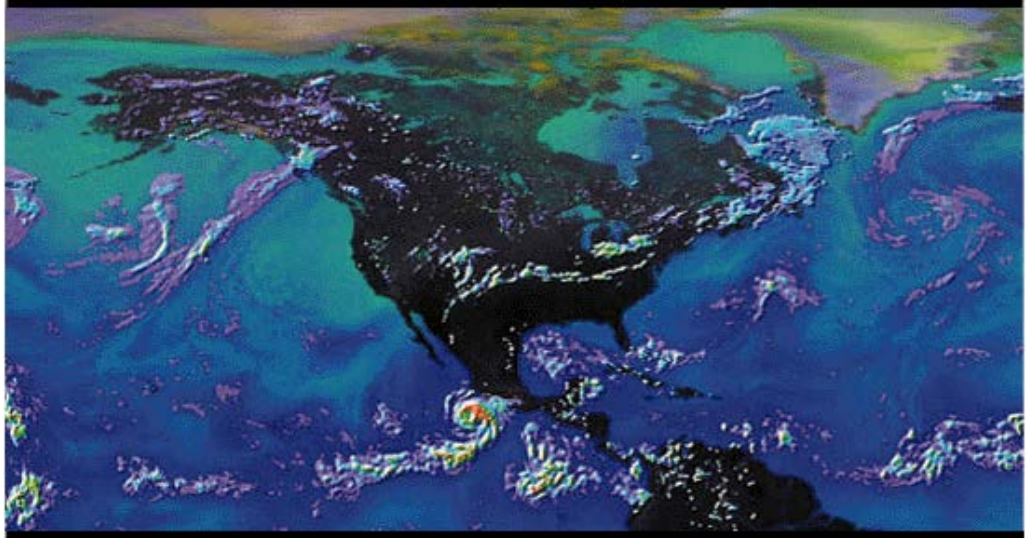
National Center for Atmospheric Research



1998 Annual Scientific Report

UCAR NCAR National Science Foundation

Photo courtesy of TRMM Program

Message from NCAR's Director

Robert J. Serafin

Dear Colleagues,

It is with great pleasure that NCAR presents its Annual Scientific Report for fiscal year 1998. This web document includes a description of all the activities of the Center over the past fiscal year in scientific research, technological development, community interactions and educational outreach.

FY1998 marked the beginning of a new five year cooperative agreement between the National Science Foundation and NCAR's corporate managers, the University Corporation for Atmospheric Research. In conjunction with NSF and UCAR, NCAR has determined six primary scientific and technological priorities for the coming decade. These are:

- **Fundamental Research:** In keeping with the mission of the NSF, the foundation of NCAR's program is fundamental research, particularly research of sufficient complexity to command the resources of a national center. Studies in atmosphere and ocean dynamics, microphysics, fundamental chemical reactions, climate variability, turbulence, and internal solar processes and characteristics are just a few of the basic research topics that NCAR pursues

- **Understanding and Predicting the Earth System:** NCAR and its many university collaborators carry out major cross-cutting, interdisciplinary efforts to model the earth system. NCAR scientists are actively participating in several national research efforts, including the US Weather Research Program, the US Global Change Research Program and the US Space Weather Program. Areas of scientific emphasis include research on prediction of weather on short temporal and small spatial scales, longer-term prediction of monthly and seasonal means, and studies of the influence of human, solar and other forcing processes on weather and climate. NCAR also participate in major field campaigns to make observations and acquire data for incorporation into coupled system models.

- **Advanced Scientific Facilities:** NCAR continues to put a high priority on developing new and cutting-edge scientific facilities, including computing systems, instruments and observing sytems, community models, datasets and advanced networking and communications tools, as well as providing these facilities to the atmospheric sciences community. Major emphases in the coming decade will consist of the acquisition of a new high-altitude research aircraft, supercomputing systems and remote sensing technologies.

- **Human Dimensions and Societal Impacts:** NCAR places increasing emphasis on studying the impacts of weather and climate on society; on human influences on the climate system; on society's ability to cope with weather- and climate-related impacts and on the use and value of meteorological, climate, and other atmosphere-related information. NCAR will incorporate a human dimensions component into all its major research programs where appropriate.

- **Education and Training:** NCAR will continue and strengthen its efforts in education through the Advanced Study Program, the support of students, visitors and colloquia in NCAR's programs, and specific education programs like SOARS and Project LEARN. NCAR's educational programs encompass all education levels, from K-12 through Post-doctoral. In addition, NCAR maintains a strong public outreach program through its tours and outreach program.

- **Applications and Technology/Information Transfer:** NCAR is committed to transferring information, technology and research results to the public and private sectors, university colleagues and constituents through direct transfer to users, s, public domain access through the Internet, and licensing of complex technologies. New, exciting opportunities will be explored in advancing computational science software applications for weather forecasting for specific user-groups in transporation, energy and agriculture.

These priorities are dicussed completely in a document prepared for the NSF entitled NCAR and UCAR at the Millennium which provides a blueprint for NCAR's activities in the coming decade. Please visit this and the many other sites contained within this report to learn more about NCAR's divisions and programs, and the activities that took place over this past year. I hope that you find them interesting, informative, and useful.

Advanced Study Program

Director's Message

William A. Cooper

The ASP mission, broadly defined, is to help NCAR (and the scientific communities it serves) prepare for the future. We work in support of other NCAR units to encourage the development of young scientists in the field of atmospheric science, to direct attention to timely scientific areas needing special emphasis, to help organize new science initiatives, to support interactions with universities, and to promote continuing education at NCAR.

The most important component of our program is the postdoctoral fellowship program, which has been a part of NCAR for more than thirty years and has brought more than 350 postdoctoral scientists to NCAR. Each year between 10 and 15 new postdoctoral scientists come to NCAR, usually for two-year appointments. They conduct their research in collaboration with NCAR scientists and work in all areas in which NCAR is involved. NCAR benefits from continuous contact with some of the brightest and most promising young scientists in our field and from the lasting associations that result. The postdoctoral scientists benefit from the opportunity to work with NCAR scientists, from exposure to the breadth of science at NCAR, and from the independence they are encouraged to develop. Many former fellows now occupy prominent positions at UCAR universities or at NCAR, and many present collaborations between NCAR and university scientists derive from associations that developed in the postdoctoral program.

The ASP also promotes the examination of research areas that merit special emphasis, either because they are particularly timely or because they seem under-emphasized relative to their importance. This is accomplished primarily by convening workshops and supporting appropriate visitors. As part of this effort, ASP hosts an annual summertime colloquium that brings graduate students to NCAR for an intensive set of lectures presented by selected scientists from within and outside NCAR. Last summer the topic was Hurricanes at Landfall, a review of hurricane structure and forecasting held jointly with the Hurricane Research Division of NOAA.

Another function of the ASP is to promote new science initiatives and programs that do not have a natural home in any one of the NCAR divisions. The Geophysical Turbulence Program seeks to represent interests in turbulence throughout NCAR. This very active program normally hosts an annual workshop, sponsors a seminar series, and in other ways helps coordinate the active program in turbulence research at NCAR. We have recently been helping promote the NCAR Aerosol Program, a new effort to coordinate and promote aerosol research at NCAR.

The ASP also includes: the NCAR Graduate Fellowship program, which provides a few opportunities for graduate students to conduct Ph.D. research projects at NCAR in collaboration with NCAR scientists; several seminar series including the NCAR-wide "Showcase Seminars" that highlight significant advances at NCAR and the "Thompson Lectures" that bring prominent scientists to NCAR to interact with the junior scientists; a Visiting Scholars Program that supports visits by NCAR scientists to UCAR affiliate universities; and a visitor program.

For more information on the ASP mission and plans, see the ASP Strategic Plan.

Examples of Research Projects:

-Relationships between tropopause features and cyclones
-Coastally trapped disturbances
-Effects of Mesoscale Topography on Meso- and Large-Scale Flow
-Numerical methods for triangular geometry
-Studies of the solar dynamo

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UCAR NCAR National Science Foundation

Highlights:

The ASP Postdoctoral Fellowships

In FY-98 ASP hosted 32 postdoctoral fellows. Nine new fellows began their appointments, 11 continued, and 12 complete their terms at NCAR. A brief description of this program can be found in the ASP Postdoctoral Fellowship Announcement. The ASP postdoctoral fellows work in all divisions and programs at NCAR, so details of their scientific achievements are included in the reports from those divisions and programs. We have linked extended reports on the research of five fellows as examples of their contributions to NCAR science and as highlights of their accomplishments.

Summer Colloquium

ASP and the Mesoscale and Microscale Meteorology Division (MMM), together with the Hurricane Research Division (HRD) of NOAA, hosted a summer colloquium on "Hurricanes at Landfall" in July 1998. Robert Gall, Peter Hildebrand and Wen-Chau Lee (all of MMM) and Frank Marks and Hugh Willoughby (HRD, NOAA) coordinated the sessions which were held for the first week of lectures and hands-on data analysis computer programs at NCAR and the second week of lectures and tours at the Hurricane Research Center in Miami, Florida. Since seating was limited, ASP concurrently used Web delivery to record and display the lectures of 24 people from 11 institutions of the U.S. The 30 student participants represented 18 institutions from 3 foreign countries and the U.S. The colloquium addressed the issues of structure and dynamics of hurricanes, how hurricanes change as they make landfall and the current state of ability to predict hurricane intensity and track. New features of this colloquium were its conduct at two sites (to expose students to the hurricane research and forecasting centers in Miami as well as to NCAR), its incorporation of data-analysis exercises using measurements from recent hurricanes, and the presentation of the lectures via audio-video delivery from our Web site. (See http://www.asp.ucar.edu/colloquium/1998)

The Thompson Lecture Series

A new series of visits and lectures was established to foster interaction between prominent scientists and the postdoctoral fellows and other junior scientists at NCAR. Three visitors were brought to NCAR under this program for meetings and discussions focussed on the research of the ASP postdoctoral fellows.

Geophysical Turbulence Program(GTP)

FY-98 was a busy year for GTP, which hosted two workshops and numerous scientific visitors.

An international symposium on Developments in Geophysical Turbulence was sponsored by GTP, The International Union for Theoretical and Applied Mechanics, The International Association of Meteorology and Atmospheric Sciences of the International Union of Geodesy and Geophysics, and coordinated by Robert Kerr of NCAR and Yoshifumi Kimura of Nagoya University, Japan. Not including NCAR and Boulder drop-ins, the June 1998 workshop and poster sessions had 91 official participants from 59 institutions representing the U.S. and 14 other countries. GTP was the natural host for such a

workshop which brought together a broad spectrum of scientists to discuss turbulence modeling, statistics of small scales and coherent structures, convective turbulence, stratified turbulence, and historical developments.

The second workshop on the topic of "Observations, Experiments and LES-A Triad for Geophysical Turbulence Studies" was hosted by GTP in August 1998 and coordinated by Donald Lenschow (MMM/ATD), Jackson Herring (MMM), Mary Barth (MMM/ACD), Chin-Hoh Moeng (MMM), Peter Sullivan (MMM), Bjorn Stevens (MMM), William Large (CGD) and Steve Oncley (ATD) locally as well as Robert Weller (WHOI), John Wyngaard (Penn State University), Bruce Albrecht (U. Miami), K. R. Sreenivasan (Yale), and Jim McWilliams (UCLA). In accordance with recent recommendations by the ASP review panel the university members of the organizing committee played a major role in planning and coordinating the workshop.
Fifty-seven scientists representing 27 institutions from the U.S. and 3 other countries attended.

GTP hosted 14 seminars which covered aspects of the following topics: rigorous mathematics of stably-stratified turbulence; Lagrangian dynamics in the atmosphere and ocean, including analysis of particle trajectories; magneto-hydrodynamical turbulence; orographic flow and turbulent mountain wakes; mathematics of 3-dimensional flow in thin layers; a dynamical systems approach to turbulence; measurements of departures from Monin-Obukhov similarity in the surface layer over the ocean; and lidar measurements of turbulence structure in the planetary boundary layer.

GTP also hosted an extended visit from Michael Spector of Colorado Springs who worked on the pressure distribution of turbulence using Fisher information theory in collaboration with John Cocke (University of Arizona), and on symmetries of higher-order structure functions. Finally, the GTP supported one-half of postdoctoral fellow Eileen Saiki's appointment. Saiki is working with GTP scientists for two years on LES of stably-stratified boundary-layer turbulence and direct numerical simulation of double diffusion.

NCAR Graduate Fellows

The ASP appointed two Graduate Fellows during FY-98. *Jennifer Kolar* (University of Colorado) is using ocean simulations produced by the NCAR CSM Ocean Model to investigate the validity of theoretical explanations of features in ocean circulations. *John Braun* (UNAVCO and University of Colorado) is participating in the development of techniques for using GPS-based measurements of precipitable water to infer mesoscale cloud structures.

Visitors

The ASP also served as host for a few visitors during FY-98. Veronica Vaida, on sabbatical from the University of Colorado, worked with scientists and postdocs in ASP and ACD on studies of chemical reactions in the atmosphere. Another "sabbatical" arrangement brought Margaret LeMone from MMM to ASP for a visit focused on educational objectives and initiation of some new research directions related to the atmospheric boundary layer. Edward Zipser (Texas A&M) also visited LeMone and Cooper to work on collaborative research projects with them.

Charles Brock (University of Denver) helped with the activities of the NCAR Aerosol Program and oversaw construction of an aerosol measuring system for use throughout NCAR. Sonia Lasher-Trapp (Texas A&M University) started a long-term visit during which she will work with scientists in MMM on studies of cloud microstructure using data from the Small Cumulus Microphysics Study. Patsy Taylor of the University of Wyoming and Myanna Lahsen of Rice University continued their sociological studies related to NCAR and NCAR science. (Lahsen graduated with a degree in anthropology and began a new appointment as an NCAR postdoctoral fellow, where she will continue her studies of the societal dimensions of climate-change research in association with the ESIG.)

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Postdoctoral Fellows' Research:

Because ASP postdoctoral fellows are involved broadly in the NCAR scientific program, their activities are discussed in depth in the reports from the various divisions and programs at NCAR. However, to show the diversity of their work and their overall influence on NCAR accomplishments, the following presents a brief overview of their activities and provides links to sections where some of the accomplishments are discussed in more detail.

In atmospheric chemistry, *Stephen Ball* (in collaboration with Fred Eisele of ACD) has completed a set of laboratory measurements of nucleation rates for clusters of sulfuric acid and water, and has conducted some preliminary extensions of those measurements to the case where ammonia is also present. The power-law dependence of the nucleation rate on concentration reveals the number of molecules involved in the formation of critical clusters, and so reveals molecular-level details of gas-to-particle conversion processes that may occur in the atmosphere. *Laura Iraci* collaborated with scientists in ACD to measure the Henry's Law coefficients of some volatile organic compounds, finding them to be too small for significant update into cloud water under equilibrium conditions. Therefore update by cloudwater is not a significant sink for those compounds and therefore oxidation by OH is likely the dominant removal mechanism for these compounds.

Several observational or instrumentation projects also contributed to progress in atmospheric chemistry. *Barry Lefer*, working with Richard Shetter of ACD, helped develop and test new airborne actinometers that measure the actinic flux driving key photochemical reactions in the troposphere. At the Research Aviation Facility, *Susan Durlak* collaborated with Bruce Gandrud to design an instrument for the measurement of the sulfate content of aerosols and for discrimination by size in such measurements. Also concentrating on observations, *Karsten Baumann* (in collaboration with others from ACD and MMM) helped collect and analyze measurements from thunderstorms that added to evidence that lightning is a significant source of atmospheric NO_x. *Denise Mauzerall* and *Larry Horowitz* both used the MOZART model of atmospheric chemistry to study tropospheric ozone. Horowitz focussed on the effects of convection on tropospheric chemistry and especially on ozone. Mauzerall has adapted the model for the study of Asian sources of pollution on tropospheric ozone, and has developed methods of using observational meteorological data in order to be able to compare results to specific cases where there are comprehensive observations.

In studies of climate and global dynamics, *Charles Zender* incorporated sources and transport of mineral dust into the Community Climate Model (CCM) and obtained good comparison between the resulting global distributions of dust and those observed by satellite. *Joel Norris* continued his studies of the characteristics of low cloud cover over the oceans by evaluating the relationship between observed clouds and synoptic-scale meteorological conditions. A significant correspondence was found between the low-level vertical motion (inferred from convergence) and the type of cloud that formed. *Chris Torrence* and *Greg Duane* also contributed to climate studies, Torrence in studies of decadal variability (esp. ENSO) using wavelet analysis tools and Duane in applications of chaos theory to dynamical systems.

In studies that bridge interests in global-scale and mesoscale dynamics, *Wendell Welch* used mesoscale simulations of airflow over topography to study potential effects of such airflow on global-scale dynamics. She is using the results in an effort to represent the effects of mesoscale topography in GCM results. (See elaboration)

In mesoscale meteorology, *Greg Hakim* has extended his earlier documentation of the links between tropopause features and weather systems by using models of idealized jet-stream flow to show that vortical upper-level disturbances trigger surface cyclogenesis. (See elaboration). In collaboration with MMM investigators and others, *Bjorn Stevens* used model simulations to study the process of entrainment at the top of the planetary boundary layer and to develop representations of the entrainment rate that include radiative effects, interfacial cooling, and the roles of small-scale mixing. *Eileen Saiki*, with

Robert Kerr and William Holland, developed realistic simulations of the salt-finger structures produced by "double diffusion" in the ocean, where salinity and heat diffuse at different rates at stratified interfaces.

Rajul Pandya, in collaboration with Richard Rotunno and William Skamarock, used a two-layer shallow water model to show that coastally trapped disturbances resemble a hybrid disturbance that arises in such a model from coupling between Rossby and Kelvin waves at different levels. (See elaboration) *Kevin Petty* collaborated with Jordan Powers in the development of a coupled ocean-atmosphere mesoscale model. *Thomas Hamill* (in collaboration with Chris Snyder) developed new methods for treating the situation-dependent forecast error in data assimilation schemes by using ensemble forecasts from a quasigeostrophic model to provide statistical descriptions of the error field.

In studies of solar physics, *Hardi Peter* has used observations of the Doppler shifts of various spectral lines (representing different altitudes above the Sun) to deduce characteristics of the outflow from the Sun. These studies provide clear documentation of outflow from the polar coronal holes and provide measurements of the outflow velocity that leads to the fast solar wind. Another result, not yet understood, was the measurement of inward flow at lower levels in the disk center but outflow at upper and hotter levels. *Mausumi Dikpati*, in collaboration with Peter Gilman and Peter Fox, has analyzed potential instabilities that arise from combined hydrodynamic and magnetic effects at the base of the convection zone. They have shown that, in the presence of differential rotation and a concentrated toroidal field, the joint system is unstable to horizontal disturbances that extract energy from the toroidal field. In collaboration with Paul Charbonneau, she has also developed a dynamo model that reproduces many features of the magnetic cycle. (See elaboration)

In an extension of her earlier studies of particle fluxes in the upper atmosphere of the Earth, *Marina Galand* collaborated with investigators in Alaska to obtain improved observational documentation of a small outgoing component in such fluxes. Her model studies indicate that magnetic reflections do not account for this outgoing flux, but processes involving collisions with neutral atoms are the likely cause.

ASP postdoctoral fellows also contributed to studies of numerical and computational methods. *Beth Wingate*, in collaboration with Mark Taylor of SCD, developed a new numerical approach for use with triangular geometry that has attractive features competitive with or superior to those conventionally used with quadrilateral geometry. (See elaboration) *William Spotz* worked with Taylor and Paul Swartztrauber to develop new methods for computation in latitude-longitude coordinates that rely on efficient filtering. They showed that the accuracy and stability of their approach is the same as for the spectral transform method, but their method is more efficient.

In the area of societal impacts, ASP postdoctoral fellow *John Magistro* has focused on Senegal as an example of a society where climate variability and climate change have a large impact on agriculture and on the society. His studies have investigated the means by which this society receives and responds to information on weather and climate. A particular focus of his work is the construction of dams, which he argues is a response to climate change that can have deletorious as well as beneficial results on the society.

To assist such studies of surface hydrology, *David Yates* has worked with others in RAP to acquire a hydrological model for use at NCAR and to make this model available to researchers within and outside NCAR. Also in RAP, *Rong-Shyang Sheu* collaborated with V. Vivekanandan in development of a new algorithm for using microwave measurements from satellites to estimate precipitation, and tested those measurements by comparing to measurements deduced using radar.

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Educational Activities:

Showcase Seminar Series

The ASP continued this series of seminars that are presented jointly by an NCAR division or program and ASP. These monthly seminars, intended for an audience of all NCAR scientists, feature prominent research results that should be widely known at NCAR. They are intended to promote greater understanding of the range of scientific activities underway at NCAR and to highlight particularly important research results.

Thompson Lectures

The ASP recently established the "Thompson Lecture Series," named in honor of Phil Thompson, who founded the Advanced Study Program and was NCAR's first associate director. Under this program, prominent scientists are brought to NCAR for short visits that promote interaction between them and the postdoctoral fellows and other junior scientists at NCAR. In addition to presenting formal lectures, the Thompson Lecturers listen to briefings on the research being conducted by ASP Fellows and comment and provide advice on those research projects. They also meet with groups of scientists to discuss some more general topics, provide career advice, and offer their perspectives on scientific trends and priorities. In FY-98, three Thompson Lecturers were brought to NCAR: Paul Crutzen (University of Mainz, Germany), John Wyngaard (Penn State University), and Brian Hoskins (University of Reading, England).

Other Educational Activities

Two ASP postdoctoral fellows, Rajul Pandya and Kevin Petty, participated with Project Learn which helps Colorado science teachers understand topics in atmospheric science and apply those topics in their classrooms.

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Staff Visitors and Collaborators:

Staff:

William A. Cooper (50%)

Garth D'Attilo (Student Assistant III from 4/13/98)

Hans Friedli (SRA from 2/22/98)

Barbara Hansford

Judy Miller

NGFs:

John Braun; University of Colorado; Global Positioning System for remote sensing.

Jennifer Kolar; University of Colorado; examining a unified ocean circulation theory.

Postdocs:

Stephen Ball; Oxford University, England; laboratory studies of the reactions and nucleations of sulfate aerosols.

Karsten Baumann; University of Stuttgart, Germany; measurement of NOx produced by lightning.

Mausumi Dikpati; Indian Institute of Science, Bangalore; the study of solar magnetic fields.

Gregory Duane; University of Colorado; synchronized chaos in the large-scale atmospheric circulation and in other extended dynamical systems.

Susan Durlak; University of Cincinnati; impact of aerosols on climate using observations from aircraft platforms to determine global aerosol climatology.

Regina Figge-Cannon; University of Colorado; Earth's carbon cycle; the effects of climate change on biodiversity.

Marina Galand; Institute National Polytechnique de Grenoble, France; energetic particle precipitations in the high latitude ionosphere.

Gregory Hakim; SUNY-Albany; dynamics of mesoscale tropopause-based disturbances and their importance to extratropical weather and the general circulation.

Thomas Hamill; Cornell University; mesoscale forecast predictability and short-range ensemble forecasting; statistical issues related to weather forecast verification.

Brad Hindman; University of Colorado; seismology of the Sun's active regions and outer atmosphere.

Larry Horowitz; Harvard University; global-scale modeling of tropospheric chemistry including ozone and nitrogen oxides.

James Howell; Oregon State Unviersity; resolving surface flux variability.

Laura Iraci; University of Colorado; laboratory studies of tropospheric and stratospheric heterogeneous chemistry.

Myanna Lahsen; Rice University; scientific and political debate about human-induced climate change.

Barry Lefer; University of New Hampshire; trace gas and aerosol measurements from aircraft; atmospheric nitrogen deposition.

Daniel LeRoux; McGill University; technical improvements to the large-scale spectral element ocean model (SEOM).

John Magistro; SUNY-Binghamton; climatic variability and food security policy in African river basins.

Denise Mauzerall; Harvard University; 3-D modeling of tropospheric ozone.

Joel Norris; University of Washington; clouds and climate variablity.

Barbara Noziere; Bergisch University Gesamthochschule Wuppertal, Germany; laboratory studies of the transformation of biogenic compounds in the troposphere; gas- and condensed-phase processes.

