING AND UNDERSTANDING A SENSOR-TOPOGRAPHIC-MODELING DATABASE

The database required in the Geoscience research consists of topographic data, sensor data from radar, lidar, satellites, etc., model output, as well as data from physical observations. Because a wide variety of data will be generated in the Geoscience research, the objective of this research is to investigate methods of generating a topographic sub-database using data from topographic mapping satellites.

T. H. Vonder Haar — Army Research office
T. A. Brubaker
G. K. Lee

INFORMATION EXTRACTION ALGORITHMS THAT OPERATE ON A TIME-VARYING DATABASE

The research on information extraction will focus on physical algorithms that generate timely and physically accurate information. The algorithms must generate information rapidly as conditions change and, at the same time, be capable of implementation on computer systems used in field operations. Algorithms will be developed and tested using sensors and models utilized within the Center for Geosciences project.

T. H. Vonder Haar — Army Research Office
T. A. Brubaker
R. Loomis

DISPLAY OF THE BEST POSSIBLE CURRENT AND FORECAST HYDROMETEOROLOGICAL CONDITIONS WHEN SENSOR DATA VARIES

This research is concerned with the information display which is effectively the user interface. The research will focus on imaging because color and visual images have the potential of rapidly conveying hydrometeorological information in a form that is quickly assimilated by personnel at all levels. Imagery methods will be tested on existing data and on data collected within the project. The human factor or MANPRINT aspects of the research will be related to the basic display research.

T. H. Vonder Haar
T. A. Brubaker

Army Research Office

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GRADUATE DEGREES

(July 1, 1986 - June 30, 1987)

Doctor of Philosophy

Cecilia Griffith
The Estimation from Satellite Imagery of Great Plains Summertime Rainfall Over Varied Space and Time Scales

Cheng-Shang Lee
An Observational Study of Tropical Cloud Cluster Evolution and Cyclogenesis in the Western North Pacific

Ming-Sen Lin
The Evolution and Structure of Composite Meso-Alpha-Scale Convective Complexes

Jim Purdom
Convective Scale Interaction: The Importance of Arc Cloud Lines in the Development and Evolution of Deep Convection

Jenn-Luen Song
A Numerical Investigation of Florida's Sea Breeze--Cumulonimbus Interactions

Greg Tripoli
A Numerical Investigation of an Orogenic Mesoscale Convective System

George Young
The Dynamics of Thermals and Their Contribution to Mixed Layer Processes

Master of Science

Dave Changnon
Economic Impacts and Analysis Methods of Extreme Precipitation Estimates for Eastern Colorado

Sue Chen
Simulation of the Stratiform Region of a Mesoscale Convective System

Yuh Mei Yin Chen
Plan B

James Cowie
Colorado Precipitation Event and Variability Analysis

Robert Craig
Three- and Four-Dimensional Display of Radar and Satellite Data

Richard Fleming
Wind Flow Over the Rocky Mountains

Qi Hu
A Diagnostic Study of Explosive Cyclogenesis in the Lee of the Rocky Mountains

Randolph Kawa
Ozone Deposition, Scalar Budgets and Radiative Heating Over Texas Coastal Forest and Ocean

Nancy Leary
Determination of Wind Shear Using Cloud Relative Tracking of Clouds from Satellite Imagery

Douglas Wesley
The Role of Radiative Processes in the Diffusional Mass Evolution of Cirrus Hydrometers

Gary Williams
Mesoscale Observations of Lee Trough in Colorado

Paul Wolyn
An Examination of Deep Stable Layers in the Intermountain Region of the Western United States

Brian Woodruff
Sampling Error in a Single-Instrument Vertical Gradient Measurement in the Atmospheric Surface Layer