NASA/TM—2003-212241

Laboratory for Atmospheres 2002 Technical Highlights

Goddard Earth Sciences Division - Atmospheres

May 2003

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Laboratory for Atmospheres 1997 Technical Highlights

Goddard Earth Sciences Division - Atmospheres
Goddard Space Flight Center

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

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Laboratory for Atmospheres

2002 ORGANIZATION, MAJOR ACTIVITIES, and HIGHLIGHTS

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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Cover Caption

Center: Hanger 981, Boca Chica Key West, where five aircraft (in order, ER-2, Proteus, WB-57, Twin Otter, Citation) plus NRL P3 and 200+ investigators teamed to execute the CRYSTAL-FACE mission in July 2002. Upper right: July 11 storm viewed from Ochopee (picture courtesy of Ed Zipser, U. Utah). Upper left: Similar convective storm sampled on July 9 (picture courtesy Proteus pilot). Top Center: Dave Starr (right) and J.V. Nystrom (left) at the NASA NPOL radar site at Ochopee in the Florida Everglades directing all six aircraft in a coordinated flight pattern around, within, above, and below a storm and anvil system. Lower: Time/space-dependent vertical profile of reflectivity from GSFC Cloud Radar System, a 95 GHz CloudSat simulator, observed from the NASA ER-2 over about a 100 km flight leg on July 23, 2002. Deep convective clouds to 15 km altitude are seen as well as the associated dense anvil system produced by these clouds. The effects of signal attenuation are seen in the lower portion of the deepest thunderstorm. A brightband (melting layer signature) is seen in the other (left) thunderstorm. Cumulus congestus are seen below the main anvil as well as away from the main storms. The tilt in the upper portion of the storms is due to vertical shear of the winds. Further details of the CRYSTAL-FACE mission are given in the Highlights section of the report.

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Laboratory Chief's Summary

Dear Reader:

Welcome to the Laboratory for Atmospheres' annual report for 2002. I thank you for your interest. We publish this report each year to describe the Laboratory and its work and to summarize our accomplishments.

We intend this document to address a broad audience. Our readers include managers and colleagues within NASA, scientists outside the agency, graduate students in the atmospheric sciences, and members of the general public. Inside, you'll find descriptions of our work scope, our people and facilities, our place in NASA's mission, and our accomplishments for 2002.

The Laboratory's more than 400 scientists, technologists, and administrative personnel are part of the Earth Sciences Directorate of NASA's Goddard Space Flight Center. Together, we pursue our mission of advancing the knowledge and understanding of the atmospheres of the Earth and other planets. In doing so, we contribute directly to two of NASA's primary Enterprises, Earth Science and Space Science.

We accomplished much in 2002. Laboratory scientists hosted 55 seminars given by outside scientists, 42 seminars were given by Laboratory scientists at Goddard, and more than 61 seminars were presented by our scientists at outside institutions. We participated in 101 workshops, 32 science team meetings, 10 science policy meetings, 12 conferences, published 200 refereed papers, hosted 176 short-term visiting scientists, and took part in an array of educational activities.

The Laboratory continued its active role in developing and calibrating new and improved instruments for spaceflight and field campaigns. In Section 4, we highlight SOLSE/LORE (Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment) and CPL (Cloud Physics Lidar) instruments.

The Laboratory had an exciting year participating in international field campaigns and in making major advances in scientific discovery and development of data sets. Laboratory scientists organized and played lead roles in CRYSTAL-FACE, IHOP, SOLVE II, and CONTOUR. In Section 5, we presented scientific highlights which include, among others:

- Observing System Simulation Experiments showing that assimilation of space-based lidar wind profiles can lead to very substantial improvement in the accuracy of weather forecasts.

- Development of a new near real-time 3-hourly global rainfall data set based on TRMM rainfall algorithms, and demonstration that TRMM rainfall data can be used to improve El Niño prediction.

- Numerical experiments with the Goddard Cumulus Ensemble model to provide better understanding of convection and circulation characteristics in diverse climatic regimes such as the Amazon, the central U.S., Western Pacific and the South China Sea.

- Publication of an authoritative review in Nature providing a satellite view of natural and anthropogenic aerosols in the climate systems based on data from MODIS, TOMS and other space-based and ground-based remote sensing platforms.

- Observational evidence from SOLVE II of ozone loss in the polar stratosphere due to catalytic chorine and bromine reactions by polar stratospheric clouds during the winter of 2002–2003.

The year 2002 was also a time to bid farewell to valuable members of the Laboratory, Art Aikin, Andrea Ledvina, C-H Sui, and Cindy Lewis.

I am pleased to greet new civil servants in the Laboratory, Mian Chin, Belay Demoz, Alexander Marshak, Steve Platnick, and Judd Welton.

Sincerely,

William K.-M. Lau,
Chief, Laboratory for Atmospheres, Code 910

May 2003

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Mission: To Advance Knowledge and Understanding of the Atmospheres of the Earth and Other Planets

1. INTRODUCTION

How can we improve our ability to predict the weather-tomorrow, next week, and into the future?

How is the Earth's climate changing? What causes such change? And what are its costs?

What can the atmospheres of distant planets teach us about our own planet and its evolution?

The Laboratory for Atmospheres is helping to answer these and other scientific questions about our planet and its neighbors. The Laboratory conducts a broad theoretical and experimental research program studying all aspects of the atmospheres of the Earth and other planets, including their structural, dynamical, radiative, and chemical properties, with the overarching goal to provide better understanding and to improve prediction of the Earth's climate.

Vigorous research is central to NASA's exploration of the frontiers of knowledge. NASA scientists play a key role in conceiving new space missions, providing mission requirements, and carrying out research to explore the behavior of planetary systems, including, notably, the Earth's. Our Laboratory's scientists also supply outside scientists with technical assistance and scientific data to further investigations not immediately addressed by NASA itself. Laboratory scientists submit competitive research proposals with diverse scientific or technological approaches to NASA and other Federal agencies to acquire research support. The Laboratory management strives to provide a working environment that promotes creativity, competition, and openness.

The Laboratory for Atmospheres is a vital participant in NASA's research program. Our Laboratory often has relatively large programs, sizable satellite missions, or observational campaigns that require the cooperative and collaborative efforts of many scientists. We ensure an appropriate balance between our scientists' responsibility for these large collaborative projects and their need for an active individual research agenda. This balance allows members of the Laboratory to continuously improve their scientific credentials.

The Laboratory places high importance on promoting and measuring quality in its scientific research. We strive to assure high quality through peer-review funding processes that support approximately 90% of the work in the Laboratory. The overall quality of our scientific efforts is evaluated periodically by committees of advisors from the external scientific community, as detailed in Appendix 2 of this document.

Members of the Laboratory interact with the general public to support a wide range of interests in the atmospheric sciences. Among other activities, the Laboratory raises the public's awareness of atmospheric science by presenting public lectures and demonstrations, by making scientific data available to wide audiences, by teaching, and by mentoring students and teachers. Section 6 presents details of the Laboratory's outreach activities during 2002. The Laboratory is also committed to addressing the demographic imbalances that exist today in the atmospheric and space sciences. We must address these imbalances for our field to enjoy the full benefit of all of the Nation's talent. The Laboratory makes substantial efforts to attract new scientists to the fields of atmospheric and space sciences. We strongly encourage the establishment of partnerships with Federal and state agencies that have operational responsibilities to promote the societal application of Earth sciences.

The Laboratory is part of the Earth Sciences Directorate (Code 900) based at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The Directorate itself is comprised of the Global Change Data Center (902); the Earth and Space Data Computing Division (930); three laboratories–the Laboratory for Atmospheres (910), the Laboratory for Terrestrial Physics (920), and the Laboratory for Hydrospheric Processes (970); and the Goddard Institute for Space Studies (GISS) in New York, New York.