Rajul Pandya; University of Washington; influence of gravity waves on the organization of mesoscale convective systems and the propagation of convectively forced gravity waves into the middle atmosphere.

Hardi Peter; Max-Planck-Institute for Aeronomy; dynamics of and connections between the solar chromosphere and corona.

Kevin Petty; Ohio State University; exploring the factors which cause the development and intensification of tropical cyclones.

Eileen Saiki; University of Colorado; large-eddy simulatin of atmospheric boundary layer turbulence.

Rong-Shyang Sheu; University of Colorado; satellite retrievals and mesoscale modeling.

William Spotz; University of Texas; high-order methods for computational fluid dynamics.

Bjorn Stevens; Colorado State University; turbulence, warm-phase microphysics and convection.

Christopher Torrence; University of Colorado; climate variability and predictability; time-series and wavelet analysis.

Wendy Welch; University of Washington; baroclinic heat transport, wavenumber selection and climate dynamics.

Beth Wingate; University of Michigan; large-scale fluid dynamics (ocean and atmosphere) and numerical analysis.

David Yates; University of Colorado; linkage of hydrologic processes in mesoscale climate models.

Charles Zender; University of Colorado; diagnosing the hydrologic cycle in the CCM2 uisng geophysical tracers.

Other Visitors:

Charles Brock; University of Colorado at Denver; NCAR aerosol program development.

Rick Igau; Texas A&M University; airborne and radar studies of cloud microphysics and dynamics.

Myanna Lahsen; Rice University; sociology of scientific groups.

Sonia Lasher-Trapp; University of Oklahoma; observations and modeling of warm cloud microphysical processes.

Peggy LeMone; NCAR; diurnal evolution of PBL as function of surface properties; structure and evolution of mesoscale convective systems as function of environmental conditions.

Patsy Taylor; University of Wyoming; social organization of research organizations.

Veronica Vaida; University of Colorado; education development and atmospheric chemistry.

Edward Zipser; Texas A&M University;

GTP Visitors:

Michael Borgas; Georgia Institute of Technology

John Cocke; University of Arizona

James Edson; Woods Hole Oceanographic Institute

Rod Frehlich; University of Colorado

David Galloway; University of Sydney, Australia

Lien Hua; University of California at Santa Cruz & IFREMER

Julian Hunt; Arizona State University

Andrew Majda; New York University

Jay Palmer; NOAA-ETL

Michael Spector; unaffiliated

Esteban Tabak; New York University

Samuel Vainshtein; University of Chicago

Volker Wulfmeyer; Max-Planck-Institute for Aeronomy, Germany

Mohammed Ziane; Stanford University

Hurricanes at Landfall Colloquium Participants:

Dorte Aller, ParnerRe, Zurich, Switzerland

Eyad Atallah, SUNY at Albany

Paul Bogner, University of Hawaii

W. Edward Bracken, SUNY at Albany

Joseph Parks Camp, Colorado State University

Daniel J. Cecil, Texas A&M University

Jennifer Collins, University College London, England

Mark Croxford, University of Hawaii

Sytske Drury, Penn State University

Jason Dunion, University of Wisconsin-Madison

Matthew Eastin, Colorado State University

Luis Farfan-Molina, University of Arizona

Rita Hausmann, Ludwig-Maximillians-Univ. Muenchen, Germany

Bob Hart, Penn State University

Christopher Hennon, Ohio State University

S. Daniel Jacob, University of Miami

Todd Kimberlain, Colorado State University

Sharan Majumdar, Penn State University

David Miller, EQECAT Insurance Co., California

Rebecca Morss, MIT

Shirley Murillo, Florida State University

Shangyao Nong, MIT

Kevin Petty, NCAR

Gregory A. Postel, University of Wisconsin-Madison

Ioannis Pytharoulis, University of Reading, U.K.

Paul Reasor, Colorado State University

Frank Roberts, University College London, England

Robert Rogers, Penn State University

Douglas Schneider, North Carolina State University

John Schroeder, Texas Tech.

Holly Snell, Colorado State University

Lecturers:

Peter Black, NOAA/HRD

Lance Bosart, SUNY at Albany

Otis Brown, University of Miami

Harold Cole, NCAR/ATD

Russell Elsberry, Naval Postgraduate School

Bob Gall, NCAR/MMM

Isaac Ginis, University of Rhode Island

William Gray, Colorado State University

Peter Hildebrand, NCAR/ATD

Samuel Houston, NOAA/OAR

Jerry Jarrell, NOAA/NWS

Frank Marks, NOAA/AOML

Colin McAdie, NOAA/NWS

Eugene McCaul, NASA

John Molinari, SUNY at Albany

Michael Montgomery, Colorado State University

Roger A. Pielke, Jr., NCAR/ESIG

Mark Powell, NOAA/OAR

Edward N. Rappaport, NOAA/NWS

Wayne Schubert, Colorado State University

David Sharp, NOAA/NWS

Nick Shay, University of Miami

Robert Tuleya, NOAA/OAR

Hugh Willoughby, AOML/NOAA

Participants of Developments in Geophysical Turbulence Workshop (GTP-hosted)
Coordinators:

Ken Gage, NOAA

Robert Kerr, NCAR

Yoshifumi Kimura, Nagoya University, Japan

Olivier Metais, LEGI/IMG, France

H. Keith Moffatt, Isaac Newton Inst. for Mathematical Sciences, U.K.

Harvey Segur, University of Colorado

Joseph Tribbia, NCAR

Stewart Turner, Australian National University, Australia

Lecturers:

Marion Bonnier, Meteo-France (CNRM), France

Robert E. Breidenthal, University of Washington

Ian Castro, University of Surrey, U.K.

P.C. Chatwin, University of Sheffield, U.K.

Olivier Eiff, Meteo-France, France

M. H. Joe Fernando, Arizona State University

Adam Fincham, LEGI-CNRS, Coriolis, France

Peter Flohr, University of Cambridge, U.K.

John Gibbon, Imperial College of Science, U.K.

Ross Griffith, Australian National University, Australia

Yoshi-Yuki Hayashi, Hokkaido University, Japan

Jackson R. Herring, NCAR

Kiyosi Horiuti, Tokyo Institute of Technology, Japan

Bach Lien Hua, IFREMER, France

Shigeo Kida, Natinal institue for Fusion Science, Japan

John Koshyk, University of Toronto, Canada

Cecil E. Leith, Jr., Lawrence Livermore National Lab.

Marcel Lesieur, LEGI-IMG, France

Doug Lilly, University of Oklahoma

Andrew Majda, New York University

James McWilliams, University of California, Los Angeles

Takeshi Miyazaki, Univ. of Electro-Communications, Japan

Koji Ohkitani, Kyoto University, Japan

W.R. Peltier, University of Toronto, Canada

S. David Porter, University of Minnesota

Annick Pouquet, CNRS U.M.R., France

J.M. Prusa, Iowa State University

Peter Rhines, University of Washington

Eileen Saiki, NCAR

Johannes Sander, University Bern, Switzerland

Alberto Scotti, Woods Hole Oceanographic Institution

Donald Slinn, Oregon State University

Chantal Staquet, Lab. des Ecoul. Geophys. & Indust., France

Bjorn Stevens, NCAR

Harry Swinney, University of Texas

Mamoru Tanahashi, Tokyo Institute of Technology, Japan

Tomomasa Tatsumi, International Institute for Advanced Studies, Japan

Arkady Tsinober, Tel-Aviv University, Israel

Zheng-Tong Xie, Chinese Academy of Sciences, China

Participants:

Yakov Afanassyev, University of Toronto, Canada

Dinshaw Balsara, University of Illinois

Olus Boratav, Cornell University

Aline Cotel, University of Manitoba, Canada

William Dannevik, Lawrence Livermore National Lab

Peter Diamessis, University of California, San Diego

Donald Eliason, Lawrence Livermore National Lab

Pedro Embid, University of New Mexico

Evgeni Fedorovich, Univesity of Karlsruhe, Germany

Rod Frehlich, CIRES, University of Colorado

Peter Gilman, NCAR

Fabien Godeferd, Politecnico di Milano, Italy

David Gurarie, Case Western Reserve Univesity

Karl Gustafson, University of Colorado

William Hall, NCAR

James Hill, Iowa State University

Lou Howard, Florida State University

Yungyun Hu, University of Chicago

H. Mario Ierkic, University of Puerto Rico

O. Iida, Nagoya University, Japan

Kurt Keller, University of California, San Diego

Alan Kerstein, Sandia National Labs.

Shari Kimmel, University of Southern California

Branko Kosovic, University of Colorado

Guillaume Lapeyre, IFREMER, France

Vincent Larson, MIT

Marie-Pascale LeLong, Northwest Research Associates

Galina Levina, Institute of Continuous Media Mech., Russia

Jonathan Lilly, University of Washington

Hanli Liu, NCAR

Richard McLaughlin, University of North Carolina

Douglas Miller, Naval Postgraduate School

Keiki Nomura, University of California, San Diego

Yign Noh, Yonsei University, Korea

Yuji Ohya, Kyushu University, Japan

Olivier Pauluis, Princeton University

Raymond Shaw, Penn State University

Michael Shefter, New York University

Igor Sytine, University of Minnesota

Wendell Welch, NCAR

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Research Applications Program

Brant Foote

Director's Message

The work in the Research Applications Program is dedicated to the transfer of atmospheric research results into the domain of practical application by those who have to make weather-sensitive decisions in government agencies and the private sector. RAP began in 1982 with an emphasis on weather information related to aviation safety, and that emphasis continues to the present. The early windshear work has been followed, for example, by significant endeavors in the warning and prediction of icing conditions, thunderstorm activity, quantitative detection and forecasts of snowfall and freezing drizzle affecting aircraft operations on the ground at airports, and several aspects of atmospheric turbulence. Significant progress has been made in these areas. Successful technology transfers have been accomplished varying all the way from simple education and training, through transfer of advanced weather products to operational agencies, to the delivery of complete, turn-key systems.

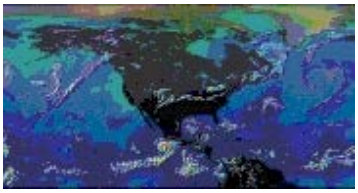
Aviation is only one of a number of sectors of the economy, though, where accurate and timely weather information can play a key role in the safety and efficiency of commerce and the daily activity of humans. Using the same methods of nowcasting, remote sensing, fine-scale numerical modeling, and development of expert systems that have been employed for aviation, RAP is currently pursuing applications in hydrometeorology and public weather forecasts. Applications to surface transportation are underway, and in the future RAP plans to explore the needs of other weather-sensitive areas of the economy such as agriculture and energy.

The RAP staff of scientists and engineers work in close collaboration with universities, government laboratories, and other divisions of NCAR, particularly the Mesoscale and Microscale Meteorology Division and the Atmospheric Technology Division.

The following report summarizes the scientific work undertaken in pursuit of RAPs technology transfer mission. Of equal importance to our overall endeavor, but largely not covered here, is the work accomplished with end-users regarding requirement specification, education, and training, and the engineering developments necessary to actually transfer a capability.

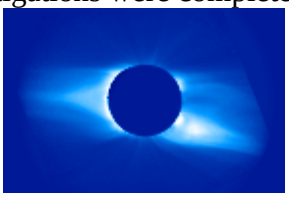
UCAR NCAR National Science Foundation

NCAR's FY1998 Science Highlights


A selection of scientific results from FY1998. Please refer to the individual divisions for additional research results and findings.

ACD	ASP	HAO	MMM	CGD
SCD	ATD	RAP	ESIG	Education

High Altitude Observatory

- On February 26, 1998, HAO continued its long history of coronal science at total eclipse with both ground-based observations at Curacao and, in collaboration with several other institutions, observations from an NCAR aircraft. At Curacao, two investigations were completed. The POISE-98 (POlarimetric Instrument for Solar Eclipse-98) recorded a white-light image  with very high photometric and polarimetric precision. The other Curacao experiment, Photometric Eclipse Polar Plume Imager (PEPPI) was optimized to achieve both high angular resolution and low noise images of the corona during the brief 3.5 minutes of totality. The goal of this experiment was to look for changes in the corona which might provide clues to the heating of the corona and the acceleration of the solar wind. A team of scientists led by R. MacQueen (Rhodes College) worked with the ATD division of NCAR to obtain unique observations of the corona at infrared wavelengths, from an airborne platform (the NCAR C-130 aircraft) over the Pacific, during the 26 February 1998 total solar eclipse. Phil Judge worked with Jeff Kuhn and Haosheng Lin (National Solar Observatory) to detect for the first time a potentially strong coronal line of Si IX at 3.934 microns. The effort was successful- the Si IX line- predicted by Judge in a theoretical article in 1998 was positively detected, and analysis of the data indicate that this line offers great potential as a diagnostic of the coronal magnetic field strength.

- A detailed analysis of SUMER full-disk observations (1) and (2) obtained by a 30 hour rastering of the 300 arcsec spectrograph slit, has revealed exciting and largely unanticipated information about the net radial motions of transition region and low coronal plasmas. The results, obtained by Hardi Peter (Visitor, Max-Planck-Institut für Aeronomie), reproduce the well-known net disk-center redshift (downflow) of 6 km/sec in the 154.8 nm C IV line which forms at a temperature of 105 K. On the other hand, the same analysis techniques when applied to the 77.0 nm Ne VIII line, which forms at a higher temperature of 6.5 x 105 K, indicate a disk-center blueshift (upflow) velocity of 2 km/sec. This finding has profound implications for our understanding of momentum and energy transport across the boundary that separates chromospheric from coronal material, and it lays to rest a great deal of uncertainty and speculation about the net motion of upper transition region material. From his analysis, Peter also demonstrated that the nonthermal line widths of these emission lines decrease from the Sun center to the solar limb, suggesting that the unresolved macroturbulent motion are anisotropic in the sense that horizontal motions are suppressed relative to those aligned with the local radial direction.

Climate and Global Dynamics Division

- The first Climate System Model (CSM) simulation of the 20th century climate was completed by Byron Boville (CSM Co-chair) and the Chemistry and Climate Working Group. The globally averaged temperature increases by about 0.6 K between the late 19th century and the 1990s, with most of the increase occuring since 1970, in agreement with observations.

- Frank Bryan (Oceanography Section, OS) and Rick Smith (visitor, Los Alamos National Laboratory, LANL) have demonstrated that a resolution of 10 km or smaller is necessary to resolve adequately mesoscale eddies in a numerical model of the North Atlantic Ocean.

Atmospheric Chemistry Division

- Air samples collected in different parts of the world during several field campaigns (NARE-97, SONEX, GASEX-98, Polar Sunrise Experiment 98, FIRETRAC, WiFE) have been analyzed in the laboratory, providing mixing ratios of about 70 chemical species including chlorofluorocarbons and other halogenated organic compounds. The analysis and interpretation of these measurements and of observations made during previous campaigns (e.g, STRAT, STERAO, PEM-Tropics, and POLARIS) have provided new information on the distributions and budgets of a variety of chemical species as well as on the chemistry and transport processes in the upper troposphere/lower stratosphere at different timescales.
- The HANK regional nested chemical-transport model of the troposphere was completed and used to extensively analyze model runs performed for the Pacific Basin in conjunction with the NCAR-led MLOPEX field campaigns. Version 1 of the NCAR MOZART global chemical transport model of the troposphere was completed, validated, and released to the scientific community. The model was used to determine changes in the chemical composition of the troposphere since the pre-industrial era and to assess the impact of human-induced perturbations including aircraft operations, fossil fuel combustion, and biomass burning.

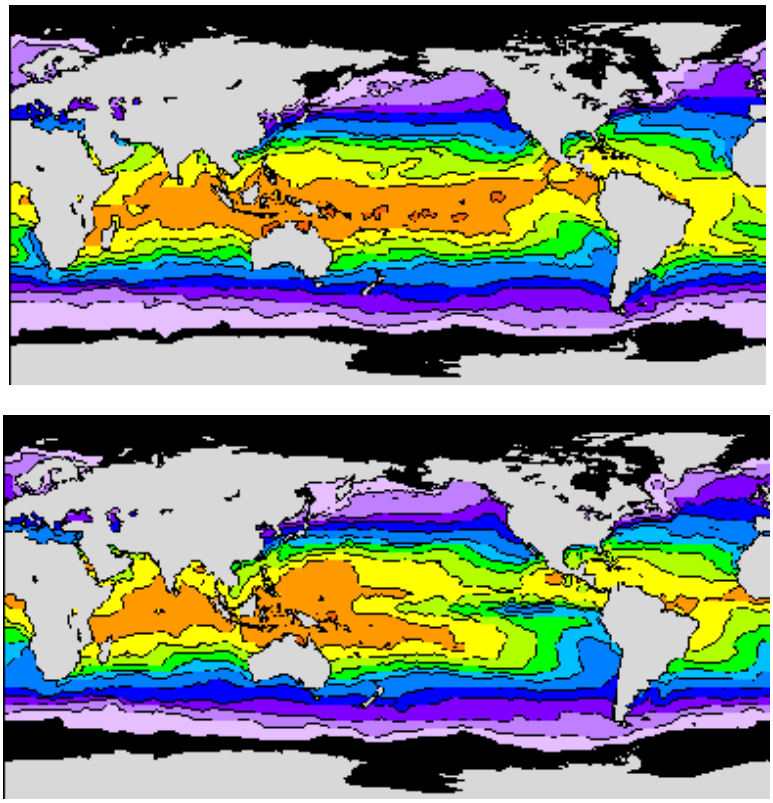
Scientific Computing Division

SCD's science highlights for FY1998 include upgrading the world's best atmospheric and oceanic datasets and enabling the steady flow of scientific insights through visualization technology.

- The NCEP/NCAR Global Atmospheric Reanalysis Project is an effort to reanalyze a long period of historical data using a single state-of-the-art atmospheric model. Artificial anomalies in the data time series can occur as the models evolve. Furthermore, under the time constraints, only rapidly available non-delayed data are used. The Reanalysis Project is a major effort designed to overcome these limitations in the operational analyses.

  This project is a cooperative effort between NCAR's Data Support Section (DSS) and the National Centers for Environmental Prediction (NCEP) of NOAA. The project goal is to reanalyze the previous 50 years of atmospheric data, and this was completed on July 23, 1998. The dataset provides output each six hours. The analyses are done at a resolution of T62 (208 Km) and 28 levels in the vertical. The project started in 1991, based on many earlier years of data gathering, model development, and related experience. This work and its extensions are also helping other reanalysis projects around the world.

Comparison of sea surface temperatures in the tropical oceans.



The top panel shows El Niño conditions at the ocean surface, and the bottom panel shows La Niña conditions. (Red indicates warmer water and blue cooler.) The Comprehensive Ocean-Atmosphere Data Set (COADS) and satellite data were combined to create these global views, courtesy of the Coupled Model Project at the National Meteorological Center.

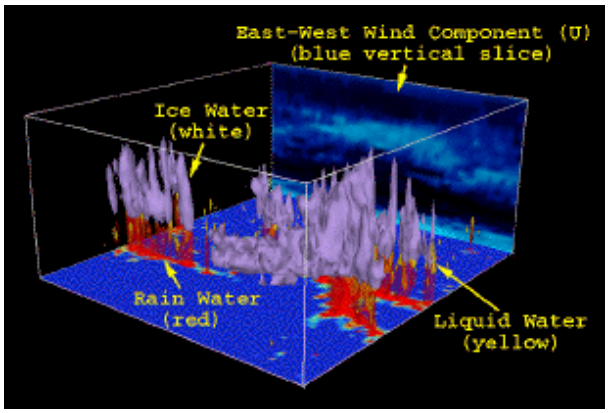
The Comprehensive Ocean-Atmosphere Data Set (COADS) has been created by combining, editing, and summarizing global in situ marine data from many different sources. Merchant ship observations back to 1854 have been supplemented in more recent years by automated measurements, e.g., from drifting and moored buoys. This project with other labs started in 1981 to expand and update the world's best surface ocean dataset. These data include temperature, pressure, wind, clouds, etc. They provide much of what the world knows about ocean surface temperature changes during the past 144 years.

- SCD's Visualization Group (VG) works to advance atmospheric and related science through state-of-the-art visualization. VG staff explore and develop new technologies that improve understanding of complex phenomena by making key processes visible. The intent of visual science is to use computers to supply the human brain with the kind of information that it uses best for exploration and understanding: visual input.

  The ability to explore and understand complex simulated and observed worlds will be of great importance not just to atmospheric science, but to all science. It will be vital to the researcher and formative to school children learning about physics or chemistry. Scientists will explore their world in ways they never could before; children will learn in ways we didn't imagine just a few years ago.

  Our simulations and our observational datasets grow larger and more complex by the day. And, as our computational capabilities continue to track the exponential curve, it may soon be the case that the primary limiting factor for research is not the technology, but the human. One must be able to digest the data and ask questions of it. There are many questions we can ask of these complex simulations -- many questions that in the past made no sense to ask or had no answer that could be easily conveyed. The Visualization Lab is aimed at helping to usher in this new era of visual science -- at providing the ability to freely explore vast dataspaces -- and produce materials that can communicate the results of such efforts to peers and public.

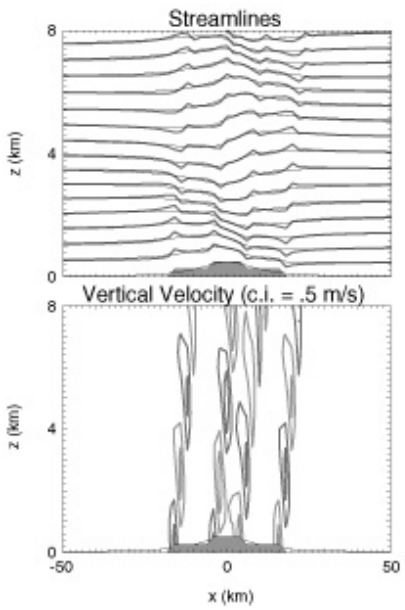
Cloud system evolution in the eastern tropical Atlantic.



This image (click for larger version) is composed of three isosurfaces and two 2D slices. The white isosurface represents a 0.5 g/kg ice water isovalue, the yellow isosurface represents a 0.5 g/kg liquid water isovalue, and the red isosurface represents a 0.5 g/kg rain water isovalue. The vertical slice at the rear of the model domain shows the east-west wind component (U), and the horizontal colored slice at the bottom of the domain shows contours of rain water at the surface. A Cloud Resolving Model was run using data from a unique 3D experiment performed during September 1-7, 1974, during Phase III of the Global Atmospheric Research Programme Atlantic Tropical Experiment (GATE). The visualization was generated using an NCAR stereo-enhanced version of Vis5D.

At present, we have well-developed capabilities and experience across the breadth of NCAR science. Extant visualization work encompasses climate, chemistry, ocean, mesoscale systems, forest fires, geophysical and astrophysical turbulence, clear air turbulence, tropical storms, and more. We have developed both interactive and production visualization environments that allow us to create and record both mono and stereo 3D visualizations of very large, very complex multivariate datasets. Highlights of our work in FY1998 are included in the Visualization Lab Research Gallery.

Mesoscale and Microscale Meteorology Division



Weather Research and Forecast (WRF) joint research and operational model: Joseph Klemp, William Skamarock, and Jimy Dudhia of the MMM Division continued to work on the development of the Weather Research and Forecast (WRF) joint research and operational model with colleagues from NCEP, NOAA/FSL, CAPS, and university scientists. Development includes a thorough analysis of treatment of the lower boundary in the vicinity of mountains (e.g., a stepped approach verses a terrain following formulation), minimization of pressure gradient force errors near steep mountains, exploration of various approaches to using only conservative quantities as prognostic variables, and examination of the advantages of a hybrid vertical coordinate where the information surfaces become isentropic surfaces away from the ground. In addition, a prototype framework is being developed that will allow easy portability of model code to a wide range of computing platforms including distributed shared memory machines as well as workstations and vector machines. Early prototypes of the WRF model will be available in calendar year 1999.

- **Development of cloud-resolving convection parameterization methods:** MMM Division scientists, Wojciech Grabowski and Piotr Smolarkiewicz, developed a method referred to as the cloud-resolving convection parameterization (CRCP) to explicitly represent the effects of tropical convection at large scales in climate models. The approach takes advantage of the nature of tropical convection in environments with significant shear that can often be described by two-dimensional processes. A two-dimensional cloud scale model is imbedded within each

column of a large-scale three-dimensional model where the large-scale model provides "ambient forcings" to the cloud scale model and the cloud scale model provides the convective response to the large-scale model. Initial tests are very promising.