In this report, you'll find a description of our role in NASA's mission. You'll also find a broad description of our research and a summary of our scientists' major accomplishments in 2002. The report also presents useful information on human resources, scientific interactions, and outreach activities with the outside community.

For your convenience, we have published a version of this report on the Internet. Our Web site includes links to additional information about the Laboratory's Offices and Branches. You can find us at http://atmospheres.gsfc.nasa.gov/

2 STAFF, ORGANIZATION, AND FACILITIES

Staff

The diverse staff of the Laboratory for Atmospheres is made up of scientists, engineers, technicians, administrative assistants, and resource analysts. The total head count is about 415, including civil servants, associates, and contractors. The civil servant composition of the Laboratory consists of 86 “in-house” members and 13 co-located members (5 resource analysts, 1 scientist, 3 engineers and 4 technicians). Of the 86 in-house civil servants, 78 are scientists, 4 are engineers. Out of the 82 civil servant scientists and engineers, 74 (or 90%) hold doctor’s degrees, 3 hold master’s degrees, and 5 hold bachelor’s degrees. These 74 people constitute 86% of the total workforce as indicated in Figure 1.

An integral part of the Laboratory staff is composed of onsite research associates and contractors. The research associates are primarily members of joint centers between the Earth Sciences Directorate and nearby universities (JCET, GEST, and ESSIC), or are employed by universities with which the Laboratory has a collaborative relationship such as George Mason University, University of Arizona, and Georgia Tech. Out of the 92 research associates, 82 or 89% hold Ph.D.s. The onsite contractors are a very important component of the staffing of the Laboratory. Out of the total of 223 onsite contractors, 60 or 27% hold Ph.D.s.

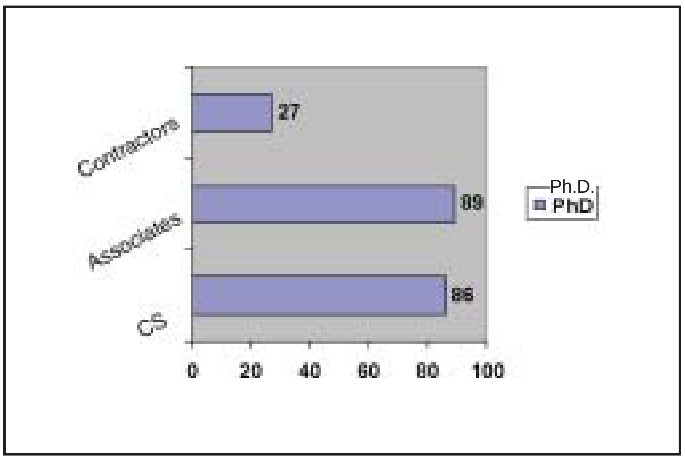

Figure 1. Percentage of Ph.D.s among Civil Servants, Associates, and Contractors in the Laboratory for Atmospheres.

A measure of the productivity of the Laboratory members and of their extensive collaboration with outside scientists is shown in the following chart, Figure 2. The extensive and increasing collaboration is borne out by the large numbers of papers having both first author and coauthor from outside our Laboratory.

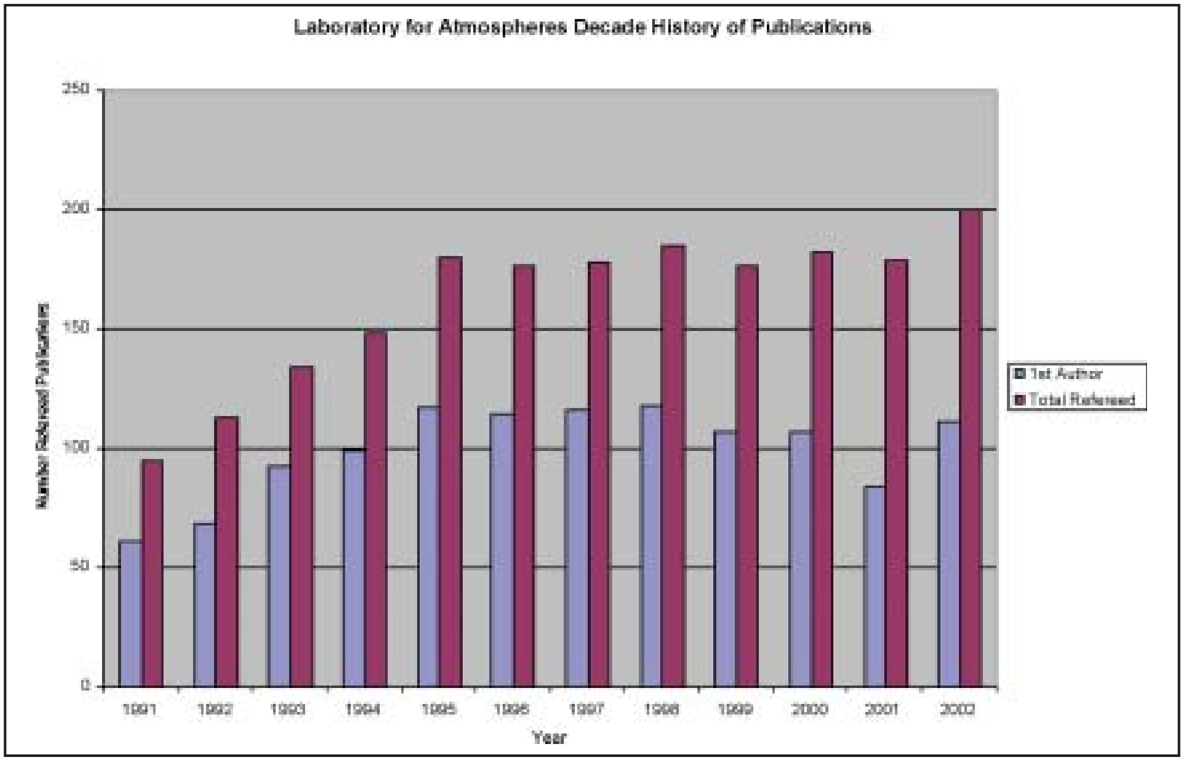

Figure 2. Chart of number of refereed publications by Laboratory for Atmospheres members over the years. Red bar is the total number of publications where a Laboratory member is a 1st author or coauthor of the paper, and the blue bar is the number of publications where a Laboratory member is 1st author. The chart exhibits a trend over time for increased collaboration, where Laboratory members are coauthors on papers written by outside scientists.

Organization

Figure 3 shows the Laboratory management structure.

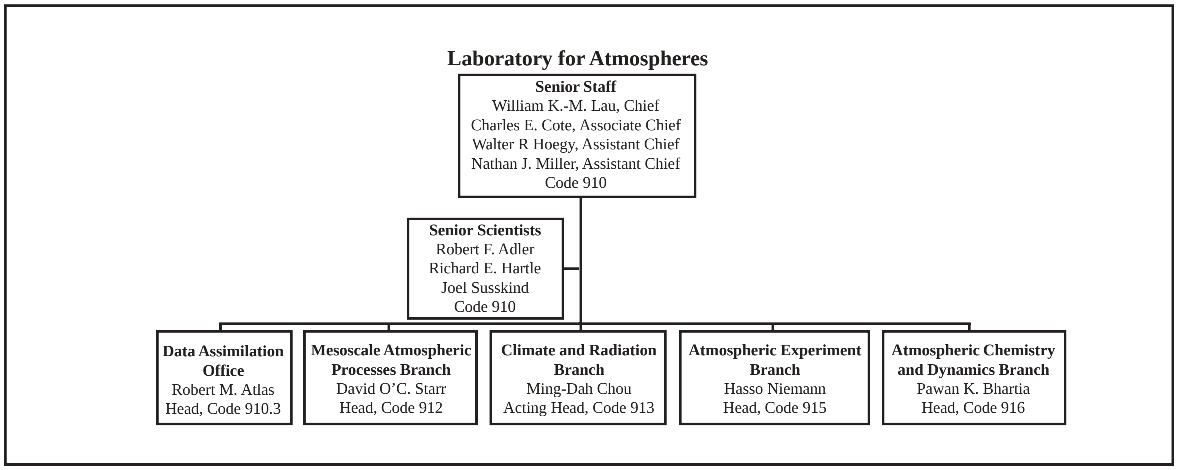

Figure 3. Laboratory for Atmospheres Organization Chart.