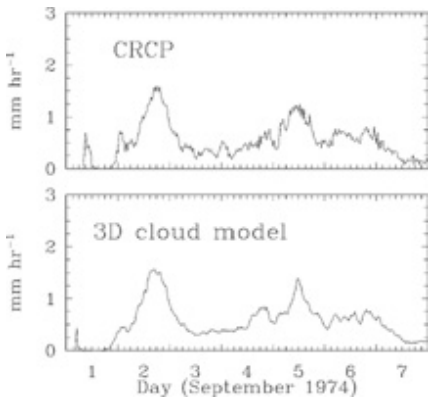


Figure 1. Hovmoeller (x-t) diagrams of the N-S (y) averaged surface precipitation rate from the 3-D cloud-resolving simulation and the simulation applying the cloud-resolving convection parameterization (CRCP). The CRCP simulation considers large-scale domain of 10 by 10 columns, each covering an area of 40 km by 40 km. Convection inside each column of the large-scale model is represented by a 2-D cloud-resolving model. The large-scale model is forced exactly as the 3-D cloud-resolving simulation. (Click on small figure above to see larger image).

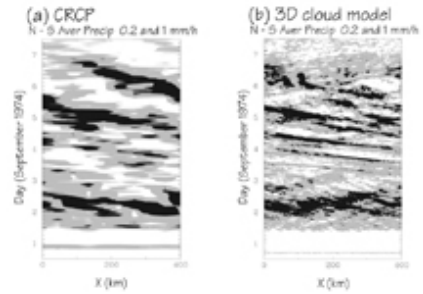


Figure 2. Evolution of the domain-averaged surface precipitation rate from the 3-D cloud-resolving simulation and the simulation applying the cloud-resolving convection parameterization (CRCP). (Click on small figure above to see larger image).

Research Applications Program

- The Auto-nowcastor system provides one-hour nowcasts of thunderstorms and strong winds and was originally developed under FAA funding. Demonstrations of the Auto-nowcastor system were held at: 1) Washington/Baltimore National Weather Service (NWS) Forecast office in Sterling, Virginia as part of the System for Convection Analysis and Nowcasting (SCAN), 2) the Army Forecast Offices at White Sands Missile Range in New Mexico, and 3) the Army Forecast Offices at the Aberdeen Proving Grounds in Maryland. In addition, a National Convective Weather Forecast (NCWF) product was demonstrated at the NWS Aviation Weather Center in Kansas City, MO, with products going to Delta, Northwest and Atlantic Coast Airlines. These efforts were sponsored by the FAA, Army, NWS/OSF and NSF under the U.S. Weather Research Program. The demonstrations were highly successful as indicated by the extensive use of the products by operational personnel. At the Sterling National Weather Service Forecast Office (WFO), forecasters utilized output from the Auto-nowcastor to assist them in issuing convective storm advisories and severe storm warnings. The Sterling WFO severe storm warnings for 1998 were far more accurate than any previous year, and they give partial credit to the Auto-nowcastor system for the improvement.
- The multi-parameter radar detection of precipitation type using fuzzy logic is a joint effort between RAP, ATD and NOAA scientists. The algorithm automatically determines precipitation types such as hail, snow pellets, ice pellets, snow, wet snow and dendrites using reflectivity, differential reflectivity, linear depolarization ratio, and differential phase measurements from S-band radars (10 cm wavelength). Because the values of the radar observables that delineate different particle types often overlap and are not sharply defined, a fuzzy logic approach is used. A real-time version of the algorithm was successfully demonstrated this past summer during the PRECIP 98 field program in Florida. Preliminary verification results for the algorithm indicate good skill, however, more verification is needed. Anticipated uses for the algorithm are to aid forecastors in determining the precipitation type, enable researchers to easily determine precipitation type to verify microphysical models, and to increase our knowledge of microphysical storm structure in general.

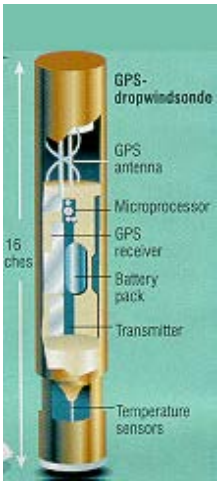
Atmospheric Technology Division

- Surface Heat Budget of the Arctic Ocean (SHEBA) The Surface Heat Budget of the Arctic Ocean (SHEBA) project was without any doubt one of the most challenging field projects ever supported by ATD staff and instrumentation. In early fall of 1997, SSSF engineers and technicians traveled to the SHEBA ice station about 300 miles north of Prudoe Bay to set up four of ATD's PAM -III stations and a GLASS system for a thirteen month period. The SSSF facilities were only a small part of a much larger array of observational instruments set up within a 62-mile radius of the SHEBA base station to measure a multitude of physical parameters for a full annual cycle. While the GLASS measured the standard meteorological measurements of wind, pressure, temperature, and humidity, the PAM-III stations measured additional parameters such as turbulent fluxes of momentum and heat, incoming and outgoing fluxes of long-wave and short-wave radiation, and the surface heat flux at the snow/ice boundary. The PAM-IIIs were heavily modified before going into the field to withstand the harsh Arctic conditions. Electrical power was produced with propane thermoelectric generators rather than solar panels, and the electronics were housed with the generators to prevent built-up of ice. GPS receivers and electronic compasses were used to continuously monitor station location and orientation, as well as to provide accurate time-keeping. The instruments had to be serviced regularly by ATD staff, who traveled in pairs on snowmobiles, carried rifles in case of polar bear encounters, and relied on survival suits, life jackets, coast guard ships and helicopters once the ice sheet had thinned during the summer months. The Canadian ice breaker "Les Grosseilliers", which was deliberately frozen into the sea ice, served as the base camp and sheltered approximately 50 scientists at the SHEBA ice camp.

  During May and July/August 1998, the NCAR C-130 and RAF and RSF staff conducted joint SHEBA operations out of Fairbanks, Alaska. ATD's Scanning Aerosol Backscatter Lidar (SABL), Airborne Imaging Microwave Radiometer (AIMR) and Multichannel Radiometer (MCR) were part of the aircraft's extensive instrumentation load. AIMR, a dual-channel (37 GHz and 90 GHz) dual-polarization microwave radiometer loaned to ATD by Canada's AES, records the characteristics of surface sea ice. MCR is a seven channel scanning radiometer originally built by NASA Goddard used to map surface emissions in visible and infrared portions of the electromagnetic spectrum. Both of these instruments underwent through significant modifications and upgrades before operations by ATD.

  In the end, the observational component of this $19.5 million project, jointly funded by the National Science Foundation, the Office of Naval Research and various international organizations, was a full success. The data collected will allow scientists to understand interactive processes involving mass changes of the sea ice, storage and retrieval of heat in the mixed layer of the ocean, and the influence of clouds on the surface energy balance. In the long run, results from SHEBA will help us better understand the role of high latitudes in global climate and assist in predicting future climate change and assessing the impact of global warming.

- 

GPS Dropsondes Development From a technology point of view, the development of the GPS dropsonde system was one of ATD's main highlights this year. In just over two years, the GPS dropsonde system has gone from a prototype developed within ATD to one of the most important observing system in atmospheric sciences. The GPS dropsonde system is now installed on 18 research aircraft within the U.S., Germany, and Canada and routinely used in hurricane reconnaissance and other research missions. The concept of the dropsonde seems to be simple: a sonde attached to a parachute is dropped from an aircraft and measures temperature, humidity, and pressure as it falls. From its position during descent, derived from the sonde's communication with the global navigation systems, winds are calculated. The actual development and deployment however is quite difficult. A dropsonde needs to provide laboratory-quality data in an inexpensive package that one can safely toss out of an airplane moving at greater than 100 meters per second. Faced with this challenge, ATD's dropsonde development team combined new sensor and GPS technology from Vaisala with a completely new structural, electronic, and transmission system of their own design. In each and every application, the GPS dropsonde has provided order-of-magnitude improvements in the quality of data and reliability of operation over previous systems. The vertical resolution for wind-speed measurements has increased nearly a hundredfold. As Hurricane Guillermo raged across the Pacific in August 1997, the sondes helped provide the first-ever high-resolution data on hurricane eyewall structure.

This spring, ATD helped equip nine Air Force WC-130s that carry out routine reconnaissance flights for tracking tropical cyclones.

ATD also improved the accuracy and range of the pressure, temperature, and humidity sensors; upgraded the electronics; and built a completely new in-flight processing system. Up to four sondes can now be launched and tracked as closely as 20 seconds apart. The success of this state-of-the-art instrument was widely noticed. Schematics and descriptions of the dropsonde showed up on the science and weather pages of newspapers and magazines across the country. NASA and NOAA proudly showed the dropsonde during their press conferences, and television stations ran video clips of weather officers launching the dropsondes from USAF C130s. Hurricane forecasters evaluated landfall models on the basis of how much dropsonde data their models assimilated. The user community praised the unprecedented high vertical resolution, excellent performance in bad weather and wind measurements were they counted the most, in the eye of a hurricane and near the surface.

Specifications for the GPS sonde were developed in collaboration with NOAA and the German Aerospace Research Establishment, both of which funded, with NCAR, the sonde's development. UCAR has licensed the technology to Vaisala for sonde manufacture since 1996.

Environmental and Societal Impacts Group

- La Niña Summit: Review of the Causes and Consequences of Cold Events

  This event was convened by Michael Glantz in Boulder, Colorado, from 15-17 July 1998. The purpose for convening such a meeting was to identify what is known, what is not known, and what societies need to know about cold events in order to forecast their onset, growth, and decay several months in advance and to prepare for their societal impacts. (The terms "La Niña" and "cold event" are used interchangeably.) An executive summary of the deliberations and presentations of the participants went on line in late September 1998 at http://www.dir.ucar.edu/esig/lanina/exec_summ.html. The full report has been on line since mid-October 1998. Both reports are available in hard copy. The workshop was supported by the United Nations University (Tokyo), NCAR, the UN Environment Programme (UNEP), and the NSF. The workshop was coordinated by an ESIG team led by D. Jan Stewart. Stewart was assisted by Baat Enosh (University of Colorado-Boulder), Ben Rasmussen (Carleton College), and Hanna Gilbert (University of Colorado-Boulder).

- Nested Regional Climate Change Scenario

  Linda Mearns, along with Larry McDaniel, Elena Tsvetsinskaya, Theo Mavromatis (with William Easterling at Penn State University and Cynthia Hays at the University of Nebraska), completed work on a four-year NIGEC (National Institute for Global Environmental Change) project, "Development of a Nested Regional Climate Change Scenario with an Application to Crop Models." The project involved regional climate modeling with RegCM2 by Filippo Giorgi and Christine Shields (CGD), detailed climate model evaluation, and application to crop models. Each stage of the work focused on some kind of uncertainty analysis: of (1) spatial scale of climate change, (2) the type of downscaling technique, (3) effect of scale differences on agricultural impacts, and (4) choice of impact model. Numerous publications have resulted from this work (see FY97 and FY98 publications).

  (1) A high-resolution climate change scenario (control and doubled carbon dioxide) was formed using the RegCM2 at 50 km grid point spacing of the western two-thirds of the United States. A coarse resolution scenario was formed from the output of the CSIRO general circulation model, which provided the boundary conditions for the regional model runs.

  (2) The climate change scenario from the regional model was compared with a semi-empirical downscaling (SDS) method. The comparison indicates that the climate changes in the RegCM2 are more pronounced than those of the SDS. Also, different directions of change in precipitation were found between the two methods.

  (3) We apply the two different scales of climate change scenarios to the EPIC corn, wheat, and soybean crop models for the GCM grid boxes in the central Great Plains. We found that the different scale scenarios produced

substantial differences in the impacts of climate change on these agricultural crops (see figures).

(4) We went on to compare the results from EPIC corn and wheat models for parts of the Great Plains with those of the CERES corn and wheat models. We found that the CERES model produced very different changes in yield from those of the EPIC model (see figures).

Advanced Study Program

- **The Thompson Lecture Series**
  A new series of visits and lectures was established to foster interaction between prominent scientists and the postdoctoral fellows and other junior scientists at NCAR. Three visitors were brought to NCAR under this program for meetings and discussions focussed on the research of the ASP postdoctoral fellows.

- **Geophysical Turbulence Program(GTP)**
  FY-98 was a busy year for GTP, which hosted two workshops and numerous scientific visitors.

  An international symposium on Developments in Geophysical Turbulence was sponsored by GTP, The International Union for Theoretical and Applied Mechanics, The International Association of Meteorology and Atmospheric Sciences of the International Union of Geodesy and Geophysics, and coordinated by Robert Kerr of NCAR and Yoshifumi Kimura of Nagoya University, Japan. Theworkshop brought together a broad spectrum of scientists to discuss turbulence modeling, statistics of small scales and coherent structures, convective turbulence, stratified turbulence, and historical developments.

  The second workshop on the topic of "Observations, Experiments and LES-A Triad for Geophysical Turbulence Studies" was hosted by GTP in August 1998 and coordinated by Donald Lenschow (MMM/ATD), Jackson Herring (MMM), Mary Barth (MMM/ACD), Chin-Hoh Moeng (MMM), Peter Sullivan (MMM), Bjorn Stevens (MMM), William Large (CGD) and Steve Oncley (ATD) locally as well as Robert Weller (WHOI), John Wyngaard (Penn State University), Bruce Albrecht (U. Miami), K. R. Sreenivasan (Yale), and Jim McWilliams (UCLA).

  In accordance with recent recommendations by the ASP review panel the university members of the organizing committee played a major role in planning and coordinating the workshop. Fifty-seven scientists representing 27 institutions from the U.S. and 3 other countries attended.

Educational Highlights

- Students from the states of Colorado and Wyoming entered 68 projects into the Colorado Computational Science Fair. Group and individual projects were submitted in the areas of Computational Science and Information Technology. Two computational science projects were sent to the national Adventures in Supercomputing Expo. The "Recursive Topographic Cost Analysis Project" from George Washington High School in Denver took first place in the Advanced Mathematics Category.

- Charlie Knight (MMM), Rajul Pandya (ASP) and Kevin Petty (ASP) were awarded the **1998 UCAR Outstanding Performance Award** for **Education** for their work in support of Project LEARN.

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Educational Activities

Education Overview

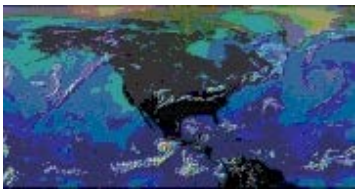
NCAR's educational activities include programs that reach groups at a variety of educational levels. Scientific visitor programs, graduate research assistantships, postdoctoral appointments, colloquia, seminars and workshops support university programs to educate the next generations of scientists, engineers, and scholars in general. Many of these programs are highlighted in division chapters elsewhere in this report. For example, the **Advanced Study Program** (ASP) provides students and graduates the opportunity to explore their educational and scientific interests in the laboratory setting. The Scientific Computing Division's (SCD) **Classroom Computing Grants** provide faculty and students access to high performance computing technologies in their classrooms. Another program, **Significant Opportunities for Atmospheric Research and Science (SOARS)** creates a pipeline for ethnically diverse college and university students to enter careers in the atmospheric and related sciences, including engineering, mathematics and the social sciences.

NCAR also places a high priority on K-12 educational outreach, as well as on other educational programs that increase public awareness and understanding of atmospheric science issues. Because climate, pollution, and the environment are part of the everyday awareness of young people, the atmospheric sciences offer an unusual opportunity to teach science in engaging, relevant ways. NCAR's **Education and Tour Program**, **Visual Communications** and **LEARN (Laboratory Experience in Atmospheric Research at NCAR)** help teachers exploit this opportunity as well as reach out to students and the general public. SCD's **Colorado Computational Science Fair** encourages high school students to utilize computing resources beyond the capabilities of secondary schools.

This chapter documents formally organized programs. In addition, individual staff throughout NCAR serve as graduate advisors or adjunct faculty at universities, make presentations to classes and public groups, write textbooks or textbook chapters, judge science fairs, or tutor elementary through secondary school students in math and science.

UCAR NCAR National Science Foundation

NCAR's Community Service Activities



ACD | ASP | ATD | CGD | ESIG | HAO | MMM | RAP | SCD

Atmospheric Chemistry Division

Editorships

Eric Apel received Editor's Citation Award for excellence in refereeing, Journal of Geophysical Research-Atmospheres.

Michael Coffey is an editor of Reviews of Geophysics.

Alex Guenther is an Associate Editor, Journal of Geophysical Research-Atmospheres.

Brian Ridley serves as the American editor of the Journal of Atmospheric Chemistry. He also received an Editor's Citation for Excellence in Refereeing from the Journal of Geophysical Research-Atmospheres.

External Scientific, Policy and Education Committees and Advisory Panels

Eric Apel is a member of the Science Team for the Southern Oxidants Study, a select group that provides scientific guidance for activities taking place within the SOS program.

Apel is co-convenor of the IGAC NOMHICE program.

Apel is a member of the NARSTO Observations Science Team and has provided input to the NARSTO QA/QC documents, and to the overview chapter on Atmospheric Measurements.

Alex Guenther is Leader of the NARSTO natural emissions assessment.

Alex Guenther serves as Director, IGAC Global Emissions Inventory Activity (GEIA) natural VOC project.

Lee Klinger, Vice-President, The Geophysiological Society, 1994-1997.

John Gille has been appointed by the Secretary General of WMO for another four year term to the Executive Committee Panel of Experts/Committee on Atmospheric Sciences Working Group on Environmental Pollution and Atmospheric Chemistry. This group serves as a scientific review committee for the Global Atmospheric Watch.

Gille continues to serve on the Science Steering Group of the Stratospheric Processes and their Role in Climate (SPARC) project. As part of this activity, he was co-organizer (with David Hofmann and Samuel Oltmans of NOAA) of a workshop held at NCAR on Water Vapor in the Upper Troposphere and Lower Stratosphere. He is also COSPAR representative to SPARC, and organized a session on SPARC at the COSPAR meeting in Nagoya this year.

Sasha Madronich participated in the 1998 Ozone Assessment process, by authoring or co-authoring several chapters in Scientific Assessment of the Ozone Layer: 1998.

Guy Brasseur, Chair, IGBP's International Global Atmospheric Chemistry Project (IGAC).

William Randel chairs the Stratospheric Reference Climatology committee of the WCRP SPARC project, in addition to serving on the Scientific Steering Group for the SPARC Stratospheric Temperature Trends Assessment. Additionally, Randel was a lead author for the SPARC Assessment of Trends in the Vertical Distribution of Ozone during 1996-98.

Randel is also chair of the American Geophysical Union Atmospheric Sciences Section Committee on Atmospheric Dynamics (since 1996), organizing a special session on stratospheric water vapor at the spring AGU meeting in Boston.

Randel participated in the 1998 UNEP/WMO Ozone Assessment by co-authoring two chapters (Stratospheric Temperature Trends and Lower Stratospheric Processes), in addition to being involved in the scientific review of this Assessment.

Advanced Study Program

Atmospheric Technology Division

Editorships

Dave Parsons, Editor, *Journal of Atmospheric Science*.

External Scientific, Policy, or Educational Committees and Advisory Panels

Charles Frush, Member, Optical Society of America (OSA).

Charles Frush, Member, The International Society for Optical Engineering (SPIE).

Charles Frush, Member, American Association for the Advancement of Science (AAAS).

Charles Frush, Member, Institute for Electrical and Electronic Engineering (IEEE).

Charles Frush, Member, Association for Computer Machinery (ACM).

Peter Hildebrand, Member, U.S. Science Steering Committee, Mesoscale Alpine Project (MAP).

Peter Hildebrand, Chair, AMS Radio Frequency Policy Statement Drafting Committee.

Peter Hildebrand, Member, AMS Committee on Radar Meteorology.

Steven Oncley, Member, Committee on Boundary Layers and Turbulence, American Meteorological Society.

David Parsons, Technical Advisor, Working group on Profilers, Office of the Federal Coordinator.

David Parsons, Chair, Review Panel for Mesoscale Processes, Severe Storms Monograph, American Meteorological Society.

David Parsons, Member, ARM Open Ocean Advisory Group.

Jeffrey Keeler, Member, NEXRAD Open RDA Advisory Panel.

Larry Radke, Chair, NASA FIRE Meeting.

Larry Radke, Chair, NASA Aerosol Program 1998 Workshop.

Larry Radke, Adjunct Professor, Atmospheric Sciences, University of Washington.

Larry Radke, Senior Research Associate, Graduate Faculty of Aerospace Engineering, University of Colorado.

Ron Ruth, Member, American Meteorological Society.

Tammy Weckworth, Chair, NCAR/NOAA Lower-Tropospheric Water Vapor Workshop.

Jim Wilson, Member, NOAA/NWS NEXRAD Technical Advisory Committee.

Jim Wilson, Chair, Review Panel for Severe Convective Systems Monograph.

Jim Wilson, Member, USWRP Quantitative Precipitation Forecasting Working Group.

Volker Wulfmeyer, Member, Working Group on Science and Data, GEWEX Global Water Vapor Project of the WMO.

Volker Wulfmeyer, Co-Chair, NCAR/NOAA Lower-Tropospheric Water Vapor Workshop.

Awards

Terry Hock, Hal Cole, Dean Lauritsen, Ken Norris, Ned Chamberlain, Errol Korn, and Chip Owens (all NCAR/ATD/SSSF) together with Jim Franklin, Alan Goldstein, and Jeff Smith (all NOAA), received the 1998 NCAR Technology Advancement Award for development of the Global Positioning System (GPS) Dropsonde System.

Lynn Russell (ASP/Princeton University), Don Lenschow (NCAR/MMM), and Krista Laursen (NCAR/ATD/RAF) received the 1998 NCAR Performance Award for Outstanding Publication for contributions to "Bidirectional mixing in an ACE-1 marine boundary layer overlain by a second turbulent layer", *Journal of Geophysical Research* 103, No. D13 (1998), 16,411-16,432.

Climate and Global Dynamics Division

Editorships

Gordon Bonan, Editor, *Journal of Climate*, 1998; Editor, *Climatic Change*, 1992; Editorial Advisory Board, *Global Change Biology*, 1994

Grant Branstator, Associate Editor, *Journal of the Atmospheric Sciences*, 1994

Clara Deser, Associate Editor, *Journal of Climate*, 1996

Scott Doney, Associate Editor, *Reviews of Geophysics*, 1997

Peter Gent, Associate Editor, *Journal of Physical Oceanography*, 1992

James Hack, Editor, *Journal of Climate*, 1998

Matthew Hecht, Associate Editor, *Monthly Weather Review*, 1998

Jeffrey Kiehl, Board of Reviewing Editors, *Science Magazine*, 1997

William Large, Associate Editor, *Journal of Physical Oceanography*, 1992

Ralph Milliff, Guest Editor, *Theoretical and Computational Fluid Dynamics*, 1998

Doug Nychka, Associate Editor, *Technometrics*, 1995

Bette Otto-Bliesner, Associated Editor, *Paleoclimates*, 1992

Philip Rasch, Editorial Panel Member, *Tellus*, 1992

David Schimel, Consulting Editor, *Biogeochemistry, Ecological Applications, Global Change Biology*, 1989

Kevin Trenberth, Editor, *Earth Interactions*, 1996-1998

Joseph Tribbia, Editor, *Journal of the Atmospheric Sciences*, 1993

Tom M. L. Wigley, Editorial Board, *Climate Dynamics*, 1994; *Global Climate Change Digest*, 1989; *Mitigation and Adaptation Strategies for Global Change*, 1995; Editorial Advisory Board, *Encyclopedia of Climate & Weather*, 1996

Robert L. Wilby, Review Editor, *Climate Research*, 1998

Scientific, Policy, or Education Committees and Advisory Panels

Maurice Blackmon, Member, Climate Research Committee, National Research Council, 1997; Chair, NCAR Climate System Model (CSM) Scientific Steering Committee, 1996; Chair, Board of Governors, Colorado Alliance for Science, 1995; Science Team Member, NASA's Clouds and the Earth's Radiant Energy System (CERES); Co-Chair, Scientific Working Group, Atlantic Climate Change Project, 1993; Chair, Working Group on Natural Variability, Model Validation and Climate Diagnostics, Climate System Modeling Program; Member, American Meteorology Society Committee on Climate Variations, 1991; Member, International Commission on Dynamical Meteorology; Member, IAMAP, Working Group D, Medium and Large-Scale Dynamics

Gordon Bonan, Co-Chair, CSM Land Modeling Working Group, 1996

Byron Boville, Co-Chair, Climate System Model (CSM) Project at NCAR, 1993; Member, IAMAS Commission on the Meteorology of the Upper Atmosphere, 1991; Member, IAMAS Commission on the Meteorology of the Upper Atmosphere (ICMUA) Working Group on Modeling of the Middle Atmosphere, 1988; Member, Organizing Committee for the NATO Advanced Study Institute on Climate Modeling, 1996; Member, CSM Scientific Steering Committee, 1996

Grant Branstator, Member, National Research Council’s U. S. Global Ocean-Atmosphere-Land System (GOALS) Panel, 1994

Frank Bryan, Member, CSM Scientific Steering Committee, 1998; Co-director, International Earth Rotation Service Sub-bureau for the Ocean, 1998

William Collins, Member, Earth Observing System (EOS) Validation Team, 1997; Member, Scanner for Radiation Budget (ScaRaB) Science Team, 1995; Member, Indian Ocean Experiment (INDOEX) Science Team, 1996

Clara Deser, Member, American Meteorology Society Committee on Climate Variations, 1994

Scott Doney, Member, U.S. JGOFS Steering Committee, 1993; Member, U.S. World Ocean Circulation Experiment (WOCE) Scientific Steering Committee, 1997; Co-chair, CSM Biogeochemistry Working Group, 1998

Ronald Errico, Member, Organizing Committee for 3rd Adjoint Workshop; Member, Organizing Committee for Workshop on Use of Satellite Observations in Data Assimilation

Peter Gent, Co-Chair, Climate System Model Project at NCAR, 1995; Co-chair, CSM Ocean Working Group, 1996; Member, CSM Scientific Steering Committee, 1996; Member, Working Group for Modeling and Prediction of the International Research Institute at Lamont-Doherty Earth Observatory and Scripps Institution of Oceanography, 1998

James Hack, Member, DOE Climate Change Prediction Program (CCPP) Science Team, 1991; Member, DOE Computational Science Graduate Fellowship Program Advisory Panel, 1990; Member, NASA FIRE-III Science Team, 1995; Member, DOE Atmospheric Radiation Measurements (ARM) Science Team, 1991; Co-Chair, CSM Atmospheric Modeling Working Group, 1997; Member, Oak Ridge National Laboratory Computer Science and Mathematics Division Advisory Committee, 1998

James Hurrell, Member, Great Plains Regional Center of the National Institute for Global Environmental Change, 1994; Member, Advisory Panel for NCEP CDAS/Reanalysis Project, 1994; Member, American Meteorology Society Committee on Meteorology and Oceanography of the Southern Hemisphere, 1995; Member, GPS/Meteorology Advisory Committee, 1995; Member, Atlantic Climate Change Advisory Committee, 1997; Co-chair, CSM Natural Variability Working Group, 1997; Member, National Research Council Panel on the Global Energy and Water Cycle Experiment, 1997; Member, U.S. CLIVAR Scientific Steering Committee, 1998

Jeffrey Kiehl, Member, International Global Aerosol Chemistry Committee on Aerosol Forcing, 1993; Member, DOE Atmospheric Radiation Measurements (ARM) Science Team, 1991; Co-Director, NSF Science and Technology Center for Clouds, Chemistry and Climate (C4), 1997; Chairman, General Circulation Model (GCM) Validation Working Group at the Center for Clouds, Chemistry and Climate (C4), 1994; Member, CSM Scientific Steering Committee, 1996; Co-Chair, CSM Chemistry and Climate Change Working Group, 1997; Member, Indian Ocean Experiment (INDOEX) International Scientific Steering Committee, 1996; Member, NCAR Aerosol Panel, 1997; Member, Climate Variability (CLIVAR) Scientific Steering Committee, 1998

Tim Kittel, Member, National Technical Advisory Committee; National Institute for Global Environmental Change (NIGEC), DOE, 1996; Member, National Science Foundation Long-Term Ecological Research (LTER) Program Climate Committee, 1990; Science Team Member, Vegetation/Ecosystem Modeling and Analysis Project, 1993; Member, Oak Ridge National Laboratory Distributed Active Archive Center User Working Group, 1997; Member, Central Great Plains Assessment Steering Committee; U.S. National Assessment of the Potential Consequences of Climate Variability and Change, 1998

William Large, Co-chairman of the International WOCE Science Steering Group, 1997; Member, NSF's Ocean-Atmosphere-Ice Interaction (OAII) Surface Heat Budget of the Arctic (SHEBA) Advisory Committee, 1996; Member, American Meteorology Society Committee on Southern Hemisphere Meteorology, 1997; Co-chair, CSM Polar Climate Working Group, 1998

Roland Madden, Member, Advisory Board for Meteorologische Zeitschrift, 1995; Member, NOAA/ERL Aeronomy Laboratory Review Committee, 1998

James C. McWilliams, Member, Scientific Advisory Council of NSF Climate Modeling, Prediction, and Analysis Program, 1990; Member, U.S. World Ocean Circulation Experiment (WOCE) Scientific Steering Committee, 1994; Member, MIT Corporation Visiting Committee for the Department of Earth, Atmospheric, and Planetary Sciences, 1995; Member, U.S. Ocean CLIVAR Planning Committee for NSF, 1995; Member, Jet Propulsion Laboratory Earth Science Advisory Council, 1997

Gerald Meehl, Member, Climate System Model Investigators Group, 1994; Member, Climate Simulation Laboratory (CSL) Allocation Panel, 1995; Visiting Senior Fellow, University of Hawaii Joint Institute for Marine and Atmospheric Research,

1995; Member, Climate Variability and Predictability Working Group on Coupled Models (CLIVAR WGCM), World Climate Research Programme, 1997; Member, Japan/U.S. Scientific Advisory Committee for the International Pacific Research Center, University of Hawaii, 1997; Chairman, Coupled Model Intercomparison Project (CMIP), 1996; Member, NRC Panel on Climate Observing Systems Status (PCOSS), 1998; Lead Author, IPCC Special Report on the Regional Impacts of Climate Change, 1997; Contributor, "Glossary of Meteorology," 1997; Coordinating Lead Author, IPCC Third Assessment Report, Chapter 9, Projections of Climate Change, 1998

Doug Nychka, Cascadia Tropospheric Ozone Peer Review Panel, 1997; Research Fellow, National Institute of Statistical Science

Bette Otto-Bliesner, Co-Chair, CSM Paleoclimate Working Group, 1996; Member, Paleoclimate Modeling Intercomparison Project (PMIP), 1995

Philip Rasch, Member, NSF Science and Technology Center for Clouds, Chemistry and Climate (C4), 1990; Co-Chair, Chemistry Modeling Group at the NSF Science and Technology Center for Clouds, and Climate (C4), 1994; Member, NCAR Aerosol Panel, 1997; Member, Coordinating Committee of the International Global Atmospheric Chemistry (IGAC) Project on Stratospheric and Upper Tropospheric Aerosols (SUTA), 1998

R. Saravanan, Member, NOAA Atlantic Climate Variability Advisory Panel, 1998

David Schimel, Member, Advisory Committee, Max-Planck Institute for Chemistry, 1997; Convening Lead Author, Intergovernmental Panel on Climate Change (IPCC) Report, 1994 and 1995; Visiting Member, Graduate Faculty, Texas A&M University; Member, U.S. National Academy Committee on Global Change Research; Member, National Research Council Committee on Global Change Research; Member, University of Colorado's Global Change and Environmental Quality Program Committee; Member, International Geosphere-Biosphere Program: Task Force on Global Analysis, Interpretation and Modeling; Member, U.S. National Academy Ecosystems Panel; Member, Governing Board, National Center for Ecological Synthesis and Analysis

Dennis Shea, Member, 7th International Meeting on Statistical Climatology, 1997; Member, 14th Conference on Probability and Statistics in the Atmospheric Sciences, 1997; Member, American Meteorology Society Probability and Statistics Committee, 1997

Starley Thompson, Smithsonian National Museum of Natural History, "Forces of Change" Exhibit, 1995; Member, Circumpolar Arctic Paleo Environments (CAPE) Steering Committee, 1995; Member, Project GLOBE Focus Group on Scientific Visualization, 1995; Member, Committee on Transportation and a Sustainable Environment, Transportation Research Board, National Research Council, 1994; Member, Committee on Global Environmental Change, American Geophysical Union, 1993; Member, Electorate Nominating Committee, Section on Atmospheric and Hydrospheric Sciences, American Association for the Advancement of Science, 1993; Member, National Science Foundation Paleoclimate of Arctic Lakes and Estuaries (PALE) Steering Committee, 1993; Member, Committee on Glaciology of the U.S. National Academy of Sciences Polar Research Board, 1988; Advisor, Atmospheric Sciences Guild of Sandia National Laboratory, 1992

Kevin Trenberth, Member, NOAA Panel on Climate and Global Change, 1987 and Executive Committee, 1991; Member, ECMWF Reanalysis (ERA) Project Advisory Group, 1993; Member, Climate Modeling, Analysis and Prediction (CMAP) Science Advisory Council, 1993; Member, Atmospheric Observation Panel for the Global Climate Observing System, 1994; Member, COLA (Center for Ocean-Land-Atmosphere Studies) Scientific Advisory Committee, 1994 and Chair, 1998; Member, Global Ocean-Atmosphere-Land System (GOALS) Panel, 1994; Member, International CLIVAR Scientific Steering Group, 1995, and Co-chair, 1996; Member, CSM Advisory Board, 1998; Member, NOAA Council on Long-term Monitoring, 1998; Member, Review Panel for NCEP Climate Prediction Center, 1998

Harry van Loon, Member, Solar Terrestrial Energy Program of ICSU, Working Group No. 5, and Project Leader, Solar Terrestrial Oscillation Project, 1995

Warren Washington, Member, National Science Board, 1995; Member, Secretary of Energy's Biological and Environmental Research Advisory Committee, 1990; Chair, Secretary of Energy's Health and Environmental Research Subcommittee on Biological and Environment Research Program in the U.S. Global Change Research Program, 1995; Member, Modernization Transition Committee of the National Weather Service, U.S. Department of Commerce, 1993; Past President,

American Meteorological Society, 1994; Member, Executive Committee, American Meteorological Society Council, 1995; Chair, Fellows Committee, American Meteorological Society, 1995; Member, Board on Sustainable Development, National Research Council, 1995; Member, Advisory Panel, National Centers for Environmental Prediction, 1995; Member, The National Committee, American Association for the Advancement of Science Center for Science and Engineering, 1994; Member, National Science Board Programs and Plans Committees: CPP Task Force on the Environment; CPP Task Force on Polar Issues; and Chair, Merit Review Criteria Task Force, 1996; Member, NASA Earth Systems Science and Applications Advisory Committee (ESSAAC), 1998; Member, Board of Trustees of the Bermuda Biological Station for Research, 1998; Member, Executive Committee, National Science Board, 1998; Member, NOAA Science Advisory Board, 1998; Member, American Meteorological Society, History of the Atmospheric Sciences Committee, 1999

Tom M. L. Wigley, Member, United Nations Environment Program (UNEP) Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF), 1995; Member, Climate and Paleoclimate Committee, 1996; Member, NCAR Aerosols Project (NAP) Steering Committee, 1997

David Williamson, Member, CAS/JSC Working Group for Numerical Experimentation (WGNE), 1991; Member, DOE Climate Change Prediction Program (CCPP) Science Team, 1991; Chairman, NSF/NCEP Workshop on Global Weather and Climate Modeling, 1998; Member, Atmospheric Modeling Intercomparison Project, 1996

Professional Society Memberships

Thomas Bettge, American Meteorological Society

Maurice Blackmon, American Meteorological Society

David Blankinship, American Meteorological Society

Gordon Bonan, American Geophysical Union

Byron Boville, American Geophysical Union; American Meteorological Society; Canadian Meteorological and Oceanographic Society

Esther Brady, American Geophysical Union; The Oceanography Society

Frank Bryan, American Meteorological Society; American Geophysical Union; The Oceanography Society

William Collins, American Geophysical Union; American Meteorological Society; American Physical Society; American Association for the Advancement of Science

Clara Deser, American Geophysical Union; American Meteorological Society

Scott Doney, American Geophysical Union; The Oceanography Society

Benjamin Felzer, American Geophysical Union; American Meteorological Society; Geological Society of America; Society of Sigma Xi

Aime Fournier, American Meteorological Society; Union of Concerned Scientists

Peter Gent, American Meteorological Society; American Geophysical Union

James Hack, American Meteorological Society

Matthew Hecht, American Meteorological Society; American Geophysical Union

Tim Hoar, American Statistical Association; American Meteorological Society; American Geophysical Union

James Hurrell, American Meteorological Society; American Geophysical Union

Akira Kasahara, American Meteorological Society (Fellow); American Association for the Advancement of Science (Fellow); American Geophysical Union; Meteorological Society of Japan (Honorary Member); Sigma Xi

Jeffrey Kiehl, American Geophysical Union; American Meteorological Society

Timothy Kittel, American Geophysical Union; American Meteorological Society; Ecological Society of America; International Association for Vegetation Science

Erik Kluzek, European Geophysical Society

Roland Madden, American Meteorological Society

Gerald Meehl, American Meteorological Society; American Geophysical Union; Pacific Science Association

Ralph Milliff, American Meteorological Society; American Geophysical Union; The Oceanography Society

Philippe Naveau, American Statistical Association; Institute for Mathematical Statistics

Douglas Nychka, American Statistical Association; Institute for Mathematical Statistics

Bette Otto-Bliesner, American Association for the Advancement of Science; American Geophysical Union; American Meteorological Society; Geological Society of America; New York Academy of Sciences

Philip Rasch, American Meteorological Society

David Schimel, American Geophysical Union; Ecological Society of America

Dennis Shea, American Meteorological Society

Christine Shields, American Meteorological Society

Gary Sneddon, American Statistical Association; Statistical Society of Canada

Claudia Tebaldi, American Statistical Association

Starley Thompson, American Association for the Advancement of Science; American Geophysical Union; American Meteorological Society

Kevin Trenberth, American Meteorological Society; American Association for the Advancement of Science; Royal Meteorological Society of New Zealand; American Geophysical Union

Warren Washington, American Association for the Advancement of Science; American Geophysical Union; American Meteorological Society

John Weatherly, American Geophysical Union

Tom M. L. Wigley, American Association for the Advancement of Science; American Geophysical Union

Robert L. Wilby, British Hydrological Society; American Geophysical Union; International Association of Hydrological Sciences; Air and Waste Management Association

David Williamson, American Meteorological Society

Honors and Awards

James Hurrell, NCAR's Outstanding Publication Award, 1997

Akira Kasahara, Honorary Member, Meteorological Society of Japan

William Large, NASA Group Achievement Award as a member of the NSCAT Science Team

Ralph Milliff, NASA Group Achievement Award as a member of the NSCAT Science Team

Warren Washington, Sigma Xi Distinguished Lecturer, 1998-1999; UCAR Walter Orr Roberts Distinguished Lecturer, 1998

Tom M. L. Wigley, 1997 Outstanding Scientific Paper Award, NOAA, Environmental Research Laboratories; 1998 Norbert Gerbier-MUMM International Award

Environmental and Societal Impacts Group

Editorships of Peer-Reviewed Journals

- Michael Glantz, Editorial Board, *Global Environmental Change* (1990-present).
- Michael Glantz, Editorial Board, *Colorado Journal of International Environmental Law* (1989-present).
- Michael Glantz, Editorial Board, *Reports to the Nation* (1997-present).
- Richard Katz, Editorial Board, *Extremes: Statistical Theory and Applications in Science, Engineering and Economics*.
- Richard Katz, Editorial Board, *Climatic Change* (1985-present).
- Linda Mearns, Editorial Board, *Climatic Change* (1990-present).
- Linda Mearns, Editorial Board, *Climate Research* (1989-present).

Scientific, Policy, or Educational Committees, Advisory Panels, Boards

- John Firor, Fellow of the American Meteorological Society (AMS).
- John Firor, Fellow, American Association for the Advancement of Science (AAAS).
- John Firor, Scientific Advisory Committee, Winslow Foundation, 1991-present.
- John Firor, Advisory Board, Natural Resources Law Center, University of Colorado, 1998-present.
- John Firor, Trustee, Environmental Defense Fund, 1974-present. Chair, 1975-80.
- John Firor, Trustee, World Resources Institute, 1982-present. Vice-Chair, 1994-present.
- Michael Glantz, UNU (United Nations University) Project Coordinator, Socioeconomic Impacts of El Niño, 1998-2002.
- Michael Glantz, Advisory Board, Global Terrestrial Observing System (GTOS) of the FAO/UNEP/WMO/ICSU, June 1996-present.
- Michael Glantz, Member of Inter-Agency Task Force On El Niño for IDNDR (International Decade for Natural

Disaster Reduction), 1998.

- Michael Glantz, Organizing Committee for Workshop on Global Change and Protected Areas, to be held September 1999 in Abruzzo, Italy.
- Michael Glantz, Nominated Expert in support of the UN Framework Convention on Climate Change (UNFCCC), January 1997-present.
- Michael Glantz, US Representative, Trade Convergency Climate Complex International Network (TC3Net). Also on Regional Coordinating Committee of TC3Net, January 1997-present.
- Michael Glantz, Advisor, Indochina Global Change Network (IGCN), 1997-2000.
- Michael Glantz, Member of Environmental Literacy Council, a program focusing on environmental education K-12, 1998.
- Michael Glantz, Member of the Scientific Advisory Panel, Southeast Asian Regional Committee for START (Global Change System for Analysis, Research and Training), 1996-present.
- Michael Glantz, Member of the Scientific Advisory Committee (SAC) for the World Climate Impact Assessment and Response Strategies Programme (WCIRP) of the UN Environment Programme, 1980-present.
- Michael Glantz, Steering Committee, Center for Environmental Journalism, University of Colorado, 1992-present.
- John Magistro, Committee Member of the Political Ecology Society Organization (PESO), 1995-present.
- John Magistro, Program Committee Member, 1999 Annual Meeting to be held in Tucson, Arizona, in April 1999, Society for Applied Anthropology, 1994-present
- Linda Mearns, Member, IPCC Task Force on Climate Change Scenarios, 1996-present.
- Linda Mearns, Member, NOAA Human Dimensions Program Proposal Review Panel, 1996-present.
- Linda Mearns, Member, NOAA/NASA Proposal Review Panel, 1995-present.
- Kathleen Miller, Member, National Academy of Sciences/National Research Council Panel on the Human Dimensions of Seasonal-to-Interannual Climate Variability, 1997-present.
- Kathleen Miller, Member, Steering Committee for the Southwest Region of the U.S. National Assessment Team, 1996-present.
- Kathleen Miller, Member, Oversight Committee, National Research Council Assessment of Future Roles, Challenges and Opportunities for the U.S. Geological Survey, 1996-present.
- Roger Pielke, Jr., Member, Committee on Societal Impacts, American Meteorological Society, 1996-present.
- Roger Pielke, Jr., Member, Panel on Risk, Vulnerability, and the True Costs of Coastal Hazards, The H. John Heinz III Center for Science, Economics, and the Environment, 1997-present.
- Roger Pielke, Jr., Member, Task Committee on Mitigating Hydrological Disasters, American Society of Civil Engineers, 1997-present.
- Roger Pielke, Jr., Member, Science Steering Committee, U.S. Weather Reserach Program, 1997-present.

High Altitude Observatory

Editorships of Peer Reviewed Journals

Paul Charbonneau was Guest Editor of *Theoretical and Computational Fluid Dynamics*, special issue on "Stratified and Rotating Turbulence," vol. 11, No. 3-4, 1998.

Peter A. Fox is an Associate Editor of *Fundamentals of Cosmic Physics*, 1993-present.

Thomas E. Holzer is an Associate Editor of *Journal of Geophysical Research*, Space Physics, 1995-1998.

Boon Chye Low is a member of the Board of Editors of *Solar Physics*, 1992-1998.

Arthur D. Richmond is an Associate Editor of *Journal of Geophysical Research*, Space Physics, 1997-2000.

Scientific, Policy, or Educational Committees and Advisory Panels or Boards

Thomas J. Bogdan is a member of the Solar Magnetism Initiative (SMI) Steering Committee, 1996-present.

Timothy M. Brown served on the Big Bear Solar Observatory Users Committee, 1997.

Timothy M. Brown serves on the NSO Users Committee, 1997-2000.

Barbara A. Emery serves on the Information Systems and Science Operations (ISSO) Management Operations Working Group (MOWG), NASA, 1997-present.

Barbara A. Emery is an ex-officio member of CEDAR Science Steering Committee, 1987-present.

Barbara A. Emery serves on the Ionosphere-Thermosphere-Mesosphere-Stratosphere Subgroup of the NASA Space Physics Data System (SPDS), 1994-present.

Peter A. Fox serves on the SunRISE Scientific Steering Committee, 1994-present.

Peter A. Fox is a member of the International Solar Cycle Studies (Scientific Committee on Solar Terrestrial Physics), Working Group 1, Subgroup 3, 1997-present.

Peter A. Fox is a member of the Distributed Oceanographic Data System (DODS) Technical Advisory Committee, 1997-present.

Peter A. Gilman serves on the Global Oscillations Network Group (GONG) Scientific Advisory Committee, 1985-present.

Peter A. Gilman serves on the SOLIS Advisory Committee, 1997-present.

Peter A. Gilman serves on the Solar Magnetism Initiative (SMI) Steering Committee, 1996-present.

Peter A. Gilman served on the Search Committee for the Director of the National Solar Observatory, 1997-1998.

Peter A. Gilman serves on the Council of the Solar Physics Division, American Astronomical Society, 1998-present.

Maura E. Hagan serves on the NASA/NRC Committee of Solar Terrestrial Research, 1996-1999.

Maura E. Hagan serves on the CEDAR Science Steering Committee, 1997-2000.

Maura E. Hagan is a co-chair of the Scientific Committee on Solar-Terrestrial Physics subgroup for Planetary Scale Mesopause Observing System (PSMOS), 1996-1997.

Thomas E. Holzer is a member of the Scientific Advisory Committee of the Max-Planck- Institut fur Aeronomie in Lindau, Germany, 1996-1999.

Michael T. F. Knoelker is a member of the Association of Universities for Research in Astronomy (AURA) Observatory Visiting Committee (OVC), 1996-present.

Michael T. F. Knoelker is a member of the Solar Magnetism Initiative (SMI) Steering Committee, 1995-present.

Michael T. F. Knoelker served as Chairman of the NCAR Search Committee for Director of the Environmental and Societal Impacts Group (ESIG), 1997-1998.

Michael T. F. Knoelker served on the NCAR Working Group on Emeritus Designation, 1998.

Michael T. F. Knoelker is a member of the Working Group on UCAR Outstanding performance Awards, 1998.

Bruce W. Lites is a member of the NASA Solar-B Science Definition Team, 1994-1997.

Bruce W. Lites is a member of the Solar Magnetism Initiative (SMI) Steering Committee, 1995-present.

Boon Chye Low is a member of the Solar Magnetism Initiative (SMI) Steering Committee, 1995-present.

Gang Lu is an Associate of the Center for Integrated Plasma Studies at the University of Colorado, 1996-present.

Keith B. MacGregor was Chairman of the Scientific Organizing Committee for the European Southern Observatory Workshop on Cyclical Variability in Stellar Winds, 1996-November 1997.

Keith B. MacGregor was a member of the NSF Stellar Astronomy and Astrophysics Program, Panel on Solar and Stellar Models, December 1997.

Keith B. MacGregor was a Member of the NASA Sun-Earth Connection Program Theory Review Panel, August 1998.

Arthur D. Richmond is a member of the Groupe International de Recherche en Geophysique Europe Afrique (GIRGEA), 1995-present.

Arthur D. Richmond is a member of the Science and Technology Definition Team for the NASA Global Electrodynamics Mission, 1998-present.