Branch Descriptions

The Laboratory has traditionally been organized into branches even though we work on science projects which are becoming more and more of a crosscutting nature. The organization chart exhibits our present branch organization. Branch members collaborate with each other within their branch, across branches, and across Divisions within the Directorate. Some of the recent crosscutting areas of research of interest to the Laboratory (and which are also science drivers of the Directorate) are: Global Water and Energy Cycle, Carbon Cycle, Weather and Short-Term Climate Forecasting, Long-Term Climate Change, Atmospheric Chemistry, Aerosols, and Planetary Studies. The composition of the Senior Staff Office (910) and the 5 branches is broken down by Civil Servants, Associates, and Contractors in Figure 4.

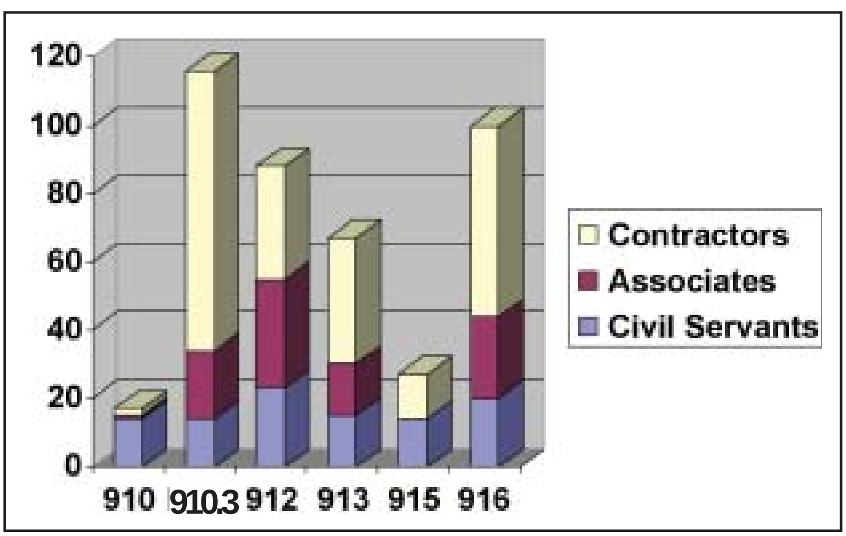

Figure 4. Employment composition of the members of the Laboratory for Atmospheres.

A brief description is given for each of the Laboratory's five Branches. In Section 5, the Branch Heads summarize the science goals and achievements of their branches, followed by science highlights.

Data Assimilation Office (DAO), Code 910.3

The DAO combines all available meteorologically relevant observations with a prognostic model to produce accurate time-series estimates of the complete global atmosphere. The DAO performs the following functions:

- Advancing the state of the art of data assimilation and the use of data in a wide variety of Earth-system problems
- Developing global data sets that are physically and dynamically consistent
- Providing operational support for NASA field missions and space shuttle science
- Providing model-assimilated data sets for the Earth Science Enterprise

For additional information on DAO activities, consult the Web (http://dao.gsfc.nasa.gov/).

Mesoscale Atmospheric Processes Branch, Code 912

The Mesoscale Atmospheric Processes Branch studies the physics and dynamics of atmospheric processes, using satellite, aircraft, and surface-based remote-sensing observations as well as computer-based simulations. This Branch develops advanced remote-sensing instrumentation (with an emphasis on lidar) and techniques to measure meteorological conditions in the troposphere. Key areas of investigation are cloud and precipitation systems and their environments–from individual cloud systems, fronts, and cyclones, to regional and global climate. You can find out more about Branch activities on the Web (http://rsd.gsfc.nasa.gov/912/code912/).

Climate and Radiation Branch, Code 913

The Climate and Radiation Branch conducts basic and applied research with the goal of improving our understanding of regional and global climate. This group focuses on the radiative and dynamical processes that lead to the formation of clouds and precipitation and on the effects of these processes on the water and energy cycles of the Earth. Currently, the major research thrusts of the Branch are climate diagnostics, remote-sensing applications, hydrologic processes and radiation, aerosol/climate interactions, seasonal-to-interannual variability of climate, and biospheric processes related to the carbon cycle. You can learn more about Branch activities on the Web (http://climate.gsfc.nasa.gov/).

Atmospheric Experiment Branch, Code 915

The Atmospheric Experiment Branch carries out experimental investigations to further our understanding of the formation and evolution of various solar system objects such as planets, their satellites, and comets. Investigations address the composition and structure of planetary atmospheres, and the physical phenomena occurring in the Earth's upper atmosphere. We have developed and are constantly refining neutral gas, ion, and gas chromatograph mass spectrometers to measure atmospheric gas composition using entry probes and orbiting satellites. You can find further information on Branch activities on the Web (http://webserver.gsfc.nasa.gov/).

Atmospheric Chemistry and Dynamics Branch, Code 916

The Atmospheric Chemistry and Dynamics Branch engages in four major activities:

- Developing remote-sensing techniques to measure ozone and other atmospheric trace constituents important for atmospheric chemistry, climate studies, and air quality
- Developing models for use in the analysis of observations
- Incorporating results of analysis to improve the predictive capabilities of models
- Providing predictions of the impact of trace gas emissions on our planet's ozone layer

For further information on Branch activities, consult the Web (http://hyperion.gsfc.nasa.gov/).

Facilities

Computing Capabilities

Computing capabilities used by the Laboratory range from high-performance supercomputers to scientific workstations to desktop personal computers.

The high-performance computers are operated for general use by the NASA Center for Computational Sciences (NCCS). Their flagship machines are a Compaq Alpha Server SC45 with 1392 (512 1 GHz and 880 1.25 GHz) Alpha-EV68 processors and 696 GB of main memory, an SGI Origin 3800 with 512 400 MHz CPUs and 256 GB of main memory, and an SGI Origin 3800 with 128 500 MHz CPUs and 64 GB of main memory. The NCCS provides a mass storage system with a potential capacity of over 10 PB. Supercomputer resources are also available through special arrangement from NASA Ames Research Center, NASA Advanced Supercomputing (NAS) facility.

Each Branch maintains its own system of computers. With the availability of very fast, large capacity, relatively inexpensive personal computers, the trend for Laboratory scientists is away from clusters of Unix workstations and toward using personal computers as scientific workstations. The major portion of scientific data analysis/manipulation and image viewing is done on the single user personal computers.

GOES Receive Site

The Laboratory operates an autonomous ground station for continuously receiving, processing, and serving the Imager and Sounder radiometric data from the GOES satellites. The site also offers recent international geosynchronous satellite data from Japan (GMS-5), China (FY-2), and Europe (METEOSAT-5 and -7). In addition, we offer a database of full-resolution radiances from India's geosynchronous satellite (INSAT) which began in March 1999.

Mass Spectrometry

The Laboratory for Atmospheres' Mass Spectrometry Laboratory is equipped with unique facilities for designing, fabricating, assembling, calibrating, and testing flight-qualified mass spectrometers used for atmospheric sampling.

The equipment includes precision tools and machining, material processing equipment, and calibration systems capable of simulating planetary atmospheres. The facility has been used to develop instruments for exploring the atmospheres of Venus, Saturn, and Mars (on orbiting spacecraft), and of Jupiter and Titan (on probes). The Mass

Spectrometry Laboratory will also be used in support of comet missions. In addition, the Laboratory has clean rooms for flight instrument assembly and equipment for handling poisonous and explosive gases.