Raymond G. Roble serves on the Advisory Board at the Geophysical Institute at the University of Alaska, 1985-present.

Raymond G. Roble serves on the University of Michigan College of Engineering Alumni Society Board of Governors, 1996-present.

Steven Tomczyk is a member of the Global Oscillations Network Group (GONG) Data Management and Analysis Center Users Committee, 1995-present.

Oran R. (Dick) White serves on the SunRISE Precision Solar Photometric Telescope (PSPT) Steering Committee, 1992-present.

Oran R. (Dick) White serves on the NOAA Solar Prediction Panel, 1997-1999.

Awards

Arthur D. Richmond received Editor's Citation for Excellence in Refereeing, *Journal of Geophysical Research, Space Physics*, April 29, 1998.

Mesoscale and Microscale Meteorology Division

- Richard Carbone, Associate Editor, Journal of Applied Meteorology, 1987-present.
- Christopher Davis, Associate Editor, Monthly Weather Review, 1994-present.
- Andrew Heymsfield, Co-Editor, Atmospheric Research, 1990-present.
- Donald Lenschow, Editorial Board, Boundary-Layer Meteorology, 1996-1999; Editorial Board, Journal of Atmospheric Chemistry, 1994-present.
- Chin-Hoh Moeng, Associate Editor, Journal of Atmospheric Science, 1992-present.
- Mitchell Moncrieff, Associate Editor, Quarterly Journal of the Royal Meteorological Society, 1994-present.
- Piotr Smolarkiewicz, Associate Editor, Journal of Computational Physics, 1997-present; Editorial Board, Applied Mathematics and Computational Science, 1997-present.
- Stanley Trier, Associate Editor, Monthly Weather Review, 1998-present.
- Morris Weisman, Associate Editor, Monthly Weather Review, 1998-present.

Scientific, Policy and Education Committees and Advisory Panels

- Richard Carbone, convenor, Quantitative Precipitation Forecasting, IUGG, ICCP, UK, 1998-1999; chairman, WMO Commission on Atmospheric Sciences World Weather, 1998 - present; delegate, USA, WMO CAS, XII Session, Skopje, Macedonia, 1998; member, AMS Committee on Weather and Forecasting, 1998; member, National Academy of Sciences, NRC GEWEX Panel, 1997 - present; chairman, WMO CAS WWRP Interim Science Steering Committee, 1996 - 1998; member, USWRP Interagency Working Group, 1996 - present; member, NOAA/NAOS Test and Evaluation Working Group, 1996 - present; vice-chairman, NCEP Advisory Panel, 1996 - present; member, NOAA GCIP Core Project Review Panel, 1995 - present; chairman, USWRP Science Steering Committee, 1995 - present; chairman, WMO Commission for Atmospheric Science (CAS) Working Group on Short Range Prediction, 1994 - 1998.
- James Dye, member, Committee on Atmospheric and Space Electricity, 1996-2000; member, Science Team - NASA Marshall Lightning Measurements from Satellite, 1997- present.
- Robert Gall, member, External Review Panel, University of Oklahoma, 1998.
- Wojciech Grabowski, member, AMS Committee on Cloud Physics, 1995-1998.
- Vanda Grubisic, member, AMS Committee on Mountain Meteorology, 1998.
- Andrew Heymsfield, member, Global Energy and Water Cycle Experiment (GEWEX) Working Group 2, 1996-1998; member, Indian Ocean field Experiment (INDOEX) U.S. Scientific Steering Committee, 1996-1998; member, Tropical Rainfall Measuring Mission (TRMM) Science Team, 1998.
- Joseph Klemp, member, AMS Publications Committee, 1986-present; chair, AMS Information Systems Committee, 1995-present; member, Comparison of Mesoscale Prediction and Research Experiment (COMPARE) Planning Committee, 1990-1997.
- Margaret LeMone, member, Review Panel for Environmental Research Division, Argonne National Laboratory, 1998; member, U.S. Weather Research Program Scientific Steering Committee, 1997 to present.
- Donald Lenschow, member, AMS Committee on Laser Atmospheric Studies, 1997 to present

- Mitchell Moncrieff, External Review Panel for Cooperative Institute for Mesoscale Meteorological Studies (CIMMS), University of Oklahoma, October 1997; member, Climate Variability Program of the Global Energy and Water Cycle Experiment (CLIVAR/GEWEX) - COARE 98 Scientific Steering Committee; member, GEWEX Radiation Panel, St. Andrews, Scotland, August 1998; Atmospheric Radiation Measurement (ARM) Tropical Western Pacific Advisory Panel, 1993 to present; Maritime Continent Thunderstorm Experiment (MCTEX) Science Panel, 1993 to present; World Climate Research Program (WCRP)/Global Energy and Water Cycle Experiment (GEWEX) Science Steering Group, Rio de Janeiro, Brazil, February 1998.
- Jielun Sun, member, AMS Committee on Boundary Layers and Turbulence, 1998-2000.
- Morris Weisman, member, AMS Committee on Severe Local Storms, 1998-2000.

Awards

- Robert Gall, Invited Speaker, Special Session Honoring the Centennial of the Birth of Carl-Gustaf A. Rossby, 78th AMS Annual Meeting, Phoenix, AZ.
- Morris Weisman, Faculty Teaching Award, University of Washington, Department of Atmospheric Sciences.

Research Applications Program

Scientific Computing Division

Education

Aaron Andersen served as a scientific research mentor in the SOARS program.

Brian Bevirt served as a scientific writing mentor in the SOARS program. He also teaches Technical Writing as a service to the University of Colorado Division of Continuing Education.

Jeff Boote provided a morning session for the Project Learn activity on the use of new web technologies to convey scientific content.

Nancy Dawson served as a scientific writing mentor in the SOARS program.

Pete Peterson served as a community mentor in the SOARS program.

Tim Scheitlin participated in the Colorado Computational Science Fair in April, and presented six half-hour demos in the Visualization Lab for science fair attendees.

External Scientific, Policy or Educational Committees

Bill Buzbee, Ph.D, serves on the Minnesota Supercomputing Institute's External Advisory Board. He is a member of ACM, IEEE and the IEEE subcommittee on Supercomputing (SIAM), and the American Meteorological Society (AMS). He is also on the advisory board of RCI, Ltd., an international consortium of leading-edge users and vendors of High Performance Computing. He is listed in Who's Who in Science and Engineering and is currently listed in American Men and Women of

Science.

Ginger Caldwell served on the SC97 Education Program Committee for the SC97 conference held in San Jose, November 15-21, 1997. She is the SC98 Education Chair for SC98 held November 7-13, 1998 in Orlando. Plans include videoconferencing a special three-day session for teachers located in four states using video over IP technology. Over 150 educators will attend sessions in Orlando with over 100 educators in Illinois, Iowa, and North Carolina attending.

Susan Cross serves as Local Planning Committee Chair for the 20th Annual National Conference of the American Indian Science and Engineering Society. She also served as a judge for the 1997 Technical Art Competition conducted by the Rocky Mountain Chapter of the Society for Technical Communication.

Rachelle Daily serves as Secretary, Executive Board, IEEE Computer Society, Mass Storage Technical Committee.

Sally Haerer is President of the Cray User Group (CUG), an international organization focused on the effective usage of high-performance computing resources from Silicon Graphics, Inc. She chairs the organization's Board of Directors and Advisory Council. She is a member of the Parallel Tools Consortium (Ptools) Steering Committee, which works to make parallel tools more responsive to user needs. She assisted with the technical programs for the '97 and '98 annual meetings hosted at NCAR. Sally served as Research Exhibits Chair for the SC'97 Conference. She now serves on the SC'98 Tutorials Committee, charged with the review and selection of high-quality tutorials to be presented to conference attendees this November in Orlando. Additionally, she is on the SC'99 Executive Committee as Exhibits Coordinator. She oversees the planning of Industry Exhibits, Research Exhibits, Research Posters, the Exhibitor Forum, HPC Challenge, and Security for that conference.

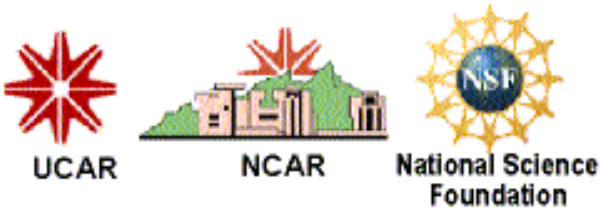
Steve Hammond, PhD, is a member of IEEE Computer Society and the IEEE Supercomputer Applications Excutive Committee. He is a member of Sigam Xi, the Scientific Research Society of North America. He is also a member of the SC98 Program Committee and the program committee for the Second International Workshop on Software Engineering and Code Design in Parallel Meteorological and Oceanographic Applications. He was co-organizer of the first Workshop of Climate, Ocean, and Weather Benchmarks. He also served as a scientific writing mentor in the SOARS program.

Roy Jenne serves as chair of the data exchange project under the US-Russia WG-VIII project. His memberships include the NRC Panel on the US co-op observing net of 8000 stations, the team for US Assessment Studies (for climate model archives), the data committee for GCIP (mesoscale model data), the EOSDIS Review Group (ERG) for NASA Earth Science Data Systems, and the study group for the new NASA EOSDIS.

Jeff Kuehn served as Chair of Performance and Evaluation SIG and Chair of Programming Environments SIG for the Cray User Group, where he is an Advisory Council Member. He also served as a Steering Committee Member for the Parallel Tools Consortium. For both of these groups, he assisted in arranging their annual meetings and managed their presence (booths) at the Supercomputing 97 conference.

Lynda Lester is the managing editor/photographer for CUG.log, the international newsletter of the Cray User Group (CUG), and secretary of the CUG Advisory Council. She managed the CUG booth at SC97, scheduling volunteers and working with Silicon Graphics Cray to produce visual materials and handouts. Lester helped produce the first of DIG's seminar series on "The Impact of the Internet on the World," working with Dr. William Moninger from NOAA who gave a presentation on "The Internet and the Relaxation of Structure."

Bernard T.O'Lear is a member of the IEEE Computer Society Mass Storage Systems Technical Committee Executive Committee. He was a member of the program committe for the combined Sixth NASA Goddard Conference on Mass Storage Systems and the 15th IEEE Symposium on Mass Storage Systems. He was co-chair with Bill Buzbee of the Computers in Atmospheric Sciences 98 (CAS98) meeting sponsored by SCD and four vendors in Annecy France, June 30 to July 2, 1998.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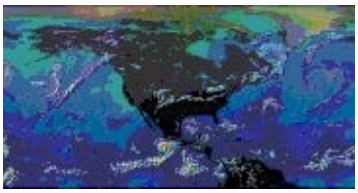

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ACD	ASP	ATD	CGD	ESIG	HAO	MMM	RAP	SCD

Atmospheric Chemistry Division

Refereed

* - *Indicates non-NCAR authors*

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*Berresheim, H., and F. Eisele, 1998: Sulfur chemistry in the Antarctic troposphere experiment: An overview of project SCATE. *J. Geophys. Res.*, **103**, 1619-1627.

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*****Bilde, M., T. Wallington*, C. Ferronato*, J. Orlando, G. Tyndall, E. Estupiñan, and S. Haberkorn, 1998: Atmospheric chemistry of CH2BrCl, CHBrCl2, CHBr2Cl, CF3CHBrCl, and CBr2Cl2. *J. Phys. Chem. A,* **102,** 1976-1986.

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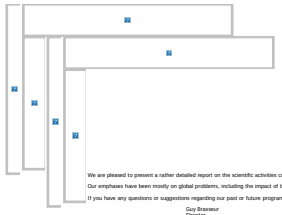


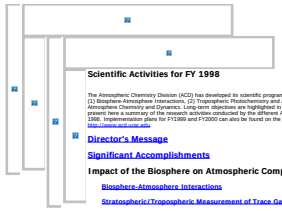
Director's Message

We are pleased to present a rather detailed report on the scientific activities conducted by a group of 120 staff and visitors within the Atmospheric Chemistry Division of NCAR. As we are trying to serve the scientific community in the US and abroad, many of the specific projects presented in this report have been completed as a result of close collaborations with colleagues in universities and national laboratories.

Our emphases have been mostly on global problems, including the impact of the biosphere on the chemical composition of the atmosphere, tropospheric photochemistry in remote or moderately polluted environments, as well as middle atmosphere chemistry and dynamics. Approaches have included laboratory investigations, field measurements, data analyses, and modeling. Our research contributes directly to the objectives of the Global Tropospheric Chemistry Program (GTCP) of the National Science Foundation, and to the goals of several international scientific projects including the International Global Atmospheric Chemistry (IGAC) project of IGBP, and the Stratospheric Processes and Their Role in Climate (SPARC) project of WCRP.

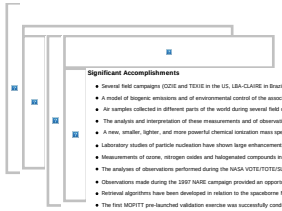
If you have any questions or suggestions regarding our past or future program, please do not hesitate to contact us. We hope very much to enhance our cooperation with other scientific groups, and to host a large number of scientific visitors to work on mutually beneficial projects.

Guy Brasseur
Director



Scientific Activities for FY 1998

The Atmospheric Chemistry Division (ACD) has developed its scientific program around a few major foci: (1) Biosphere-Atmosphere Interactions, (2) Tropospheric Photochemistry and Aerosols, and (3) Middle Atmosphere Chemistry and Dynamics. Long-term objectives are highlighted in the ACD Strategic Plan. We present here a summary of the research activities conducted by the different ACD projects during fiscal year 1998. Implementation plans for FY1999 and FY2000 can also be found on the ACD Web page http://www.acd.ucar.edu.



Significant Accomplishments

- Several field campaigns (OZIE and TEXIE in the US, LBA-CLAIRE in Brazil, VOC emissions in China, flux measurements in the Sierra Nevada and Rocky Mountains) and laboratory studies have been conducted to characterize the emissions of biogenic organic compounds in different environments and to assess processes controlling these emissions.
- A model of biogenic emissions and of environmental control of the associated fluxes has been developed to be coupled with regional and global chemical transport models of the atmosphere.
- Air samples collected in different parts of the world during several field campaigns (NARE-97, SONEX, GASEX-98, Polar Sunrise Experiment 98, FIRETRAC, WIFE) have been analyzed in the laboratory, providing mixing ratios of about 70 chemical species including chlorofluorocarbons and other halogenated organic compounds.
- The analysis and interpretation of these measurements and of observations made during previous campaigns (e.g. STRAT, STEARO, PEM-Tropics, and POLARIS) have provided new information on the distributions and budgets of a variety of chemical species as well as on the chemistry and transport processes in the upper troposphere/lower stratosphere at different timescales.
- A new, smaller, lighter, and more powerful chemical ionization mass spectrometer instrument has been developed, and is designed for the measurement of several chemical compounds (OH, H_2SO_4, MSA, NH_3, DMSO, $DMSO_2$, HO_2, RO_2, HNO_3, hydrocarbon oxidation products, etc.). This new aircraft measurement capability opens the door to more comprehensive studies of photochemistry, sulfur oxidation chemistry, and aerosol nucleation and growth in the atmosphere.
- Laboratory studies of particle nucleation have shown large enhancements (several orders of magnitude) in sulfuric acid/water nucleation in the presence of gas phase atmospheric ammonia.
- Measurements of ozone, nitrogen oxides and halogenated compounds in the Arctic suggest that the oxidizing capacity of the atmosphere is not always dominated by the hydroxyl radical, but that the presence of high levels of bromine and chlorine compounds are responsible for the dramatic destruction of ozone near the surface at high latitudes during springtime. The latest Polar Sunrise Experiment at Alert, Canada, in which several ACD scientists participated, has provided an opportunity for observing several ozone destruction episodes.
- The analyses of observations performed during the NASA VOTE/TOTE/SUCCESS programs have shown that in wave clouds, NO_y (presumably in the form of gaseous HNO_3) is rapidly depleted onto ice particles. The experiments also clearly demonstrated the importance of convection of boundary layer constituents on the upper troposphere and specifically on the photochemical ozone production.
- Observations made during the 1997 NARE campaign provided an opportunity to elucidate the mechanisms that control the transport of ozone and its precursors from North America to the Atlantic Ocean, and specifically to investigate the role of frontal passages in transporting boundary layer air to the upper troposphere. ACD has contributed to this IGAC-sponsored project by measuring formaldehyde and carbon monoxide from the NOAA P3 aircraft.
- Retrieval algorithms have been developed in relation to the spaceborne MOPITT instrument, which is expected to be launched in 1999. Computer simulations have shown that the required accuracy and precision expected from the algorithm will be achieved.
- The first MOPITT pre-launched validation exercise was successfully conducted at the DOE/CART site in Oklahoma. A data assimilation algorithm, using simulated MOPITT CO measurements was successfully completed, and will produce synoptic global CO maps as well as high resolution vertical profiles.
- The first generation products of the OH-initiated oxidation of several terpenes has been identified in the laboratory. Acetone, a key species in the generation of HO_x radicals in the free troposphere, was identified as a major product in the oxidation of terpinolene and myrcene.
- Measurements of the vibrational overtone spectrum of nitric acid shows that the corresponding absorption strengths are up to a factor 2 higher that previously assumed, suggesting that absorption of infrared light could affect the chemistry of the atmosphere (i.e., the production of OH) at low sun angles (e.g., at the edge of the polar vortex).
- As a service to the international scientific community, ACD continues to provide high quality VOC standards and state-of-the-art instrumentation which allows more accurate measurements needed for photooxidation studies. An instrument that allows for continuous measurements of methanol and formaldehyde, as well as an ion trap mass spectrometer are being developed.
- Test flights for the newly developed CO and N_2O tunable diode laser were conducted with the NASA WB57 high altitude aircraft.
- A high-resolution infrared spectrometer was tested at Thule, Greenland, and will be installed as part of the Network for Detection of Stratospheric Change.
- NCAR, in collaboration with the University of Colorado, Oxford University, and other partners, has continued to oversee the design, fabrication, testing, and calibration of the HIRDLS instrument, to be launched in year 2002.
- A coordinated effort has been performed to analyze observations by the Upper Atmosphere Research Satellite including aerosol distributions in the stratosphere, water vapor measurements in the vicinity of the tropopause, and other chemical constituents. Emphasis has been put on the quantification of trends in a variety of stratospheric chemical species and in the development of data assimilation techniques.
- Several ACD scientists contributed to the preparation of the WMO/UNEP Ozone Assessment report which will be published in 1999.
- ACD scientists are members of the science team in charge of the preparation of the TIMED space mission, which will investigate the dynamics, energetics, and chemistry of the mesosphere, lower thermosphere, and ionosphere.
- The HANK regional nested chemical-transport model of the troposphere was completed and used to extensively analyze model runs performed for the Pacific Basin in conjunction with the NCAR-led MLOPEX field campaigns.
- A global UV climatology at the Earth's surface, based on satellite observations of ozone and clouds, and using the NCAR TUV radiative model was generated.
- Version 1 of the NCAR MOZART global chemical transport model of the troposphere was completed, validated, and released to the scientific community. The model was used to determine changes in the chemical composition of the troposphere since the pre-industrial era and to assess the impact of human-induced perturbations including aircraft operations, fossil fuel combustion, and biomass burning.
- Detailed modeling of stratospheric ozone depletion, taking into account observed changes in aerosol loading, temperature, QBO and solar variability effects, as well as increasing levels of atmospheric chlorofluorocarbons was completed.

Stratospheric/Tropospheric Measurements of Trace Gases

The Stratospheric/Tropospheric Measurements (S/TM) project investigates the sources, budgets, distribution and variations of atmospheric trace gases, with particular emphasis on those species related to the ozone formation and destruction processes in both the troposphere and the stratosphere. An integral part of the program is to evaluate and develop state-of-the-art sampling and analytical facilities for trace gas measurement from different environments.

During this past year, S/TM participated in a number of field studies. The NARE 97 and SONEX studies focused on tropospheric chemistry over the northern Atlantic Ocean and the influence of outflow from the North American and European continents and aircraft emissions along the Atlantic flight corridor. Whole air sampling and analyses during NARE and SONEX were performed in collaboration with NOAA / York University and with the University of California at Irvine (UCI), respectively. Air samples were taken at several height levels above the surface over the Atlantic Ocean during the GASEX-98 cruise on board the NOAA RV Ron Brown to evaluate fluxes of trace gases from the ocean surface. Air samples were also collected by researchers from ACD, York University, and the Atmospheric Environment Service (Canada) at the surface at Alert, Canada (82°N) during the Polar Sunrise Experiment (PSE 98). Fire air samples were collected on Devon Island and on the Antarctic continent by researchers from the University of East Anglia (UEA) during the FIRETRAC campaign. Finally, air samples are being collected and analyzed by S/TM during the ongoing WIFE experiment headed by NOAA/ATD. All whole air samples are generally analyzed on four different instruments providing mixing ratios for about 70 different organic species including $CFCs$, $HCFCs$, $HFCs$, Halons and other halogenated species, methane and non-methane hydrocarbons and alkyl nitrates. This large suite of tracers encompasses a variety of different sources as well as individual atmospheric lifetimes from a few days to >100 years allows to obtain information on source regions and distributions as well as chemistry and transport processes on different timescales.

Emphasis was placed on the interpretation of data collected during four major field studies STRAT, STERAO, PEM-Tropics, and POLARIS, conducted in 1996 and 1997 (see 1997 annual report or click on the links for details on these field programs)

Instrument development and improvement efforts during the last year included the initial redesign of the NASA-ER2 whole air sampler to fit into it's new accommodation in the drop tank mounted underneath the aircraft. In addition, an automated inlet system for the unattended analysis of air from up to 12 canisters was developed and tested.

NARE 97: North Atlantic Regional Experiment

NARE is an international collaborative effort in the framework of the IGAC project and involves a large number of institutions and universities in North America and Europe. NARE focuses on the influence of continental outflow of anthropogenic and biogenic trace constituents on the atmospheric chemistry of the remote marine environment over the North Atlantic Ocean. Involvement of S/TM included the analysis of air samples collected during science flights on board the NOAA-WP3B by fellow researchers from York University. The WP3B operated out of St Johns, Newfoundland and conducted science flights along the east coastal regions of the US and Canada as well as over the north Atlantic Ocean in September and October 1997.

SONEX: SASS Ozone and Nitrogen Oxide Experiment

SONEX was a two aircraft mission sponsored by NASA with the primary objective to investigate the influence of the exhaust components of commercial aircraft on the chemistry of the upper troposphere and lower stratosphere over the North Atlantic Ocean. The experiment overlapped with NARE 97 as well as with the POLINAT study conducted by a number of European research groups. As previously for the 1996 PEM-Tropics study, S/TM performed analyses of selected whole air samples collected by the F. S. Rowland and Don Blake group (University of California, Irvine). Interpretation of the trace gas concentrations measured in the whole air samples collected during NARE and SONEX has just begun and will be used to derive diagnostic information on sources, transport processes, and photochemical processing in the North Atlantic atmosphere.

Some preliminary findings are: Alkyl nitrates, in general, demonstrated relationships with parent hydrocarbons that were consistent with sources from "normal" photochemical production. This behavior is different from that observed during the GTE PEM Tropics campaign in more remote marine regions, such as the tropical Pacific Ocean. During SONEX, the alkyl nitrates were a minor component of the NO_y budget. However, the contribution of alkyl nitrates to NO_y increased with decreasing NO_x and reached about 10%of NO_y when NO_y was in the range of 100-200 ppbv. The organic trace gases measured during NARE and SONEX showed complex distributions and relationships. Somewhat different relationships between hydrocarbon tracers were observed in the regions sampled during NARE and SONEX. A more comprehensive understanding of source regions and source signatures may be achieved by including a variety of halocarbons in the data analysis. The halocarbons which appeared most useful in distinguishing different source regions were dichloromethane and perchloroethylene. In addition, halocarbons with oceanic sources, such as methyl iodide and bromoform, demonstrate the influence of marine boundary layer air masses in the North Atlantic troposphere.