Lidar

The Laboratory has well-equipped facilities to develop lidar systems for airborne and ground-based measurements of aerosols, methane, ozone, water vapor, pressure, temperature, and winds.

Lasers capable of generating radiation from 266 nanometer (nm) to beyond 1,000 nm are available, as is a range of sensitive photon detectors for use throughout this wavelength region. The lidar systems employ telescopes with primaries up to 30 inches in diameter and high-speed counting systems for obtaining high vertical resolution. The Cloud, Aerosol, Lidar, Radiometer Laboratory has specialized facilities for optical instrument development, including optical tables, large auto-collimator, air handlers, and flow bench.

Lidars developed in the Laboratory include the Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTAL) to measure ozone, temperature, and aerosols; the Stratosphere Ozone Lidar Trailer Experiment (STROZ LITE) to measure atmospheric ozone, temperature, and aerosols; the Aerosol and Temperature Lidar (AT Lidar) for measurement of stratospheric temperature and aerosols, and tropospheric water vapor; the Large Aperture Scanning Airborne Lidar (LASAL) to measure clouds and aerosols; the Cloud Physics Lidar (CPL) to measure clouds and aerosols; the Scanning Raman Lidar (SRL) to measure water vapor, aerosols, and cloud water; and the Goddard Lidar Observatory for Winds (GLOW) which uses an edge technique to measure winds. A Cloud and Aerosol Lidar, the Aerosol Lidar (AL) is currently being built for deployment to Kritimati Island (Christmas Island).

The Code 912 Raman Lidar Laboratory has instrumentation for performing a broad range of atmospheric measurements using backscatter, polarization and Raman lidar techniques. Recent activities in the Lab include multiwavelength lidar measurements for studying aerosol and cloud properties, spectrally scanned measurements of Raman scattering from atmospheric CO_2, O_2, N_2, water vapor and liquid water. In addition, the Raman Airborne Spectroscopic Lidar (RASL), recently developed under the Instrument Incubator Program, has completed successful testing in the Raman Lidar Laboratory and is currently being configured for first flight. RASL offers daytime and nighttime measurements of water vapor mixing ratio, aerosol backscattering, aerosol extinction and aerosol depolarization as well as nighttime measurements of cloud liquid water.

The next generation Micro-Pulse Lidar (MPL) design was recently prototyped in our Laboratory, and is undergoing transfer to a company to become a commercial product. The next generation MPL includes more rugged components for better durability in the field, a longer lasting laser system, a fiber coupled detector arrangement for in-the-field repair, a multichannel data system to include measurement of the lidar overlap function in real-time, and computer control of all the MPL components via an internet connection.

Members of the Laboratory are building a new lidar calibration facility called SLAM (Small Lidar Advanced Measurement). It will be used primarily to calibrate and maintain the several MPL systems here at Goddard, and other privately owned MPL systems that are part of our MPLNET project. It can also be used to calibrate other small optics.

Radiometric Calibration and Development Facility

The Radiometric Calibration and Development Facility (RCDF) supports the calibration and development of instruments for ground- and space-based observations of atmospheric composition including gases and aerosols. http://ventus.gsfc.nasa.gov

As part of the Earth Observing System (EOS) calibration program, the RCDF provided and will provide calibrations for all UV/VIS spaceborne solar backscatter instruments, which include Solar Backscatter Ultraviolet/version 2 (SBUV/2), and Total Ozone Mapping Spectrometer (TOMS) instruments. Calibrations were conducted on the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY), flying on European Space Agency's (ESA) Environmental Satellite (ENVISAT) mission, ODIN Spectrometer and IR Imager System (OSIRIS), on the Canada/Sweden ODIN mission, and the Israeli MEIDEX (Mediterranean Israeli Dust Experiment) and SOLSE/LORE shuttle instruments. Calibrations are scheduled for the Ozone Monitoring Instrument on Aura and the Global Ozone Monitoring Experiment-2 (GOME-2) on Metop.

The RCDF also supports Instrument Incubator Program development such as the Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA) and the Geostationary Spectrometer (GeoSpec). The Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE) were also developed in the RCDF.

The RDCF also houses several instruments for conducting zenith sky observations. The SSBUV instrument that flew on the space shuttle eight times during the period 1989 to 1996 is now routinely collecting zenith sky observations as part of a Code 916 program called *Skyrad*. The objective of this program is to improve radiative transfer models and algorithms used for UV/VIS space- and ground-based backscatter instruments. The RDCF also maintains a double Brewer spectrometer, used as field calibration transfer, and several other sky-observing instruments for composition and aerosol research. Experiments are being conducted to determine if calibrated zenith sky observations can be used to validate radiance observed from space. This technique could be applicable to present fly UV/VIS backscatter instruments and future operational instruments on NPP, NPOESS and Metop.

The RCDF contains state-of-the-art calibration equipment and standards traceable to the National Institutes of Standards and Technology (NIST). Calibration capabilities include wavelength, linearity, signal to noise (s/n), instantaneous field of view (IFOV), field of regard (FOR), and goniometry. The facility is also capable of characterizing such instrument subsystems as spectral dispersers and detectors. A tunable dye laser operating in the UV/VIS is also used to measure optical filter characteristics with high accuracy and to characterize instrument throughput such as slit functions and wavelength registration. The Facility includes a class-10,000 clean room with a continuous source of N_2 for added contamination control. For further information contact Ernest Hilsenrath (hilsen@ventus.gsfc.nasa.gov).

3. OUR WORK AND ITS PLACE IN NASA'S MISSION

NASA's Enterprises

NASA's overall program, as outlined in the Agency's strategic plan, is composed of five enterprises: Earth Science; Space Science; Aerospace Technology; Biological and Physical Research; and Human Exploration and Development of Space. The Laboratory for Atmospheres concentrates on two of these, the Earth Science and Space Science Enterprises.

Earth Sciences Directorate Areas of Research

The Earth Sciences Directorate research is driven by a number of crosscutting science areas on which the Laboratory for Atmospheres focuses much of its research:

- Aerosols
- Atmospheric Chemistry
- Carbon Cycle
- Global Water and Energy Cycle
- Long-Term Climate Change
- Planetary Studies
- Weather and Short-Term Climate Forecasting

Earth Science and Space Science in the Laboratory for Atmospheres

The Laboratory for Atmospheres has a long history (40+ years) of research in Atmospheric Science, both of the Earth and the planets. The wide array of our work reflects this history of atmospheric research, from the early days of weather satellites and emphasis on weather forecasting to a present focus on global climate change. For example, one goal is to increase the accuracy and lead-time with which we can predict weather and climate change. Our history also reflects research from the early days of the OGO (Orbiting Geophysical Observatory), Explorer, and Pioneer Venus Satellites to Galileo missions, and current studies of the outer planets and comets with the Mars Nozomi mission, the Cassini mission to measure the chemical composition of gases and aerosols in the atmosphere of Titan, and the Ion and Neutral Mass Spectrometer (INMS) to measure the chemical composition of positive and negative ions and neutral species in the inner magnetosphere of Saturn and in the vicinity of Saturn's icy satellites.

The Laboratory for Atmospheres conducts basic and applied research in the crosscutting research areas of the Earth Sciences Directorate. Specifically, Laboratory scientists focus their efforts on satellite mission planning, data development and analysis, data assimilation and modeling in the following areas:

- Aerosols and clouds
- Atmospheric hydrological processes
- Atmospheric radiative transfer
- Carbon sources and sinks
- Climate variability and forcings
- Composition of planetary atmospheres
- El Niño and predictability studies
- Observing system simulation studies
- Ozone and trace gases
- Precipitation systems studies
- Severe weather and mesoscale processes

Our work involves four primary activities or products: measurements, data sets, data analysis, and modeling, such as those listed in Table 1.