WIFE: The Wildfire Experiment

The Wildfire Experiment was designed to study the fine scale temperature and airflow structures within wildfires to enhance the capabilities of models used to describe and predict the behavior of wildfires. WIFE is a collaborative experiment that includes three NCAR divisions, the Mesoscale and Microscale Meteorology Division, the Atmospheric Technology Division, and the Atmospheric Chemistry Division as well as NASA Ames Research Center, the U.S. Forest Service's Rocky Mountain Research Station and Riverside Fire Research Laboratory. In collaboration with Hans Friedli, Verity Stroud collected whole air samples for analysis of biomass burning emissions from the fires. Of particular interest are the methyl halides, for which there is relatively little information on emissions from midlatitude forest fires. Initial results indicate exhaus-tmissions over background levels of methyl halides and alkyl nitrates. Measurements of CO_2 and CO collected during the flights will allow us to calculate emissions of various trace gases relative to CO_2 and CO emissions once the mission is completed.

FIRETRAC: Firn and Ice Record of Trace Atmospheric Chemistry

FIRETRAC is a collaborative effort between Stuart Penkett and Bill Sturges (University of East Anglia), glaciology groups in the United Kingdom, France, and Australia, and the S/TM group. Deep snow (firn)-overlying ice formed on high glaciers and ice sheets in the Arctic and Antarctic holds a record of air dating back several decades. The goal of FIRETRAC is to examine this air for indications of past atmospheric chemistry and composition. Firn air samples were collected from Canada and Antarctica and analyzed for halocarbons to evaluate recent trends and date the air; for natural reactive halocarbons capable of affecting radical halogen chemistry; for organosulphur gases; for hydrocarbons; and for alkyl nitrates as indicators of nitrate chemistry. Preliminary results show expected changes in mixing ratios over time for the major CFC's and HCFC's and indicate changes in mixing ratios of several alkyl nitrates, halogenated solvents and additives, and some non-methane hydrocarbons over the last few decades. Mixing ratios of several trace gases, including methyl bromide, were significantly elevated relative to atmospheric levels in the Canadian firn samples, suggesting a source in the firn. Sampling for FIRETRAC will be completed in 1999.

GASEX-98: The Gas Exchange Experiment

GASEX-98 is a multilocational, international effort involving 4 NOAA laboratories and 13 universities and research institutions. The goal of GASEX-98 is to refine our understanding of the intrinsic rate of exchange of CO_2 and other climatically important gases between the ocean and atmosphere in order to constrain regional mass balances of carbon and other atmospheric gases. During the GASEX-98 cruise, experiments were designed to measure fluxes on short time-scales by several micro-meteorological techniques and to verify those measurements with gas fluxes determined from water column mass balance calculations. Whole air samples were collected for S/TM by Shari Yvon-Lewis (NOAA AOML) at several levels above the ocean surface for flux calculations to be compared with in-situ sampling systems. Preliminary results indicate gradients for several trace gases, including methyl iodide, above the ocean surface that may be used to calculate fluxes at various times during the cruise.

STRAT, POLARIS and PEM Tropics: Data interpretation

One of the goals of the STRAT mission was to investigate the tropical upwelling region where air is transported from the troposphere into the stratosphere. An interesting question is how much mixing of the tropical air masses with photochemically aged air from mid latitudes in the lower stratosphere occurs during ascent. The variety of chemical lifetimes and removal mechanisms covered by the compounds that are measured by S/TM in the whole air samples provides a unique opportunity to model the observed altitude profiles in the tropics. The NASA ER2 performed four flights to the equator including a dive from cruising altitude (21 km) down to 15 km during STRAT and one such flight during POLARIS. Preliminary model calculations suggest that it will be possible to derive mixing timescales and, possibly, information on the role of chlorine radicals in the tropical lower stratosphere.

A comprehensive suite of brominated organic compounds were measured from whole air samples collected during the STRAT and the PEM Tropics aircraft campaigns. The difference between tropospheric mixing ratios in the northern and southern hemispheres for halons were approximately equivalent to their annual tropospheric growth rates, while the interhemispheric ratio of CH_3Br was 1.18. The shorter-lived brominated organic species showed higher tropospheric mixing ratios in the tropics relative to mid-latitudes which reflects their marine biogenic sources. Significant vertical gradients in the troposphere were observed in the short-lived species with upper troposphere values 40-70% of the lower troposphere values. Much smaller vertical gradients (3–14%) were observed for CH_3Br, and no significant vertical gradients were observed for the halons. Above the tropopause, the decrease in organic bromine compounds was found to have some seasonal and latitudinal differences. The combined losses of the individual compounds resulted in a loss of total organic bromine between the tropopause and 20 km of 38-49% in the tropics, and 75-85% in mid-latitudes. The fractional dissociation of the halons and CH_3Br relative to CFC 11 showed latitudinal differences, with higher values in the tropics.

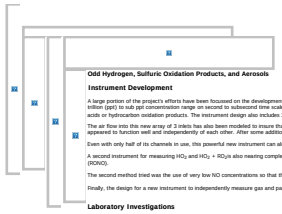
Finally, an estimate of the formation rate of methyl nitrate from the reaction of methyl peroxy radicals with NO was derived from the observed methyl nitrate concentrations in the lower stratosphere during STRAT using box model simulations with the NCAR master mechanism and the TUV photolysis rate model.

PSE 98: Polar Sunrise Experiment

The Polar Sunrise Experiment 1998 was an international collaboration to study the effects of the transition from dark to light on atmospheric chemistry in the Arctic. Alert, at the northern edge of Ellesmere Island (82°N) does not receive any sunlight from late September until the beginning of March, and the average ambient temperature is normally below -30°C during that time. The combination of atmospheric conditions and the absence of efficient transport routes out of the Arctic basin suggest that the arctic atmosphere serves as a holding reservoir which results in a build up of contaminants. At the time when the sun reappears, more active chemistry once again becomes possible through the photochemical production of reactive atomic and free radical compounds. Polar sunrise studies are specifically concerned with attempts to evaluate the chemical changes that take place during this transition from dark-phase to sunlight- irradiated chemistry. Whole air samples were collected at Alert for S/TM by Brian Ridley, James Walega, and Denise Montzka for analysis of a variety of organic nitrates, halocarbons, and non-methane hydrocarbons. These compounds can provide insight into the roles of emissions, transport, and radical chemistry in surface ozone depletion in the Arctic region.

Instrumentation

The Whole Air Sampler (WAS) system for the ER-2 aircraft is undergoing redesign to fit into the centerline drop tank. This process entails complete redesign of the manifold/canister/pump configuration. An upgraded electronics package is also being designed to fit the new configuration. An automated inlet system for our laboratory GC systems is being developed and tested which should allow the unattended analysis of up to 12 whole air sample canisters. This will improve the number of canisters that can be processed in our laboratory per day that reduces storage time and increases the sample number capacity for individual campaigns.



Odd Hydrogen, Sulfuric Oxidation Products, and Aerosols

Instrument Development

A large portion of the project's efforts have been focussed on the development of a new, smaller, lighter, but more powerful chemical ionization mass spectrometer instrument. This has been accomplished through the design and construction of very compact customized electronic circuit boards to control nearly all aspects of instrument operation and data collection and the introduction of improved vacuum pumping techniques. This new instrument on which construction began less than a year ago, is unique, having 4 independent mass spectrometers each designed for different types of ion sources coupled to specially tailored inlets. Each ion source/mass spectrometer is capable of measuring several different compounds in the part per trillion (ppt) to sub ppt concentration range on second to subsecond time scales. The instrument is designed for aircraft operation and is smaller and lighter than the original CIMS (H_2SO_4)/MSA instrument used on the NCAR C-130 in the ACE-1 mission, but can measure about 4 times as many compounds. Presently, the instrument is configured to measure OH, H_2SO_4, and MSA with the central inlet/mass spectrometer channel. A second channel is dedicated to the measurement of NH_3. DMSO, and $DMSO_2$, while a third channel will be used to test aircraft measurement capabilities for HO_2 and RO_2. The fourth channel has not yet been dedicated to any specific set of compounds, but will probably be used in the future to measure nitric and related acids or hydrocarbon oxidation products. The instrument design also includes 3 inlets, each capable of sampling air from the free stream flow, slowing it, and introducing it into an ion source with essentially no wall contact. Thus, highly reactive or sticky compounds such as those mentioned above can be sampled without wall loss and memory effects.

The air flow into this new array of 3 inlets has also been modeled to insure that the inlets do not interfere with each other. This modeling was done using a fluid dynamic program called STAR CD which confirmed both the results of previous wind tunnel tests of the flow inside of the OH inlet and showed that the flow perturbation caused by anyone inlet or set of inlets did not disturb the flow in any other inlet. The fourth inlet is for sampling compounds that can undergo wall contact prior to measurement and thus is not susceptible to the same potential interference effect as the other three. This new instrument with 2 of its 4 inlets installed was recently flown on a series of preliminary test flights. Both mass spectrometer channels and inlets appeared to function well and independently of each other. After some additional testing and further improvements, the instrument will participate in its first aircraft mission in March 1999.

Even with only half of its channels in use, this powerful new instrument can already provide measurements of several key species for which there are no competitive measurement techniques. This new aircraft measurement capability opens the door to more comprehensive studies of photochemistry, sulfur oxidation chemistry, and aerosol nucleation and growth.

A second instrument for measuring HO_2 and HO_2 + $RO_2$is also nearing completion. It has undergone a series of laboratory tests and a prototype instrument is now being installed in the ONR/NRL Calspan chamber to measure HO_2, RO_2, and H_2SO_4 in support of this Aerosol/Cloud study. Over the past year several experiments were performed in an effort to characterize and optimize the performance of the peroxy radical CIMS instrument. Two schemes were tried to yield separate signals for HO_2 and for HO_2 + RO_2. The first involved very high concentrations of NO and SO_2 with the gases added through separate injectors to try and exploit the reaction of RO (produced in the reaction RO_2 with NO) with NO to produce undetectable products (RONO).

The second method tried was the use of very low NO concentrations so that the conversion chemistry is slowed down considerably. The chemistry in this case favors conversion of HO_2 (one step to OH) over say, CH_3O_2 (three steps to OH). While the latter method yielded slightly larger separation, the former provided much higher sensitivity and is thus more practical. The lack of HO_2 measurements is a critical bottleneck in understanding photochemical oxidant production, especially in the presence of clouds and particles. Thus, both of these new instruments and the studies in which they will shortly be involved will contribute substantially to ongoing ACD goals.

Finally, the design for a new instrument to independently measure gas and particle nitric acid is presently underway in conjunction with Paul Wennberg and Richard Flagan (California Institute of Technology).

Laboratory Investigations

The major laboratory thrust has been to quantify particle nucleation parameters. Bimolecular sulfuric acid/water nucleation has been studied to determine the functional dependence of particle production rates on the concentration of each of the precursor molecules. While results are generally consistent with theoretical productions, several interesting experimental effects have been observed, and much additional work is required for a full quantification of this process. Preliminary investigations of the effect of ammonia on the sulfuric acid/water nucleation process were very dramatic. They suggest large enhancements in nucleation rate in the presence of gas phase atmospheric ammonia. The latter work is very preliminary, and much additional effort will be required to quantify this important but poorly understood effect. This work is part of a collaborative effort with Peter McMurry (University of Minnesota).

Other laboratory studies explored new selected ion chemical ionization mass spectrometric (SICIMS) techniques for measuring hydrocarbons and their oxidation products. These were preliminary studies which surveyed various gas phase ion chemistry schemes to see which reactant ions were best suited for the measurement of several hydrocarbons of interest. It was concluded that some of the most desirable reactant ions could only be produced and maintained under ion source/reaction tube conditions much different than those initially tested. This has led to a new, more specialized SICIMS approach for hydrocarbon compounds.

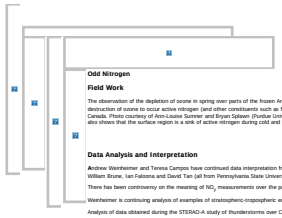
Field Investigation

The only field investigations that were conducted in the past year were a brief study of ions formed in air sampled from just outside of the Mesa Laboratory using a new SICIMS ion source, and the aircraft flight tests described above.

Data Analysis

During the past year, the analysis of data from several field campaigns was completed and the results published. The campaigns to which significant contributions were made include:

Sulfur Chemistry in the Antarctic Troposphere Experiment (SCATE) which was a ground-based study conducted jointly by NCAR and Georgia Institute of Technology with additional instrumentation from NOAA and NASA; Aerosol Characterization Experiment (ACE-1) a ground, ship, and aircraft based study sponsored largely by NSF with support from NOAA and NASA; a NASA aircraft study Pacific Exploratory Missions in the Tropics (PEM-Tropics A).



Odd Nitrogen

Field Work

The observation of the depletion of ozone in spring over parts of the frozen Arctic ocean surface layer has been one of the most interesting facets of tropospheric chemistry in the past decade. The Atmospheric Environment Service (AES) of Canada and more recently European groups have led investigations of this phenomenon and have provided convincing evidence through measurements and modeling that halogen atom/radical chemistry is responsible for the observed behavior of hydrocarbons and other species and for the destruction of ozone over the Arctic maritime region in springtime. Thus the oxidizing capacity of the troposphere is not always dominated by hydroxyl radical chemistry. In order for the chlorine and bromine destruction of ozone to occur active nitrogen (and other constituents such as formaldehyde) must be of small concentration so as not to significantly interrupt the catalytic cycles. In late February through early May, James Walega, Frank Grahek, Denise Montzka and Brian Ridley participated in the Polar Sunrise Experiment (PSE) 1998 conducted near the Canadian Forces Station Alert located on the northern tip of Ellesmere Island at 82.5°N, only about 500 miles south of the North Pole. Our contribution to PSE '98 was measurements of NO, NO_y, and NO_2 from the AES Special Studies Trailer (SST) located about 5 km from the military base. An [Arctic fox] outside the Special Studies Trailer during PSE '98 conducted near Alert, Nunavut, Canada. Photo courtesy of Ann-Louise Sumner and Bryan Splawn (Purdue University).Collaborators in the study were John Deary, Alexandra Steffan, Hacine Boudries, Alan Gallant, Jan Bottenheim, Kurt Anlauf, William Schroeder, and Len Barrie (all from AES), Ann-Louise Sumner, Bryan Splawn, and Paul Shepson (all from Purdue University), Jochen Ruddolph (York University), and Elliot Atlas, Frank Rocke, and Verity Stroud (ACD). Other data important to the field study were provided by personnel who operate the Baseline Air Pollution Monitoring Network station also located near the SST. Apart from providing data during a strong ozone depletion event resulting from transport from the ocean/ice to the Alert region, our preliminary analysis also shows that the surface region is a sink of active nitrogen during cold and low sun periods, a result that was not unexpected. NO_y was essentially zero during these periods within the accuracy of the measurements of a few parts per trillion mixing ratio. However, once the solar insolation was significant or continuous for 24 hours a few days after equinox, it appears that the snow surface was a source of NO_y, an unexpected result. Data analysis is ongoing.

Data Analysis and Interpretation

Andrew Weinheimer and Teresa Campos have continued data interpretation from the NASA VOTE/TOTE/SUCCESS programs which employed the DC-8 aircraft. The group has been co-authors on seven manuscripts that discuss some of the results from these missions in special issues of *Geophysical Research Letters*. Some highlights from these missions relative to $NO_{(y)}$ and HO_2 measurements were: In wave clouds NO_y presumably in the form of gaseous HNO_3 was rapidly depleted onto ice particles; the effects of convection of boundary layer constituents from over the central US to the upper troposphere and consequent enhancement in photochemical ozone production rates were clearly demonstrated. Collaborators in these analyses were William Brune, Ian Faloona and David Tan (all from Pennsylvania State University), Lyell Jaeglé and Daniel Jacob (Harvard University), Glen Sachse, Stephanie Vay and James Collins (NASA Langley Research Center), and Eric Jensen (NASA Ames Research Center). Other results were briefly discussed in last year's report.

There has been controversy on the meaning of NO_y measurements over the past several years. During the DC-8 aircraft programs discussed above, our converters were tested in situ to determine the efficiency of conversion of HCN, a species not normally considered part of the NO_y family. Tests showed, and the results have been submitted for publication, that converters can be chosen in which the HCN interference is acceptably small (<5%).

Weinheimer is continuing analysis of examples of stratospheric-tropospheric exchange processes observed during the DC-8 SUCCESS flights. Observations from one flight show clear evidence of bi-directional and irreversible mixing via chemical tracers. In collaboration with J-F Lamarque, a mesoscale model is being used to assess whether gravity wave breaking is the responsible mechanism. In another flight, a significant ice cloud was observed in air that was otherwise clearly stratospheric since ozone mixing ratios were up to 260 ppbv. Back trajectories suggest an admixture of moist tropical air.

Analysis of data obtained during the STERAO-A study of thunderstorms over Colorado conducted in summer 1996 has also been ongoing by Ridley, Karsten Baumann, Montzka, Walega, James Dye (MMM) and Jeff Stith (University of North Dakota) but there has been some delay in getting final data from all of the instruments involved in the two aircraft program.

Instrument Development

The photolytic technique for measurements of NO_2 has been improved so that gas residence times in the cell have been reduced to 1-2 sec without loss of efficiency. The new design was employed in the Alert field program.

Work on the WB-57 four-channel chemiluminescence instrument for measurements of NO_y, NO_x, and O_3 in the upper troposphere and lower stratosphere has continued. The instrument is expected to fly on the WB57 in August and September of next year in flights organized by the NOAA Aeronomy Laboratory (Adrian Tuck and colleagues), NASA (Don Anderson and Randall Friedl) and the Air Force (Martin Ross). The instrument will undergo some performance tests before that time by participating in the NASA PEM-Tropics B P3 aircraft mission into the South Pacific this coming winter and spring.

Formaldehyde

Tunable Diode Laser (TDL) Spectroscopy

Alan Fried and Bruce Henry continued work on fast, highly sensitive and accurate airborne measurements of formaldehyde (CH_2O). This gas is an important reactive intermediate present in all regions of the atmosphere and its decomposition is a major source of HO_2 radicals as well as CO in the non-urban atmosphere. Elevated concentrations of CH_2O from convective transport as well as from in situ production may play a significant role in the production of HO_2 radicals in the upper troposphere where current models indicate additional HO_x sources are necessary. The role of CH_2O in this regard has generally been overlooked, and this is a research area that has been actively investigated this past year. The paucity of highly accurate measurements of CH_2O in the middle to upper troposphere has no doubt contributed to this lack of understanding. The airborne CH_2O measurements acquired by the TDL group during the 1996 and 1997 STERAO and NARE campaigns are providing a high quality data base with which to further assess the role of CH_2O as an upper tropospheric HO_x source. As a necessary part of this endeavor, work has continued with its multi-year effort to carry out ever more sensitive airborne measurements of CH_2O with verifiable measurement accuracy. High measurement accuracy encompasses many instrumental issues such as: selectivity, calibration, instrument precision, instrument background, and inlet surface effects. The following activities summarize the research efforts carried out this past year related to the above issues.

Participation in the 1997 NARE Study in Measuring CH_2O and CO

In collaboration with James Drummond (University of Toronto), airborne measurements of CH_2O throughout the 1997 North Atlantic Regional Experiment (NARE) field campaign were successfully acquired. The goals of this study were designed in part to elucidate the mechanisms that control the transport of ozone (O_3) and its precursors from source to remote regions of the atmosphere, and to investigate the regional and vertical distributions of photochemically important species in the marine and continental planetary boundary layers as well as the free troposphere. A secondary goal was to investigate the role of frontal passage in transporting boundary layer air to the upper troposphere. The 1997 mission, moreover, provided a second opportunity to intercompare independent CH_2O measurement techniques based on the TDL and the Brookhaven National Laboratory's (Yin-Nan Lee) coil DNPH derivatization technique onboard the same aircraft platform. The results of this intercomparison along with that carried out by the same participants during the NARE 1996 campaign represent the first such study employing independent CH_2O techniques on airborne platforms. This activity is essential in assessing measurement accuracy of both instruments. The intercomparison results for both campaigns are being analyzed and a *Journal of Geophysical Research* paper will be prepared this upcoming year.

During the transit flight to St. Johns, Newfoundland, CO was measured instead of CH_2O. This afforded the opportunity to compare TDL CO measurements with those acquired employing a new wing pod UV fluorescence system developed by NOAA and mounted on the same aircraft. Like CH_2O, fast, accurate and sensitive CO measurements are required to further our understanding of transport processes, and the TDL measurements thus provided a highly selective spectroscopic method by which to validate the new fluorescence system. The data from both instruments has been reduced; over approximately an 8-hour flight, 5-second results from both instruments were in agreement to within 5–7%. A *Journal of Geophysical Research* manuscript is presently being prepared describing this study.

Completion of Data Reduction for All NARE and STERAO Airborne Campaigns & Continuation of Data Analysis

As discussed in the FY 1996 annual report, the 1996 NARE and STERAO field measurements have been reduced employing highly rigorous quality control procedures to parse out outlying data. These post mission quality control procedures have been further expanded and used to complete the data reduction for the 1997 NARE campaign.

Working with both NCAR and NOAA modelers, the TDL group has now embarked on an effort to analyze the CH_2O measurements from all three campaigns in a photochemical context. Although still in its formative stages, this endeavor attempts to:

1. Compare CH_2O measurements with box model calculations using the measured hydrocarbons at both high altitude, where simplified methane chemistry prevails, and in the boundary layer, where additional sources and sinks become important. Such comparisons will point to the presence of unknown CH_2O sources, sinks and/or oxidation pathways.
2. Compare in-cloud CH_2O measurements with box model calculations employing various liquid-phase uptake mechanisms to further our understanding of gas-liquid phase partitioning.
3. Compare in-cloud CH_2O/CO ratios during deep convective events with those in the boundary layer to assess the role of transport in conveying high concentrations of CH_2O into the middle and upper troposphere. This ratio together with other ratios such as CH_2O/NO_y will be used to further assess the presence of in situ CH_2O production mechanisms in the middle and upper troposphere.
4. Employ box model calculations to assess the utility of CH_2O/CO and CH_2O/NO_y ratios in providing information regarding the origins and age of the air mass being sampled. The box model will help in determining the sensitivity of these ratios to the exact nature and concentration of the input hydrocarbons. This analysis will be augmented by measurements in different hydrocarbon regimes.
5. Employ radiation code to determine CH_2O clear sky *j*-values in order to determine the HO_x production efficiency from CH_2O photolysis in the middle troposphere.
6. Compare measurements with three-dimensional model calculations using emission inventories in an effort to discern transport from in situ production.

The above questions represent the initial focus of the analysis, and invariably additional questions will arise as the data analysis further proceeds. One of the initial surprises in the NARE-97 data set acquired by the TDL group relates to the extremely high CH_2O concentrations measured in remote regions of the Atlantic far removed from continental sources.

Inlet Characterization & Modifications to the TDL Inlet System During the 1997 NARE Study

Last year's Annual Scientific Report detailed a number of questions concerning CH_2O measurement accuracy whenever inlet outgassing (slow desorption of CH_2O from inlet surfaces) becomes prevalent, which typically occurs during time periods of high CH_2O and high relative humidity. Although preliminary evidence indicates minimal error in past measurements, the TDL group has embarked on two different corrective strategies. First, the TDL group has devoted a great deal of effort this past year in modifying the aircraft inlet system to minimize such outgassing in the first place. These modifications, which were described in last year's report, worked extremely well during the entire 1997 NARE field study. Two different publications (Fried et al., SPIE, volume 3385, 154 –162, 1998; Fried et al., Spectrachimica Acta, submitted, October 1998) further describe these modifications and present data showing the effectiveness of these improvements. Secondly, a series of well-defined and controlled laboratory studies to further characterize the inlet behavior under a variety of ambient conditions of temperature, relative humidity, and pressure were initiated. Although these tests are not yet complete, the modified aircraft inlet system employed during the 1997 NARE mission accurately transmits input CH_2O concentrations in the 0.2 to 5 ppb range without any losses, gains, or time-lags, under a variety of relative humidities and sampling temperatures. More specifically, these laboratory tests have shown that the inlet tip, which does not get heated during flight, quantitatively transmits ambient CH_2O at temperatures as low as $-17^{o}C$. Additional tests are being carried out to simulate even lower ambient temperatures. These measurements, however, point to the importance of heating and/or zeroing the majority of the inlet sampling system; without such precautions, some of the inlet tests have shown that ambient CH_2O measurements may contain large systematic errors. A comprehensive discussion of the laboratory inlet tests will appear in a future publication.