Table 1. Laboratory for Atmospheres Earth Science Activities

Measurements	Data Sets	Data Analysis	Modeling
Aircraft Balloon Field campaigns Ground Space	DAO assimilated products Global precipitation MODIS cloud and aerosol TOMS aerosol TOMS surface UV TOMS total ozone TOVS Pathfinder TRMM Global Precipitation products TRMM validation Products	Aerosol cloud climate interaction Aerosols Atmospheric Hydrologic cycle Climate variability and climate change Clouds and precipitation Global temperature trends Ozone and trace gases Radiation UV-B measurements Validation studies	Atmospheric chemical Clouds and mesoscale Coupled climate/ocean Data assimilation Data retrievals General circulation Radiative transfer Transport models Weather and climate

The divisions among measurements, data sets, data analysis, and modeling are somewhat artificial, in that activities in one area often affect those in another. These activities are strongly interlinked and cut across science priorities and the organizational structure of the Laboratory. The grouping corresponds to the natural processes of carrying out scientific research: Ask the scientific question, identify the variable needed to answer it, conceive the best instrument to measure the variable, analyze the data, and ask the next question.

4 MAJOR ACTIVITIES

In the previous section, we provided a snapshot of the activities we pursue in the Laboratory for Atmospheres. This section presents a more complete picture of our work in measurements, field campaigns, data sets, data analysis, and modeling. In addition, we summarize the Laboratory's support for the National Oceanic Atmospheric Administration's (NOAA) remote-sensing requirements. Section 4 concludes with a listing of our project scientists, a description of our interactions with other scientific groups, and an overview of our efforts toward commercialization and technology transfer.

Measurements

Studies of the atmospheres of our solar system's planets–including our own–require a comprehensive set of observations, relying on instruments on spacecraft, aircraft, balloons, and on the ground. Our instrument systems perform one or both of the functions: 1) providing information leading to a basic understanding of the relationship between atmospheric systems and processes; 2) serving as calibration references for satellite instrument validation.

Many of the Laboratory's activities involve developing concepts and designs for instrument systems for spaceflight missions, and for balloon-, aircraft-, and ground-based observations. Balloon and airborne platforms facilitate viewing such atmospheric processes as precipitation and cloud systems from a high-altitude vantage point but still within the atmosphere. Such platforms serve as stepping stones in the development of spaceborne instruments.

Two instrument systems are featured in some detail. The SOLSE/LORE system was designed and developed in the Laboratory and was included in the STS-107 payload that was lost with the tragic loss of the shuttle Columbia. Throughout the flight of Columbia the system performed flawlessly and much data was returned through the real-time downlink.

A second featured instrument is the Cloud Physics Lidar (CPL) system developed for flights on the ER-2 aircraft. This system was used during the CRYSTAL-FACE field campaign. In combination with the Cloud Radar System (CRS), the two instruments produced composite Lidar/Radar profiles of moisture and aerosols through the cloud layers from as high as 19 km to the surface. These flights provided a unique opportunity to demonstrate the potential for combined active sensing systems to provide higher quality scientific data.

Table II follows these articles and shows the principal instruments that have either been built in the Laboratory or for which a Laboratory scientist has had responsibility as Instrument Scientist. The instruments are grouped according to the scientific discipline each supports. Table II also indicates each instrument's deployment–in space, on aircraft, on the ground, or in the laboratory. A brief description of each instrument is given after the table.

The Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE)

SOLSE/LORE was included in the STS-107 payload that was lost with the Columbia tragedy. The experiment performed flawlessly during the flight and data was received via the Shuttle downlink. The bulk of data was stored on a hard disk in the Shuttle, and was not recovered. Nevertheless this experiment was a success for STS-107, a story that needs to be told.

The purpose of the SOLSE/LORE experiment was to demonstrate that measurements of limb-scattered sunlight can be used to derive ozone profiles from the stratosphere down to the tropopause with high vertical resolution. SOLSE was an imaging spectrometer that operated in either visible or UV wavelengths, while LORE was a filter radiometer with channels covering UV and visible wavelengths. The two instruments were flown in a single Hitchhiker Jr. GAS can on the shuttle. The instruments, developed at Goddard Space Flight Center, were first flown on STS-87. The SOLSE/LORE STS-107 mission had two purposes: first, to better understand the capability of limb scatter measurements for ozone retrieval over a wide range of conditions, and second, to provide an initial simulation of the performance expected from the Ozone Mapper and Profiler System (OMPS). OMPS is the ozone sounder instrument planned for the National Polar Orbiting Environmental Satellite System (NPOESS).

For flight on STS-107, the instruments were reconfigured in the Laboratory for Atmospheres Radiometric Calibration and Development Facility to simulate the performance expected from OMPS. This mission was partially funded by the Integrated Program Office as a risk mitigation activity for this future ozone measurement instrument. The concept of limb scatter used for ozone measurement is shown in the illustration below.

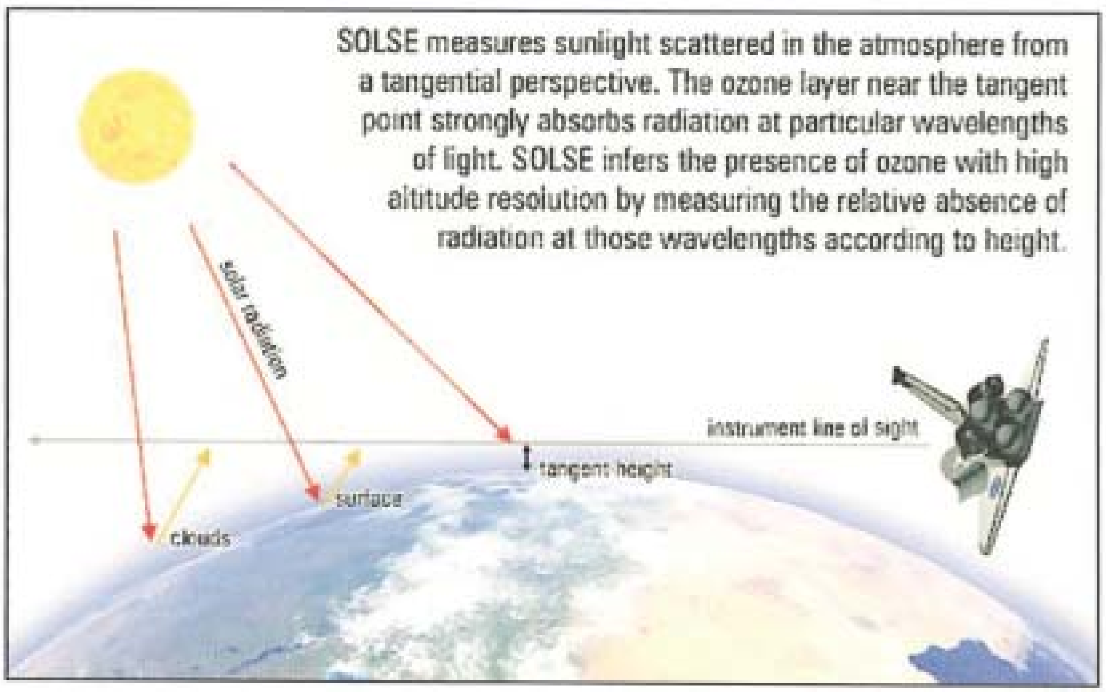

Figure 4-1. Illustration of how ozone is seen using scattered light from the Earth's limb.

SOLSE imaged the limb of the Earth onto a CCD array through a spectrometer, forming a multiwavelength image–530 nm to 850 nm, at 0.7 nm resolution. Shorter wavelengths (near 300 nm), which are highly sensitive to ozone, were used to measure the ozone profile up to 50 km, while longer, less sensitive wavelengths (near 600 nm) measured ozone in the lower stratosphere, possibly down to 10 km.

Optical Design:

SOLSE was a Czerny-Turner imaging spectrometer designed to produce a high-quality image of the limb of the Earth while minimizing internal scattered light. The resolution of the vertical image was better than 1 km. The optical bench layout and major or system specifications are shown below.

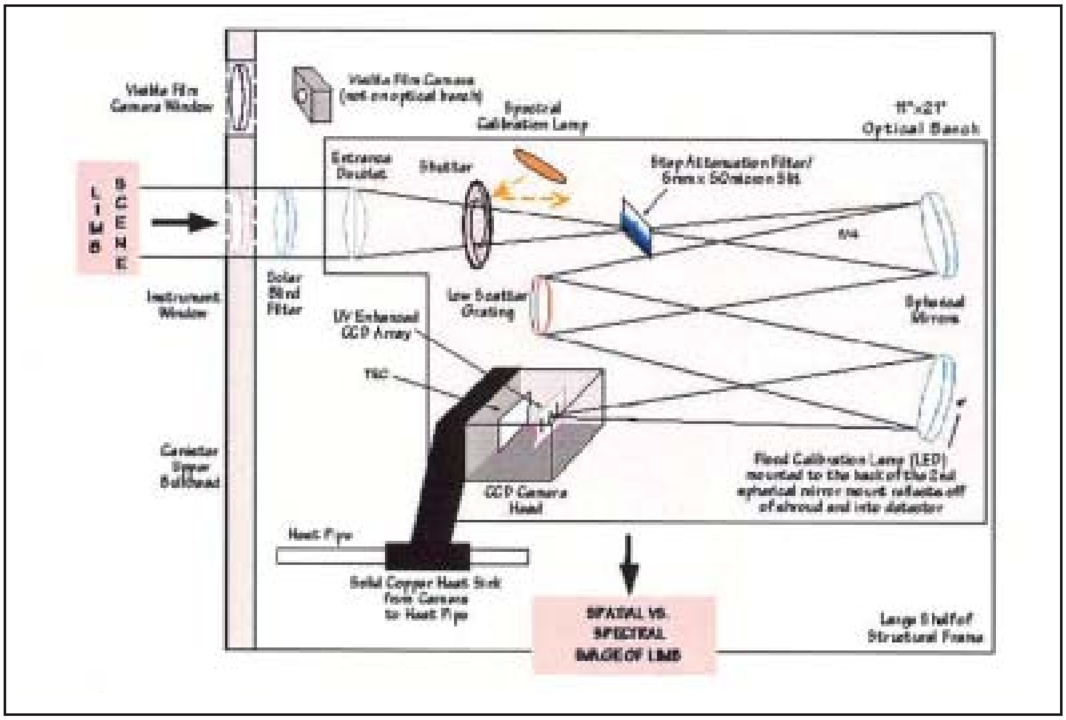

Figure 4-2. Diagram of optical design on the SOLSE instrument.

LORE, the Limb Ozone Retrieval Experiment, was a small camera system that accompanied SOLSE. LORE was a filter radiometer with a linear diode array detector in the SOLSE canister to measure the limb-scattered radiance at ultraviolet and visible wavelengths. LORE had channels at 322, 350, 603, 675, and 760 nm. The 603 nm channel was used to measure ozone in the 15–30 km region using Chappuis band absorption. The channel at 760 nm was used to measure oxygen absorption, while the channel at 322 nm measured ozone above 30 km. The channel at 350 nm provided pointing information. An isometric view of the limb ozone retrieval apparatus is shown below along with key specifications.

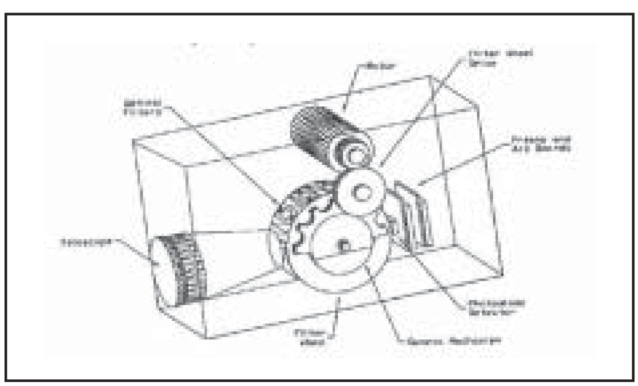

Figure 4-3. Isometric view of the LORE limb ozone retrieval apparatus.

Wavelength	Purpose	Spatial Resolution
322 nm	mid to upper stratospheric ozone	0.5 km
350 nm	pointing channel	0.5 km
603 nm	Chappuis band ozone channel	0.75 km
675 nm	aerosol background channel	0.75 km
760 nm	ozone absorption and pointing	0.75 km

SOLSE and LORE provided the first retrieval of stratospheric ozone by limb scattering as a shuttle payload on STS-87 in 1997. The results from the first flight demonstrated that limb sounding of ozone can achieve 1–3 km altitude resolution down to 15 km. The spectral coverage of SOLSE was changed for the reflight to include visible wavelengths, in addition to UV, to achieve LORE's depth of retrieval which clearly detected the tropopause.

During flight STS-107 the spectra shown below from the 25 km altitude point were measured as the shuttle crossed the terminator moving into sunlight. Note the strong ozone absorption feature near 600 nm that becomes less prominent as the Sun rises higher in the sky. (Raw counts are shown; absolute levels depend on the varying exposure time.)

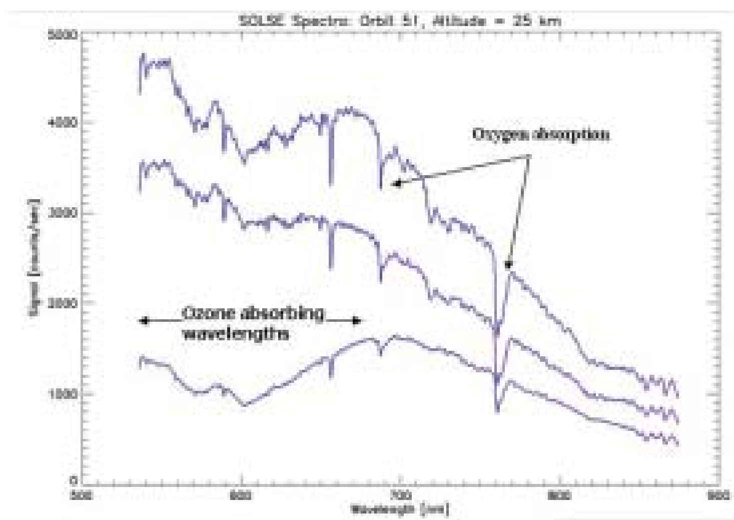

Figure 4-4. SOLSE spectra from the 1st limb-viewing orbit at three different solar zenith angles. The amount of absorption depends on various factors including the solar zenith angle and the particular tangent altitude that is being viewed.

Approximately 70% of the LORE and 12% of SOLSE data was received through the shuttle downlink. Therefore, most of the science objectives were met, such as the goal to demonstrate that limb scattering works over a wide range of latitudes. Preliminary results were presented at a scientific conference in April 2003 and a publication is expected before the end of the year. For more information, contact Richard McPeters (Richard.D.McPeters@nasa.gov).

Cloud Physics Lidar

One of the most important components of airborne remote-sensing experiments is the high altitude NASA ER-2 aircraft. Because the ER-2 typically flies at about 65,000 feet (20 km), its instruments are above 94% of the Earth's atmosphere, allowing ER-2 instruments to function as spaceborne instrument simulators. The ER-2 provides a unique platform for atmospheric profiling, particularly for active remote-sensing instruments such as lidar, because the spatial coverage attainable by the ER-2 permits studies of aerosol properties across wide regions. Lidar profiling from the ER-2 platform is especially valuable because the cloud height structure, up to the limit of signal attenuation, is unambiguously measured.