Completion of Laboratory Studies to Further Improve Airborne CH_2O Detection Limits

Based upon the three aircraft missions, ambient CH_2O concentrations as low as 81 to 103 pptv (1σ measurement precision) in 20-seconds of averaging can routinely be measured. These results improve to around 45 pptv employing 5-minute averages. Although extremely good, ambient concentrations typically attain levels of 100 pptv and lower, and thus it becomes highly desirable to improve instrument performance even further. This is particularly important when one attempts to assess upper tropospheric HO_x sources where CH_2O levels as low as 20 to 50 ppbv become important. A series of laboratory studies to identify and ameliorate sources of imprecision in airborne TDL measurements of CH_2O were carried out. A number of sources, particularly the temperature stability of the entire optical train, were found to be important. As a result, an effort is underway to improve significantly the entire temperature control scheme for the optical bench, surrounding enclosure, and laser controller. These efforts will be incorporated with modifications (see next topic) for upgrading the airborne TDL system to dual laser channel operation. As discussed in recent publications by the TDL group (Fried et al., *Applied Physics*, **B 67**, 317 – 330, 1998; and *Spectrachimica Acta*, submitted, October 1998), the system modifications hold the promise of improving the above 5-minute CH_2O detection limits to 25 – 32 ppbv.

Completion of Aircraft System Upgrades for Simultaneous Measurements of CH_2O and H_2O_2

A joint ACD/ATD effort to upgrade the present aircraft TDL system for simultaneous measurements of CH_2O, hydrogen peroxide (H_2O_2), and potentially CH_3 has been discussed the past two years. Greg Kok (Atmospheric Technology Division) was initially involved with this effort. This work is being carried out jointly by James Drummond (University of Toronto) and Bryan Wert (graduate student visitor, University of Colorado) and is working closely with Alan Fried and Bruce Henry to effect such changes as part of his doctoral research program. Progress on this system has proceeded much slower than originally anticipated in part due to time required on other activities and in part the availability of funds. This effort has become the main focus of the TDL this next year, and tentative plans call for flying a dual channel system during the 1999 NOAA airborne study over Nashville, Tennessee. However, a number of components associated with H_2O_2 detection may not be ready in time and another molecule may be detected along with CH_2O instead for this study to test out the entire dual channel optics and data acquisition systems. The full CH_2O/H_2O_2 capability would then be ready for the proposed TOPSE study in the year 2000.

Completion of Carbonyl Sulfide Permeation Standards Paper

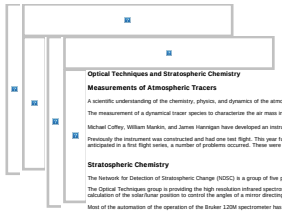
A manuscript has now appeared in the *Journal of Geophysical Research* describing research on potential calibration errors in carbonyl sulfide (OCS) permeation devices and implications for atmospheric studies. Calibration errors as high as 37% have been observed in this study with some OCS permeation devices due to the presence of impurities co-permeating with OCS. Such errors can produce significant erroneous temporal trends and/or inconsistencies between ambient measurements carried out by different laboratories.

Completion of Laboratory Heterogeneous Studies on Sulfuric Acid Aerosols

In collaboration with Michael Mozurkewich (York University, Toronto), Steven Ball (ASP postdoctoral fellow), Geoff Tyndal and John Orlando, the TDL group finished the second phase of its heterogeneous studies focusing on the reaction probability between $ClONO_2$ and H_2SO_4 aerosols. A paper has appeared in *Geophysical Research Letters*. The above reaction is extremely important in effecting the depletion of stratospheric ozone on a global scale, but the reaction probabilities on neat H_2SO_4 particles have only been determined over a very narrow range of particle compositions. The present study not only offers a much needed confirmation of earlier measurements but extends the measurements over a wider range of H_2SO_4 compositions.

Collaboration with Other NCAR Groups

In addition to the above collaboration with the Kinetics group, the TDL group has been active in collaborating with this group in measuring the HCl product yield from the reaction of ClO with OH employing a laboratory TDL system. Small differences in this product yield can have large effects in modeling stratospheric ozone concentrations. This work is near completion and a manuscript will be prepared this upcoming year. The TDL group has also collaborated with the Kinetics group on a manuscript describing tunable diode laser studies of the reaction between Cl atoms and CH_2CHO. The manuscript is in preparation. The TDL group has also collaborated this past year with the Optical Techniques Group in helping to set up an airborne TDL system for simultaneous measurements of CO and N_2O on NCAR's WB-57 airplane.



Optical Techniques and Stratospheric Chemistry

Measurements of Atmospheric Tracers

A scientific understanding of the chemistry, physics, and dynamics of the atmospheric region near the tropopause is important for a number of problems which have both intrinsic scientific interest and relevance for societal issues, including the depletion of ozone in the lower stratosphere due to halogen compounds, the atmospheric impact of subsonic and supersonic aircraft operations, and the anthropogenic impact on climate. This region has been the subject of relatively little experimental investigation in the past.

The measurement of a dynamical tracer species to characterize the air mass in which measurements are made is an important component of the interpretation of measurements of many species; comparison of concentrations of reactive species and tracers helps to distinguish the effects of transport and chemical and physical transformations. N_2O has been extensively used for this purpose in the lower stratosphere, and CO is particularly valuable in the upper troposphere.

Michael Coffey, William Mankin, and James Hannigan have developed an instrument based on absorption of radiation from a tunable infrared diode laser that measures both gases simultaneously. The instrument uses a laser operating at 2190 cm^{-1} to measure absorption by each of the two atmospheric gases. Each gas has a strong absorption line within the tuning range of a single mode of the laser. The instrument is designed to measure both gases with a sensitivity of around a part per billion within a one second measurement time.

Previously the instrument was constructed and had one test flight. This year further tests were performed, and some upgrades made to the operating software, as well as developing software for data analysis. During FY98, the diode laser instrument was used in its first airborne research program, the WB57 Aerosol Measurements (WAM) program. The instrument was deployed on the NASA WB57 operated at Johnson Space Center in a program organized by investigators at NOAA's Aeronomy Laboratory for measurements of the chemistry of aerosol particles in the upper troposphere and lower stratosphere. The instrument flew on six flights, covering latitudes from 12°N to 50°N, at altitudes from below the tropopause to 19 km. As might be anticipated in a first flight series, a number of problems occurred. These were dealt with in the field, and in the later flights of the program, many data were collected. The data are currently being analyzed; there appear to be some difficulties with the calibrations, but once those problems are solved, the data will be available for use in conjunction with measurements by other observers, and the instrument can be deployed on future missions on the WB57 or other platforms.

Stratospheric Chemistry

The Network for Detection of Stratospheric Change (NDSC) is a group of five primary stations and numerous complementary observation sites for long term observation of the stratosphere for the purposes of making the earliest possible detection of changes will affect ozone, for providing observations which will help discern the cause of those changes, and for comparing high quality, carefully calibrated ground-based data with global observations from satellites to determine changes on a global scale.

The Optical Techniques group is providing the high resolution infrared spectroscopic observations from Thule, Greenland, at a latitude of 76°N. A Bruker 120M high resolution spectrometer has been acquired for these observations. During this year, the spectrometer was installed in Thule for testing purposes, then returned to Boulder for further testing and development of automation as it is necessary for the instrument to operate unattended. Weather instruments have been acquired to determine suitable observing conditions. A two part system for collection of radiation from the sun or full moon and direction of the radiation into the spectrometer has been built; the first stage is located on the observatory roof and uses computer calculation of the solar/lunar position to control the angles of a mirror directing the radiation downward to the observing room; the second stage uses a photoguided system with automatic gain control to remove the effects of any small errors in the pointing from the first stage, including changes in the atmospheric refraction and wind induced loads on the mirror, before forming the final stable image inside the spectrometer.

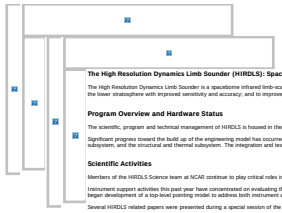
Most of the automation of the operation of the Bruker 120M spectrometer has been completed and largely tested. Some further testing will be done in Boulder before the final shipment of the instrument to Thule in FY99. Further work on the analysis of spectra for the determination of the columns of various species was done this year, and some work on the extraction of profiles was performed.

For the spectroscopic determination of columns and especially for profile measurement, it is essential to know the instrument line shape function very accurately. With careful adjustment, the ILS of the spectrometer approaches its theoretical value closely; to test this performance, we need to observe an isolated line from a heavy molecule. HBr was thought to be a suitable molecule. Coffey, Mankin, and Hannigan constructed a sealed absorption cell containing HBr at low pressure. The cell is constructed entirely of glass and sapphire, with no valves or sealing materials with which the HBr can react. Measurements over a period of several months indicate that the amount of HBr stays constant to the accuracy of the measurements. The lines appeared to be wider than the computed Doppler width. Investigation showed that the hyperfine structure of HBr, caused by the interaction of the nuclear spin of the bromine nucleus with the electric field of the electrons was producing a splitting of the energy levels, resulting in a broader spectral line. Careful measurements were made of this effect in Both HBr and HI, and collaboration with Aaron Goldman (University of Denver), David Griffith and C. Bernardo (University of Wollongong), Curtis Rinsland (NASA Langley Research Center), and K. V. Chance (Harvard Smithsonian Center for Astrophysics), produced new spectroscopic constants for the community data bases of spectral parameters, so that these gases may be used for calibrating the performance of the NDSC spectrometers.

Coffey has further developed the technique of using potential vorticity at multiple levels in the atmosphere to fit sparse observations of the column of conserved trace gases; this allows reconstructions of the columns of the gases at all locations in the polar vortex. Comparison of the reconstructed columns with subsequent observations allows determination of the time variation of the species. This technique will be used for the analysis of data from future observing expeditions, such as the SOLVE campaign planned for 1999, to determine the extent of ozone loss by separating dynamical and chemical effects.

Earth Observing System

Mankin and Coffey are Co-Investigators on the High Resolution Dynamics Limb Sounder (HIRDLS) for the Earth Observing System (EOS), with John Gille (ACD and University of Colorado) and John Barnett (Oxford University) as Principal Investigators. Coffey is the Project Manager for the activity that involves 13 NCAR personnel. Mankin and Coffey have worked with the HIRDLS project and contractors in the conceptual design of the instrument as well as the specification of science and instrument requirements; they are reviewing developments and plans for the integration and test of the instrument. Mankin participated in the review of detector nonlinearity effects, and devised a way of determining changes of detector nonlinearity in orbit.



The High Resolution Dynamics Limb Sounder (HIRDLS): Space Observations of Stratospheric and Upper Tropospheric Composition

The High Resolution Dynamics Limb Sounder is a spaceborne infrared limb-scanning radiometer designed to sound the upper troposphere, stratosphere, and mesosphere to determine temperature; the concentrations of O_3, H_2O, CH_4, N_2O, NO_2, HNO_3, N_2O_5, $ClONO_2$, CFC11, CFC12, and aerosols; and the locations of polar stratospheric clouds and cloud tops. These are the key elements that are needed to understand the chemistry and dynamics in those regions, including the roles of planetary and gravity waves in transporting and mixing radiatively and chemically active species important in climate change. The goals are to provide sounding observations with horizontal and vertical resolution superior to that previously obtained; to observe the lower stratosphere with improved sensitivity and accuracy; and to improve understanding of atmospheric processes through data analysis, diagnostics, and use of two- and three-dimensional models. Development of the HIRDLS instrument is lead by the U.S. Principal Investigator, John Gille (NCAR and the University of Colorado (CU)), and by the U.K. Principal Investigator, John Barnett (Oxford University). HIRDLS is a joint US-UK development effort, with sponsorship by the British National Space Centre and the Natural Environment Research Council in the UK, and by NASA in the US. HIRDLS is planned for flight on the Earth Observing System Chemistry Mission in the year 2002.

Program Overview and Hardware Status

The scientific, program and technical management of HIRDLS is housed in the Center for Lower Atmospheric Sounding (CLAS) at the University of Colorado. Susan Avery (CU) serves as the Director of CLAS, with Daniel Baker (CU) as the Deputy Director. HIRDLS management and technical staff at CLAS includes Joanne Loh, Michael Dials, Douglas Woodard, Phillip Arler, Russell Howard, David Wilson and Linda Henderson who continue their connection to ACD as visitors. As a subcontractor to CU, NCAR continues its key role in supporting the definition of instrument specifications, instrument design, testing and calibration and in the development of data reduction software.

Significant progress toward the build up of the engineering model has occurred over the past year. Several key components and subsystems have been built or are nearing completion. Components and subsystems that have been completed this past year include sets of warm and cold spectral filters, the mechanical chopper, the vibration isolators for mounting the optical bench to the instrument baseplate, the mechanical cryocooler, the detector focal plane and dewar subsystem, the telescope electronics unit, the breadboard instrument computer processor unit, and the power supply subsystem. Subsystems to be completed early next year include the optical bench and scanner assemblies, the in-flight blackbody unit, the sunshade subsystem, and the structural and thermal subsystem. The integration and testing of engineering model subsystems, and instrument-level performance testing is scheduled to occur early in fiscal year 1999.

Scientific Activities

Members of the HIRDLS Science team at NCAR continue to play critical roles in overseeing the design, fabrication, testing and calibration of the HIRDLS instrument, as well as, in the development of data reduction algorithms.

Instrument support activities this past year have concentrated on evaluating the effects of variations of the line-of-sight produced by predicted spacecraft disturbances, as well as, internally generated disturbances. This effort has lead to a refinement of the requirements on spacecraft attitude stability. There has been continued effort to further understand and refine the long-term pointing knowledge requirements relating measurements from one elevation scan to another within an azimuth swath, and from orbit to orbit. This is a complex problem requiring a combination of spacecraft, instrument and post-launch data processing to achieved the desired pointing requirements. Richard Powers (graduate student at CU) and Brian Johnson began development of a top-level pointing model to address both instrument and data processing aspects of this problem.

Several HIRDLS related papers were presented during a special session of the SPIE conference in San Diego this past year, including papers by Gille presenting an overview of the HIRDLS instrument and expected performance, and by Johnson describing the HIRDLS Radiometric Model (HIRAM) developed by William Mankin and Johnson. HIRAM has been a very useful analysis tool used in wide range of instrument studies.

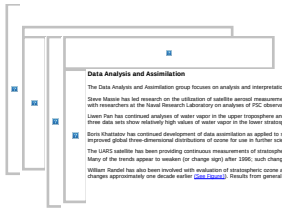
To evaluate the possibility of nonlinear response of the HIRDLS detectors, a detailed model based on the fundamental physics of infrared detector operation was developed by Aaron Lee (graduate student at CU) and Johnson. The detector model was used to predict the departure from a linear response under the appropriate HIRDLS operating conditions and to explore various schemes for making in-flight corrections to the instrument response measured during ground calibration. On-orbit changes to instrument response due to changes in detector properties over the 5 to 6 year orbit lifetime of HIRDLS are possible, though the mechanism for such a changes is uncertain.

The development of the retrieval algorithms, which invert the observed limb radiance profiles to obtain vertical profiles of temperatures and the concentrations of several trace species, is being led by Alyn Lambert and Gille. The algorithm incorporates a computationally fast forward radiance model being developed by David Edwards and Chris Halvorson based on experience gained from the MOPITT program. Steven Massie has begun to develop models of aerosol opacity as a function of frequency for several different aerosol and cloud types. Lawrence Lyjak has begun to develop a priori means and covariances for the variables to be retrieved from HIRDLS radiance measurements. Both of these are being prepared for inclusion in the retrieval code.

In related work, Boris Khattatov has been extending his data assimilation techniques, which are expected to be applied to HIRDLS data. He has prepared two papers, one on the technique, the other a demonstration of its application to UARS data.

Gille and Johnson are also working with the Operational Algorithm Team developing the Ozone Monitoring and Profiling System (OMPS), to be flown as part of the National Polar Orbiting Environmental Satellite System (NPOESS), the main system providing operational meteorological data early in the next millenium.

HIRDLS co-investigators include Paul Bailey, Byron Boville (CGD), Brasseur, Michael Coffey, and Mankin (all at NCAR), Linnea Avallone and O. Brian Toon (CU), James Holton and Conway Leovy (University of Washington), David Andrews, Clive Rodgers, Fredrick Taylor, Robert Wells, John Whitney, and E. James Williamson (Oxford University), Michael McIntyre and John Pyle (Cambridge University), H.G. Muller (University of Sheffield), C.T. Mutlow (Rutherford Appleton Laboratory), and Geraint Vaughan (University College of Wales).



Data Analysis and Assimilation

The Data Analysis and Assimilation group focuses on analysis and interpretation of global constituent data sets obtained from satellite measurements, in conjunction with meteorological analyses. Recent work has focussed on stratospheric constituent and aerosol measurements obtained from the Upper Atmosphere Research Satellite (UARS). Additionally, long time records of ozone and temperature have been studied to provide updated estimates of global stratospheric trends.

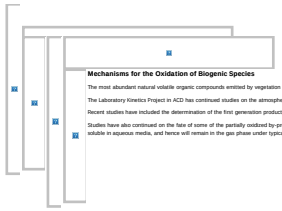
Steve Massie has led research on the utilization of satellite aerosol measurements from UARS. This includes studies on the Mt. Pinatubo volcanic aerosol, and polar stratospheric clouds (PSC's). Theoretical models of heterogeneous chemistry (e.g. models which calculate how PSC's convert unreactive chlorine containing molecules into active chlorine) require estimates of PSC area density values. Steve Massie, Darrel Baumgardner (ATD) and James Dye (MMM) published calculations that enable the user community to transform UARS extinction data into area densities. Current work involves the inclusion of these data into three-dimensional chemical transport models to quantify the effects on polar ozone depletion. Massie also collaborated with researchers at the Naval Research Laboratory on analyses of PSC observations from the POAM II satellite.

Liwen Pan has continued analyses of water vapor in the upper troposphere and lower stratosphere in a continuing effort to determine satellite data quality and quantify observed variability. Water vapor is valuable in this region for the information it provides regarding transport, especially the exchange between the troposphere and stratosphere via the extratropical tropopause. Detailed comparisons have been made between water vapor measurements from satellite data (SAGE II using solar occultation measurements and MLS using microwave limb emission) and aircraft measurements (ER/2 data from Harvard); these show reasonable agreement (see Figure), providing evidence for the validity of satellite measurements in this region. All three data sets show relatively high values of water vapor in the lower stratosphere (compared to the middle and upper stratosphere), which demonstrates the importance of rapid transport processes in midlatitudes between the troposphere and stratosphere. Furthermore, the large seasonal cycle (with maximum in summer) demonstrates a seasonal modulation of these transport characteristics. Ongoing analyses of meteorological data are aimed at quantifying transport in this region.

Boris Khattatov has continued development of data assimilation as applied to stratospheric constituent data. A method for assimilating observations of ozone was implemented in the three-dimensional global stratospheric chemistry transport model ROSE, in collaboration with Pieternel Levelt (a long-term visitor from Royal Netherlands Meteorological Institute). The assimilation model contains an extensive photochemical scheme which includes heterogeneous chemistry and uses temperature and wind fields from the United Kingdom Meteorological Office stratospheric analysis. Ozone measurements from the MLS instrument on UARS were assimilated in the model using the sequential statistical interpolation approach. The results provide improved global three-dimensional distributions of ozone for use in further scientific or modeling studies. For further validation, the stratospheric total ozone fields computed from the analyses are compared with TOVS total ozone measurements, showing good agreement within uncertainty of the data.

The UARS satellite has been providing continuous measurements of stratospheric constituents since 1991 (and is currently still in operation). William Randel has used these data to quantify trends in stratospheric constituents CH_4, H_2O, HF, HCl, CO, O_3, NO_2, and HNO_3 over the period 1991-98. Each of these constituents exhibits significant trends over at least some region of the stratosphere during this time, and many of the trends were unanticipated (and remain unexplained). For example, there are negative trends in upper stratospheric CH_4 and positive trends in H_2O throughout the stratosphere which are of unknown origin. There are also significant changes in the reactive nitrogen budget, with increases in NO_2 and decreases in HNO_3. Many of the trends appear to weaken (or change sign) after 1996; such changes in the long-lived species suggest a modulation of the large-scale stratospheric circulation about this time.

William Randel has also been involved with evaluation of stratospheric ozone and temperature trends for the 1998 WMO/UNEP Ozone Assessment and WCRP Stratospheric Processes and their Role in Climate (SPARC) Assessments. Evaluation of long record of global data shows that the most dramatic ozone and temperature changes occur in the stratosphere over both polar regions in spring. Time series of polar ozone and temperature which extend back to the 1950's show a near step-like decrease in Antarctic temperatures during the 1980's (of order 10 K), coincident with appearance of the Antarctic 'ozone hole'. Furthermore, the Arctic has exhibited a string of unusually cold and low ozone years in the 1990's (similar to the Antarctic changes approximately one decade earlier (see Figure). Results from general circulation model simulations demonstrate that the Antarctic temperature changes are primarily a response to the (chemical) ozone depletion. Although similar calculations have not been performed for the Arctic case, the similarity in space-time patterns between the hemispheres suggests that the radiative response to ozone loss is an important process in this region also.



Mechanisms for the Oxidation of Biogenic Species

The most abundant natural volatile organic compounds emitted by vegetation are isoprene and a variety of monoterpenes, such as α -pinene and b -pinene. The oxidation of these compounds and their by-products, particularly in the vicinity of anthropogenic NO_x emissions, has been shown to contribute significantly to the production of ozone and other secondary pollutants (including organic aerosol) in many rural and urban areas. Thus, studies of their atmospheric fate is crucial to the assessment of their contribution to regional air quality issues.

The Laboratory Kinetics Project in ACD has continued studies on the atmospheric fate of biogenic hydrocarbons. The work has primarily been carried out in a temperature-regulated "environmental chamber", coupled to a Fourier transform IR spectrometer for product quantification. The work has involved collaborations between John Orlando and Geoff Tyndall, Suzanne Paulson (University of California, Los Angeles); Yinon. Rudich (Weizmann Institute, Israel); Camilla Bacher (University of Copenhagen), and Barbara Nozikre and Laura Iraci (ASP post-doctoral fellows).

Recent studies have included the determination of the first generation products of the OH-initiated oxidation of a number of terpenes, including α - and b -pinene, terpinolene, and myrcene. Among the key findings was the identification of acetone (a key species in the generation of HO_x radicals in the free troposphere) as a major product in the oxidation of terpinolene and myrcene, and as a minor product in the oxidation of the pinenes. Complementary studies of the O_3-initiated oxidation terpene oxidation mechanisms are being carred out at UCLA.

Studies have also continued on the fate of some of the partially oxidized by-products of isoprene chemistry. The OH-initiated oxidation of methacrolein has been studied. Products identified include methylglyoxal, hydroxyacetone, CO, CO_2, MPAN, and formaldehyde, and a new reaction pathway has been postulated to explain the product distribution. In addition, the first quantitative UV absorption spectrum of glycolaldehyde has been obtained, which shows that photolysis will be of only minor importance in the atmospheric destruction of this species. Finally, Henry's law constants for methacrolein and methyl vinyl ketone have been obtained by Iraci and Brad Baker (University of Colorado), which show that these species are not highly soluble in aqueous media, and hence will remain in the gas phase under typical atmospheric conditions.

Overtone Spectra

The Laboratory Kinetics Project was involved in two collaborative projects to measure the intensities of vibrational overtone spectra. Normally these spectral transitions are considered to be too weak to be of any consequence, and consequently they have not received much attention. However, in a recent study Donaldson et al. (*Geophys. Res. Lett.*, **24**, 1997) suggested that certain molecules could absorb sufficient energy in the overtones of the -OH stretch to dissociate and form OH radicals. Normally production of OH is limited by the availability of ultraviolet light, which is in short supply particularly at low sun angles and in winter. Thus, the formation of OH by the absorption of infrared light would be a facile process that could "kickstart" the chemistry, say, at the edge of the polar vortex.

Measurements were made at NCAR of the vibrational overtone spectrum of nitric acid, a common stratospheric component, by Orlando and Tyndall in collaboration with Jamie Donaldson (University of Toronto) and Veronica Vaida (University of Colorado). The measured absorption strengths were up to a factor of two higher than those assumed by Donaldson et al. Theoretical calculations were performed by R. Pross and Brian Henry (University of Guelph) that confirmed the measured values and also extrapolated them out to higher energies that were inaccessible experimentally.

In order to confirm the trend found for nitric acid, measurements were made on a series of alcohols, which also contain the -OH group, by Orlando, Tyndall, Vaida and James Phillips (University of Colorado, now at University of Wisconsin, Eau Claire). These measurements were accompanied by an empirical analysis performed by Phillips relating the intensities of the transitions to some simple molecular parameters. Good consistency was found between the various molecules, suggesting that the methods used could be used to estimate the absorption strengths of other, unstable molecules that may not lend themselves to experimental study.

Regional and Process Studies

Regional Modeling

The first version of the regional nested chemical transport model (HANK) has been completed by Peter Hess, and model runs for the Pacific Basin have been analyzed extensively. Detailed comparisons have been made with chemical observations from the MLOPEX Spring 1992 field intensive. Analysis of radon simulations were made at several resolutions. Mary Barth and Hess implemented aqueous chemistry in HANK and simulations were performed to examine the effect of cloud chemistry on ozone concentrations. Results show that for boundary layer clouds the aqueous chemistry may deplete ozone by 10-14% over a 10 day period. The sensitivity of this result to the pH of the cloud and rain drops will be investigated next. Simulations of STERAO observations are being carried out by Hess and Jordan Powers (MMM). A nested non-hydrostatic version of the regional model coupled to MM5 is nearly complete.

Lower Stratosphere-Upper Troposphere Modeling

Hess and Jean-Francois Lamarque continued studies of stratosphere-troposphere exchange and its effect on tropospheric chemistry, and (with William Randel) on the seasonal transport of ozone and water vapor into the lower stratosphere. Hess and Xuexi Tie also completed a study of the effects of volcanic eruptions on the ozone mass exchange between the stratosphere and the troposphere.

Hydrocarbon Modeling

Hydrocarbon oxidation intermediates may dissolve in aqueous aerosols and be a significant sink for gas-phase multi-functional species, as well as a good source of the observed aerosol organic fraction, according to a modeling study completed by Sasha Madronich and Bernard Aumont (University of Paris). The results are sensitive to the gas phase mechanism being used, so we are developing a new, more explicit master mechanism that is generated in part by coded chemical instructions. We have also completed a modeling study of the NO_2 + soot reaction in polluted environments, confirming very recent studies that that the latter is also a source of HONO. Madronich and Marcy Litvak (University of Colorado) carried out a modeling study of how the chemistry of the forest boundary layer is influenced by high emissions of terpenes seen after herbivore infestation. Enhanced ozone production was noted for ranges of NO_x that are not uncommon in such environments.

Madronich and Stephanie Rivale (SOARS student) have began to study how Mexico City pollution attenuates sunlight and consequently alters its own chemistry. Initial model results show large effects on photochemical rate coefficients, with some implications for strategies of smog reduction. These studies will be extended to use more realistic atmospheric input data (in collaboration with Graciela Raga, National Autonomous University of Mexico) and to examine the effects on ozone formation by NO_x-hydrocarbon mixtures (in collaboration with Jana Milford, University of Colorado).

UV-Visible Modeling

The Tropospheric Ultraviolet-Visible (TUV) model continues to be applied to scientific issues, in addition to being improved and supported for the broad user community. Madronich and Bernhard Mayer (Fraunhofer Institute for Atmospheric Environmental Research, Germnich) studied photon-pathlength enhancements in clouds using a Monte Carlo model, the TUV model, and spectral UV measurements. Both models indicated a ca. 30-fold path enhancement and high sensitivity to absorbers such as tropospheric ozone and aerosols. In a related study, the actinic flux enhancement in spherical droplets was re-estimated based on Mie calculations. Madronich and Richard McKenzie (New Zealand Institute for Water and Air Research) used the TUV model and spectral UV observations to characterize the effects of snow reflectivity on the down-welling sky radiation. Additional validation of TUV is ongoing through participation in the International Photolysis Frequency Measurement and Model Intercomparison (15-19 June 1998, Boulder).

Madronich, Mayer, and Chris Fischer have combined TUV with satellite-based observations of ozone and clouds, to generate global maps of spectral UV irradiance at the Earth's surface. This satellite-derived UV climatology is being evaluated with longer-term UV measurements now becoming available (see illustration). The method has now been extended to compute actinic fluxes, and therefore photolysis rates, near the surface.

Global Modeling

The focus of the Global Modeling project during FY-98 has been on the development and use of global chemical transport model with emphasis on ozone and related trace species in the troposphere and the middle atmosphere. The following models have become the major tools of the Project:

- SOCRATES: Two-dimensional chemical dynamical radiative model (0-120 km)
- IMAGES: Simplified three-dimensional chemical transport model of the troposphere
- MOZART: Detailed three-dimensional chemical transport model of the troposphere
- ROSE: Mechanistic three-dimensional chemical dynamical model of the stratosphere and mesosphere
- STARS: Detailed three-dimensional chemical transport model of the stratosphere

These models have been used to address specific scientific questions.

1. Troposphere

The IMAGES model has been used by J. F. Muller (visitor, Belgian Institute for Space Aeronomy) and Guy Brasseur to investigate the budget of HO_x in the upper troposphere. It has been shown that the major source of OH is generally proved by the photolysis of ozone and the reaction of electronically excited oxygen atoms with water vapor in most of the troposphere, except in the tropical upper troposphere, where the convective transport of organic compounds from the surface including acetone and aldehydes provides a major source of HO_x. A paper on this subject will soon be published in the *Journal of Geophysical Research*.

IMAGES has also been used by Brasseur, Jeffrey Kiehl, Timothy Schneider (both CGD) and other colleagues to assess the changes in the global abundance of tropospheric ozone since the pre-industrial era and the consequences of these changes on the climate forcing. A simulation has also been made to predict expected changes in the future (1990-2050), on the basis of an adopted IPCC scenario for future emissions of chemical compounds. Special attention has been given to the impact of biomass burning, fossil fuel combustion and aircraft emissions on the ozone budget. A paper summarizing the results of this study will be published in *Geophysical Research Letters*.

Finally, IMAGES has been used by Claire Granier (visitor, NOAA Aeronomy Laboratory) and Brasseur to evaluate the global budget of carbon monoxide, and quantify the contribution of several CO sources to the observed CO distribution. A paper on the subject has been accepted by *Chemosphere*.

The first version of the MOZART model has been completed and is now released. Details on the description of the model can be found on the ACD web page. The model can also be downloaded from the Web by interested users in the scientific community.

Two papers on the description and validation of MOZART are in press in the *Journal of Geophysical Research*. A specific effort has been made by Louisa Emmons visitor, University of Michigan)and Didier Hauglustaine to compare the model results with available observations. For this purpose, Emmons has developed a comprehensive data base that includes in a standardized format many of the existing measurements of chemical compounds in the troposphere.

MOZART has been used by Hauglustaine and colleges to address several scientific issues: (1) the impact of the current fleet of subsonic aircraft on the formation of tropospheric ozone; (2) the impact of biomass burning, and specifically of the intense fires that took place in Indonesia during the last El Nino event; (3) the changes in the chemical composition and the the climate forcing since the pre-industrial period. Papers on these issues are in preparation.

The second version of MOZART is currently being tested, and should be released in FY-99. This version makes use of the MATCH model developed by Philip Rasch (CGD) to treat resolved advection and sub-scale transport. The winds and temperature are provided either from the NCEP analysis (are representative of observed situations) of from CCM-3 (and should be regarded as climatological values). MOZART -version 2 will first be used in an episodic mode to analyze observations obtained during field campaigns.

Finally, an aerosol module is currently being developed by Xuexi Tie to be included in MOZART. This module focuses on sulfate aerosols, and is very similar to the sulfate code developed by Kiehl, Rasch and Mary Barth, but account for the size distribution of aerosols. An additional effort to include mineral dust in the model is currently underway and is under the responsibility of Charles Zender (visitor, unaffiliated). Finally, a more detailed description of the exchanges of chemical compounds between the continental biosphere and the atmosphere is being implemented in MOZART, using the NCAR Land Surface model (LSM) as the biospheric model.

2. Middle Atmosphere

Development has continued on the three-dimensional ROSE model of the middle atmosphere. The dynamical formulation has been improved so that the model now does a good job of simulating the diurnal and semidiurnal tides as well as the zonal mean fields. Since this is one of the few existing tidal models that includes full three-dimensional dynamics, it will be valuable for investigation of a number of factors related to tidal variability and tidal interactions with other wave modes. The chemistry is being rewritten to be more accurate and versatile, and will be incorporated back into the model once it is complete.

Rashid Khosravi, Anne Smith and Guy Brasseur have used the ROSE model to investigate the budget of ozone in the upper stratosphere.

Different model runs have been performed by constraining various chemical compounds using observations by the UARS satellite. The study has revealed the underestimation of ozone by many stratospheric models is probably associated with an incorrect partitioning of chlorine compounds in the upper stratosphere or/and an overestimation of the ozone loss rate by HO_x radicals.

The ROSE model has also been used by Martin Riese (visitor, University of Wuppertal) to analyze the high-resolution observations of chemical compounds in the stratosphere provided by the CRISTA instrument onboard the Space Shuttle. Good agreement has been found between the observed and calculated distributions when analyzed winds are used to force the model. An assimilation technique has been used to provide global distributions of chemical compounds during the period of observation.

The new version of the two-dimensional SOCRATES model has been completed, and is currently being validated and verified. A detailed description of this new model has been posted on the ACD web page. Some improvements to the model are still being implemented.

The two-dimensional SOCRATES model is being used for investigations of the chemistry of the upper part of the middle atmosphere. As new data become available, comparisons are made and we get a clearer idea of the strengths of weaknesses of the model chemistry formulation. One effort now underway by Brad Sandor (post-doctoral student) is modeling of atomic hydrogen exchange between H_2 and H_2O. The existence of unappreciated processes for converting H_2 to H_2O has been suggested as a possible explanation for surprisingly large H_2O abundances near 65 km in recent global satellite data. Sandor is adding deuterium to the model and will compare results with measurements of the HDO/H_2O ratio, which is unexpectedly large and variable. It is believed that this will shed light on isotope differences in reaction rates and lead to a better understanding of the hydrogen-oxygen chemical system.

Rolando Garcia has completed work (with Susan Solomon and Robert Portmann, NOAA Aeronomy Laboratory) on detailed modeling of ozone depletion, taking into account observed changes in aerosol loading and temperature. The effect of the QBO as well as interannual variability in wave forcing will also be included, using NMC data as the boundary condition for the planetary wave model. The aim is to determine whether the behavior of ozone over the last 20 years can be explained in terms of current understanding of photochemistry and dynamics.

With Fabrizio Sassi and Byron Boville (CGD) Garcia has determined the characteristics of transport in the lowermost stratosphere as simulated by CCM3; compare with observations and use as guidance for the development of better parametrizations in 2D models. Investigate the dependence of age of air on physical processes and numerical transport schemes used in the model.

With Lucrezia Ricciardulli (visitor, University of L'Aquilla), James Hack, and Jeffrey Kiehl (both at CGD), Garcia has published results obtained with standard version of CCM3 using Zhang and Hack deep convection parameterizations. They conducted and analyzed runs with high-resolution version of middle-atmosphere CCM3. They verified whether wave flux into middle atmosphere estimated via projection of convective heating onto Hough modes is consistent with direct determination from model fields in the lower stratosphere. Garcia also tested various convective parameterizations and compare the vertically-propagating wave spectrum obtained with each. The ultimate aim is to determine whether GCMs (CCM3 in particular) underestimates the excitation of short period, smaller-scale waves that may be important for the QBO and SAO, and to develop the space-time spectral analysis of convection into a diagnostic tool to assess the ability of convective parameterizations to force a realistic spectrum of tropical waves.

Joseph Prusa (Iowa State University) and Garcia will include an extension of his gravity wave model to three dimensions. They will examine the propagation into the upper atmosphere of waves forced by realistic sources, e.g., convection, squall lines, flow over topographic obstacles. The ultimate goal is to prepare a modeling tool to interpret observations that may be made by the planned CEGWE experiment.

Garcia collaborated with Hugh Pumphrey (University of Edinburgh) in interpreting the reprocessed MLS water vapor data set using the Garcia-Solomon model.

Data

Several observational studies have been concluded by Anne Smith that look at the tropical mesosphere using global satellite data. The High Resolution Doppler Imager (HRDI) instrument on UARS made multi-year measurements of winds in the mesosphere. These show strong evidence of stationary planetary scale variations, including the intermittent presence of a Kelvin wave during the easterly phase of the semi-annual oscillation.

Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) spectra have been inverted to give very high horizontal resolution profiles of temperature and a number of trace gases in the middle atmosphere. In a study just completed by Smith, CRISTA data during the first (November, 1994) flight reveal clear indications of inertially unstable circulation cells in the tropics and subtropics of the Northern Hemisphere. These circulations move air in the horizontal and vertical directions. Since they occur at times and locations when planetary waves from midlatitudes extend into the subtropics, they can augment the mixing associated with planetary wave breaking.

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High Resolution Dynamics Limb Sounder (HIRDLS): Space Observations of Stratospheric and Upper Tropospheric Composition

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Visitors and Collaborators

Sylvie Aubry, I.U.I. Louis Pasteur, France, stratospheric measurements, October 1995 to June 1997.

Bernard Aumont, Universite Paris 7, Paris12, France, regional and process studies, March 1997 to September 1997.

Brad Baker, University of Colorado, biosphere-atmosphere interactions, January 1996 to December 1998.

Alan Bandy, Drexel University, PEM Tropics, September 4-5, 1997.

William Baugh, University of Colorado, biosphere-atmospheric interactions, July 1994 to June 1998.

Rachel Beaule, University of Lyon I, France, global modeling, April 1996 to December 1997.

Merete Bilde, University of Copenhagen and Riso, Denmark, laboratory kinetics, January 1997 to May 1997.

Lane Bishop, Buffalo Research Laboratory, ozone trends assessment meeting, 12-13 May 1997.

Nicola Blake, University of California, Irvine, PEM Tropics, September 4-5, 1997.

Ronald Bosch, Netherlands Meteorological Institute, regional and process studies, February 1997 to September 1997.

Olivier Bourion, National Institute of Applied Science in Lyon, France, odd nitrogen studies, July 1997 to December 1997.

Simon Cantrell, Earth Observation Sciences, Ltd., MOPITT, 7 July 1997.

Mariah Carbone, Wesleyan University, biosphere-atmosphere interactions, June 199

7 to August 1997.

Julius Chang, State University of New York, Albany, methane chemistry program review, July 28-29, 1997.

Gao Chen, Georgia Institute of Technology, PEM Tropics, September 4-5, 1997.

Martyn Chipperfield, University of Cambridge, UNEP meeting, August 12-15, 1997.

Anthony Clark, University of Hawaii, PEM Tropics, September 4-5, 1997

Jonah Colman, University of California, Irvine, PEM Tropics, September 4-5, 1997.

Geoffrey Cornstine, NASA Langley Research Center, PEM Tropics, September 4-5, 1997.

Elizabeth Courter, University of Colorado, carbon and nitrogen biogeochemistry, May 1996 to September 1996.

David Creasey, University of Leeds, United Kingdom, HO_x Radicals, 10-13 December 1996.

Dirk DeMuer, Meteorological Institute of Belgium, ozone trends assessment meeting, 12-13 May 1997.

Mark Dombrowski, NASA Goddard Space Flight Center, HIRDLS, July 1995 to December 2002.

James Drummond, University of Toronto, Canada, MOPITT, 22-25 January 1997.

Louisa Emmons, University of Michigan, tropospheric chemistry, 9-14 December 1996.

Corinne Ferronato, Institute de Technologie, France, laboratory kinetics, March 1997 to September 1997.

Gene Francis, University of Colorado, global and stratospheric studies, September 1993 to December 1996.

Paul Ginoux, University of Brussels, Belgium, global modeling, March 1991 to February 1998.

Arun Gopalan, State University of New York, Stony Brook, UARS, December 19993 to May 1998.

Claire Granier, NOAA/CNRS, global modeling, January 1997 to December 1998.

Allen Grossman, Lawrence Livermore National Laboratories, methane chemistry program review, July 28-29, 1997.

Chris Halvorson, unaffiliated, HIRDLS/MOPITT, June 1991 to March, 1998.

Jean-Luc Hamm, I.U.I. Louis Pasteur, France, standards and intercomparisons, October 1996 to June 1997.

Alexis Hartz, University of Colorado, carbon and nitrogen biogeochemistry, June 1996 to June 1997.

Didier Hauglustaine, Universite Paris VI, global and stratospheric studies, November 1996 to November 1998.

Wenderlyn Hernandez, Universidad Metropolitana, Puerto Rico, biosphere-atmosphere interactions, June 1997 to August 1997.

Wei Min Hao, USDA Forest Service, global and stratospheric studies, August 18, 1997.

Peter Haynes, University of Cambridge, UNEP meeting, 12-15 August 1997.

Stacey Hollandsworth, NASA Goddard Space Flight Center, ozone trends assessment meeting, 12-13 May 1997.

Zaichun Hu, Chinese Academy of Sciences, atmospheric modeling and data analyses techniques, November 1996 to May 1998.

Theresa Huang, University of Michigan, methane studies, March 1993 to March 1998.

Barry Huebert, University of Hawaii, HO_x measurements, September 4-5, 1997.

Anne Jefferson, University of Colorado, HO_x measurements, August 1997 to December 1998.

Brian Johnson, University of Michigan, HIRDLS, July 1995 to July 1997,

S. Randy Kawa, NASA Goddard Space Flight Center, UNEP meeting, 12-15 August 1997.

Carla Kegley-Owen, University of Colorado, laboratory kinetics, July 1993 to May 1998.

Boris Khattatov, State University of New York, Stony Brook, HIRDLS/MOPITT/UARS, January 1996 to April 1998.

Raschid Khosravi, University of Colorado, global modeling, January 1995 to February 1998.

V. R. Kotamarthi, University of Illinois, global and stratospheric studies, August 18, 1997.

Julia Lee-Taylor, University of East Anglia, global modeling, August 1997 to February 1998.

Pieternel Levelt, Royal Netherlands Meteorological Institute, validation of atmospheric models; February 1997 to July 1997.

Roy Leon Mauldin, NOAA/CIMDL, HO Measurements, April 1994 to April 1998.

x

Denise Montzka, NOAA, odd nitrogen studies, October 1996.

Weng-Mui Lee, The Blackett Laboratory, United Kingdom, optical techniques, July 1997 to September 1997.

Edeltraud Leibrock, IFU Fraunhofer Institute, Germany, regional and process studies, 16-18 May 1997.

Jennifer Logan, Harvard University, ozone trends assessment meeting, 12-13 May 1997.

Robert Lott, Gas Research Institute, methane chemistry program review, July 28-29, 1997.

Robin Martin, Colorado State University, carbon and nitrogen biogeochemistry, October 1996 to September 1997.

John Mak, State University of New York at Stony Brook, laboratory kinetics, August 1997.

Martin Muller, Institut fur Atmosphamsche Chemie, Germany, PEM Tropics, February 1996 to February 1998.

Kenkichi Nagato, Kochi National College of Technology, Japan, HO_2 measurements, October 1996 to September 1997.

Raymond Najjar, The Pennsylvania State University, global and stratospheric studies, August 18, 1997.

Jason Neff, Stanford University, carbon and nitrogen biogeochemistry, July 1996 to Octber 1998.

Michael Newchurch, University of Alabama in Huntsville, ozone trends assessment meeting, 12-13 May 1997.

Kai Ling Ng, University of Tasmania, biosphere-atmosphere interactions, January 1997 to April 1997.

Stuart Penkett, University of East Anglia, atmospheric chemistry, July 1997 to August 1997.

Jai-Ho Oh, Iowa State University, regional and process studies, 5-9 January 1997.

Sam Oltmans, NOAA/CMDL, ozone trends assessment meeting, 12-13 May 1997.

Daniel O'Sullivan, United States Naval Academy, PEM Tropics, September 4-5, 1997.

Sue Owen, Lancaster University, biosphere-atmosphere interactions, August 1997 to September 1997.

Kenneth Patten, Jr., University of Illinois, global and stratospheric studies, August 18, 1997.

Thomas Peter, Max Planck Institute for Chemistry, Germany, UNEP meeting, 12-15 August 1997.

R. Alan Plumb, Massachusetts Institute of Technology, UNEP meeting, 12-15 August 1997.

Richard Powers, University of Nebraska at Lincoln, HIRDLS, June 1997 to February 1998.

Joseh Prusa, Iowa State University, atmospheric chemistry modeling, 5-9 January 1997.

A. Ravi Ravishankara, NOAA Aeronomy Laboratory, UNEP meeting, 12-15 August 1997.

Thomas Reimer, Max Planck Institut fur Chemie, Germany, HO_2 Measurements, 10 June 1997.

John Remedios, Clarendon Laboratory, United Kingdom, HIRDLS, August 1997-November 1997

Lucrezia Ricciarduli, University of L'Aquila, Italy, analysis and modeling of the tropical quasi-biennial oscillation, January 1997 to January 1998.

Karla Rivas-Rivera, Universidad Metropolitana, global and stratospheric studies, June 1997 to August 1997.

Joseph Sabuda, University of California, Los Angeles, UARS, November 1995 to May 1997.

Murry Salby, University of Colorado, global modeling, January 1992 to December 1998.

Eric Saltzman, University of Miami, HO_2 Measurements, 13-14 February 1997.

Fabrizio Sassi, Universita Degllia Studie L'Aquila, Italy, global measurements, October 1994 to March 1998.

Schonbeck, Niels, Metropolitan State College, March 1996 to February 1998.

Christophe Seuzaret, Elf Aquitaine, Inc., global and stratospheric studies, January 1996 to December 1997.

Theodore Shepherd, University of Toronto, Canada, UNEP meeting, 12-15 August 1997.

Christoph Spirig, Swiss Federal Institute of Technology, ecosystem studies, July 1996 to January 1997.

John Stanford. Iowa State University, UARS, 5-15 November 1996.

Richard Stolarski, NASA Goddard Space Flight Center, 23-30 January 1997.

Anne Struss, I.U.I. Louis Pasteur, France, odd nitrogen, October 1996 to June 1997.

James Sulzman, unaffiliated, ecosystem studies, June 1994 to June 1998.

W. H. Taylor, unaffiliated, ecosystem studies, May 1995 to October 1996.

Donald Thornton, Drexel University, PEM Tropics, September 4-5, 1997.

Alan Townsend, Harvard University, biogeochemistry/biosphere atmosphere exchange, May 1996 to January 1997.

Wilma Trawnicek, Fachlochschule Aachen, Germany, stratospheric measurements, October 1996 to January 1998.

Veronica Valda, University of Colorado, atmospheric chemistry, July 1997 to January 1998.

Perola Vasconcellos, Universidade de Sao Paulo, Brazil, biosphere-atmosphere interactions, January 1997 to June 1998.

Gabriel Vazquez, Universidad Nacional Mexico, September 1996 to December 1996.

Lee Vierling, University of Colorado, biosphere-atmosphere interactions, May 1996 to May 1998.

Margaret Walsh, Colorado State University, carbon and nitrogen biogeochemistry, September 1997 to December 1998.

Darryn Waugh, Monash University, Australia, UNEP meeting 12-15 August 1997.

Bryan Wert, University of Colorado, optical techniques, June 1995 to June 1999.

John Whitney, Oxford University, United Kingdom, HIRDLS, 11-15 October 1996.

Oliver Wingenter, University of California, Irvine, PEM Tropics, September 4-5, 1997.

Douglas Worsnop, Aerodyne Research, UNEP meeting, 12-15 August 1997.

Donald Wuebbles, University of Illinois, global and stratospheric studies (August 19, 1997) and methane chemistry program review, (July 28-29, 1997).

Peicai Yang, Chinese Academy of Sciences, global and stratospheric studies, October 1997 to December 1997.

Jiangfen Zheng, NOAA/CMDL, odd nitrogen studies, January 1996 to August 1997.

Audrey Zimmer, I.U.I. Louis Pasteur, France, Laboratory Kinetics, October 1996 to June 1997.