The Cloud Physics Lidar, or CPL, is a backscatter lidar designed to operate simultaneously at 3 wavelengths: 1064, 532, and 355 nm. The purpose of the CPL is to provide multiwavelength measurements of cirrus, subvisual cirrus, and aerosols with high temporal and spatial resolution. Figure 4-5 shows the optical bench, which is the heart of the instrument, while Figure 4-6 shows the entire CPL package in flight configuration. The CPL utilizes state-of-the-art technology with a high repetition rate, low pulse energy laser and photon-counting detection. Vertical resolution of the CPL measurements is fixed at 30 m; horizontal resolution can vary but is typically about 200 m. Primary instrument parameters are listed in the table below. The CPL fundamentally measures range-resolved profiles of volume 180-degree backscatter coefficients. From the fundamental measurement, various data products are derived, including time-height cross-section images; cloud and aerosol layer boundaries; optical depth for clouds, aerosol layers, and planetary boundary layer (PBL); and extinction profiles.

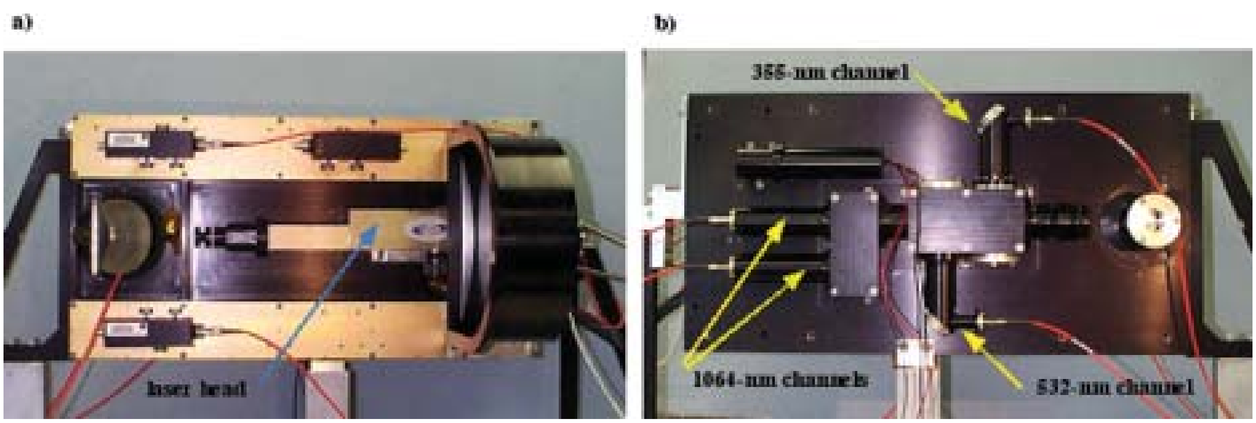

Figure 4-5. a) Photo of transmitter side of CPL optical bench, showing laser head and off-axis mirror. b) Photo of receiver side of CPL optical bench, showing the component layout and the different wavelength channels.

Figure 4-6. Photo of the CPL in flight configuration. The optical bench, shown in Figure 4-5, resides inside the blue box (top) to keep the optics clean, dry, and thermally stable. The entire package slides into the ER-2 wing pod.

CPL system parameters

PARAMETER	VALUE
Wavelengths	1064, 532, and 355 nm
Laser type	solid-state Nd:YVO_4
Laser repetition rate	5 kHz
Laser output energy	50 µJ at 1064 nm 25 µJ at 532 nm 50 µJ at 355 nm
Telescope	20 cm diameter, off-axis parabola
Telescope field of view	100 microradians, full angle
Effective filter bandwidth (full width, half-height)	240 pm at 1064 nm 120 pm at 532 nm 150 pm at 355 nm
Raw data resolution	1/10 second (30 m vertical by 20 m horizontal)
Processed data resolution	1 second (30 m vertical by 200 m horizontal)

The CPL provides information to permit a comprehensive analysis of radiative and optical properties of optically thin clouds. Primary data products include:

- Cloud profiling with 30 m vertical and 200 m horizontal resolution at 1064 nm, 532 nm, and 355 nm, providing cloud location and internal backscatter structure.

- Aerosol, boundary layer, and smoke plume profiling at all three wavelengths, providing calibrated profiles of backscatter coefficients.

- Depolarization ratio to determine the phase (e.g., ice or water) of clouds using the 1064 nm output.

- Determination of optical depth for both cloud and aerosol layers (up to the limit of signal attenuation, ~ optical depth 3).

- Determination of extinction-to-backscatter parameter.

The CPL uses photon-counting detectors with a high repetition rate laser to maintain a large signal dynamic range. This dramatically reduces the time required to produce reliable and complete data sets. The CPL analysis provides data within 24 hours of a flight including: (1) cloud and aerosol quick-look pictures, (2) cloud and aerosol layer boundaries, and (3) depolarization information. The optical depth determinations require more careful analysis. Determination of optical depths for uncomplicated layers of cirrus clouds with homogeneous scattering characteristics can be completed within a day using an automated analysis algorithm. However, situations where the cloud layering and structure is complex, which often precludes an automated data processing algorithm, may require several weeks for processing. The ability to produce data products in near-real time has proven invaluable during field campaigns.

The fundamental CPL data product is a time-height cross-section image of the atmosphere, as illustrated in Figure 4-7. Data shown in Figure 4-7 is a 3-1/2 hour segment of data from the CRYSTAL-FACE experiment on July 26, 2002.

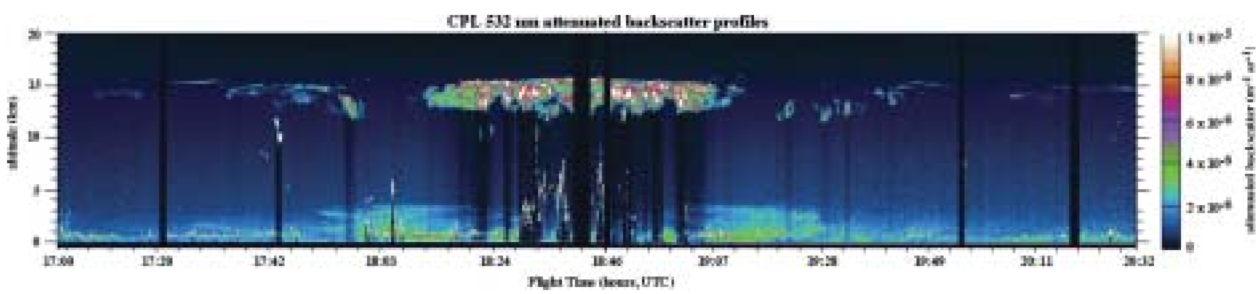

Figure 4-7. Example of CPL data. This image shows profiles of 532 nm attenuated backscatter from July 26, 2002. This image is representative of airborne lidar data, showing cloud height and internal structure and boundary layer aerosol. In addition, a period of elevated aerosol, known to be Saharan dust, is evident in the middle of the time period.

To date the CPL has participated in several field campaigns, including:

SAFARI-2000 (Pietersburg, South Africa, August–September 2000)

CRYSTAL-FACE (Key West, Florida, July 2002)

TX-2002 (San Antonio, Texas, November–December 2002)

THORPEX (Honolulu, Hawaii, February–March 2003)

For more information about the CPL or CPL data products, please visit the CPL Web site at http://virl.gsfc.nasa.gov/cpl or contact Matthew McGill (Matthew.J.McGill@nasa.gov).

Table 2. Principal Instruments Supporting Scientific Disciplines in the Laboratory for Atmospheres

	Atmospheric Structure and Dynamics	Atmospheric Chemistry	Clouds and Radiation	Planetary Atmospheres/Solar Influences
Space		Total Ozone Mapping Spectrometer (TOMS) - Earth Probe (EP) Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE) Earth Polychromatic Imaging Camera (EPIC) - Triana (renamed DSCOVR)		Gas Chromatograph Mass Spectrometer (GCMS) – Cassini Huygens Probe Ion and Neutral Mass Spectrometer (INMS) – Cassini Orbiter Neutral Mass Spectrometer (NMS) – *Nozomi* Neutral Gas and Ion Mass Spectrometer (NGIMS) – Comet Nucleus Tour (CONTOUR)
Aircraft	ER-2 Doppler Radar (EDOP) Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)	Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTAL) Raman Airborne Spectroscopic Lidar (RASL)	Cloud Physics Lidar (CPL) cloud THickness from Offbeam Returns (THOR) Lidar Leonardo Airborne Simulator (LAS) Cloud Radar System (CRS)	
Ground/ Laboratory/ Development	Scanning Raman Lidar (SRL) Goddard Lidar Observatory for Winds (GLOW) Lightweight Rainfall Radiometer (LRR-X)	Stratospheric Ozone Lidar Trailer Experiment (STROZ LITE) Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA) Aerosol and Temperature Lidar (AT Lidar) Brewer UV Spectrometer Goetz Radiometer Aerosol Lidar (AL) L2-SVIP	Micro-Pulse Lidar (MPL) Scanning Microwave Radiometer (SMiR) Sun-Sky-Surface photometer (3S) COmpact Vis IR (COVIR) Surface-sensing Measurements for Atmospheric Radiative Transfer (SMART)-Chemical, Optical and Microphysical Measurements of In situ Troposphere (COMMIT)	

Spacecraft-Based Instruments

The Total Ozone Mapping Spectrometer (TOMS) on Earth Probe (EP) continues to provide daily mapping and long-term trend determination of total ozone, surface UV radiation, volcanic SO_2, and UV-absorbing aerosols since 1996. For further information, contact Richard McPeters (Richard.D.McPeters@nasa.gov).

The Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE) measures ozone profiles from the stratosphere down to the tropopause with high vertical resolution. SOLSE is a grating spectrometer that operates in the UV and visible wavelengths while LORE is a filter radiometer with channels in the UV and visible wavelengths. The instruments have been reconfigured in the Laboratory for Atmospheres' Radiometric Calibration and Development Facility (RCDF) to more accurately simulate the performance expected from the Ozone Mapper and Profiler System (OMPS) where both will measure high vertical resolution profiles in the stratosphere down to the tropopause. The OMPS is the ozone sounder instrument which will fly on the National Polar Orbiting Environmental Satellite System (NPOESS) and the NPP (NPOESS Preparatory Project). See the instrument above for more details on SOLSE/LORE. For further information, contact Ernest Hilsenrath (Ernest.Hilsenrath-1@nasa.gov), or Richard McPeters (Richard.D.McPeters@nasa.gov).

Earth Polychromatic Imaging Camera (EPIC) on Triana (renamed DSCOVR) is a 10-channel spectroradiometer spanning the ultraviolet (UV) to the near-infrared (IR) wavelength range (317.5 to 905 nm). The main quantities measured are (1) column ozone, (2) aerosols (dust, smoke, volcanic ash, and sulfate pollution), (3) sulfur dioxide, (4) precipitable water, (5) cloud height, (6) cloud reflectivity, (7) cloud phase (ice or water), and (8) UV radiation at the Earth's surface. We will also measure other quantities related to vegetation, bidirectional reflectivity (hotspot analysis) and ocean color. EPIC has two unique characteristics: (1) EPIC takes the first spaceborne measurements from sunrise to sunset of the entire sunlit Earth and (2) EPIC performs the first simultaneous measurements in both the UV and visible wavelengths. These capabilities will allow us to determine diurnal variations and permit extended measurements of aerosol characteristics (2002). The Triana spacecraft and instruments are complete and tested for flight; however, they are temporarily in storage awaiting a flight opportunity. Recent work has improved the scattered light rejection capability to improve the instrument's signal to noise capabilities. For further information, contact Jay Herman (Jay.R.Herman@nasa.gov).

The Gas Chromatograph Mass Spectrometer (GCMS) for the Cassini Huygens Probe will measure the chemical composition of gases and aerosols in the atmosphere of Titan (1997), starting in 2004. For further information, contact Hasso Niemann (Hasso.B.Niemann@nasa.gov).

The Ion and Neutral Mass Spectrometer (INMS) on Cassini Orbiter will determine the chemical composition of positive and negative ions and neutral species in the inner magnetosphere of Saturn and in the vicinity of its icy satellites (1997), starting in 2004. For further information, contact Hasso Niemann (Hasso.B.Niemann@nasa.gov).

The Neutral Mass Spectrometer (NMS) on the Japanese spacecraft Nozomi (Planet-B) will measure the composition of the neutral atmosphere of Mars to improve our knowledge and understanding of the energetics, dynamics, and evolution of the Martian atmosphere. The Nozomi spacecraft and mission were developed by the Japanese Institute of Space and Astronautical Science (1998). For further information, contact Hasso Niemann (Hasso.B.Niemann@nasa.gov).

The Atmospheric Experiment Branch delivered the Neutral Gas and Ion Mass Spectrometer (NGIMS) to Johns Hopkins University Applied Physics Laboratory on December 10, 2001, for integration onto the CONTOUR spacecraft. CONTOUR was launched on July 3, 2002, and performed flawlessly throughout the first month of spacecraft and instrument checkouts. Unfortunately, the spacecraft was destroyed at the end of the Solid Rocket Motor 50-second burn that was required to send the spacecraft into a trajectory needed for the comet encounter. Telescopic images confirmed the spacecraft had broken up into at least three pieces. For further information, contact Paul Mahaffy (Paul.R.Mahaffy@nasa.gov).

Aircraft-Based Instruments

The `ER-2 Doppler Radar (EDOP)` is an X-band (9.6 GHz) system which measures vertical profiles of rain and winds within precipitation systems. It has been used for validation of spaceborne rain measurement algorithms used in TRMM and for providing improved understanding of the structure of mesoscale convective systems, hurricanes, and convective storms. It has been involved in 8 major field campaigns with the ER-2, including 3 TRMM validation efforts, 4 CAMEX convection and hurricane campaigns, and CRYSTAL-FACE. For further information, contact Gerald Heymsfield (Gerald.M.Heymsfield@nasa.gov).

The `Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)` measures cloud and aerosol structure in three dimensions via laser backscatter at a wavelength of 1064 nm. Utilizing a unique scanning holographic telescope, this compact lidar fits into small aircraft as well as in a ground-based trailer for field experiment deployments. HARLIE was used in several field experiments including HARGLO, ARMIOP2000, and IHOP. Technical descriptions of the instrument and examples of data products are described at http://harlie.gsfc.nasa.gov/. For further information, contact Geary Schwemmer (Geary.K.Schwemmer@nasa.gov).

The GSFC `Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTAL)` is a two wavelength lidar system (308 nm and 355 nm) that detects two elastically scattered wavelengths and N2-Raman scattered radiation at 332 nm and 387 nm. The system uses 20 data channels spread over the four detected wavelengths. The instrument was on board the DC-8 during the SOLVE campaign in the winter of 1999/2000. Colleagues at NASA Langley Research Center contributed data channels for depolarization measurements at 532 nm and channels for aerosol backscatter at 1064 nm. Data products are aerosol backscatter and vertical profiles of ozone and temperature. This instrument was installed on the DC-8 in November–December 2002 for a SAGE III Validation campaign flown from Kiruna, Sweden, during January 2003. For further information, contact Thomas McGee (Thomas.J.McGee@nasa.gov).

The `Raman Airborne Spectroscopic Lidar (RASL)` was developed under NASA's Instrument Incubator Program (IIP). The instrument was laboratory tested on September 18, 2002, for a 24-hour measurement period that demonstrated all claimed capabilities including daytime and nighttime measurements of water vapor mixing ratio, aerosol backscatter coefficient/extinction/depolarization, extinction to backscatter ratio and liquid water scattering (night only), which offers the possibility of retrieving cloud droplet properties such as liquid water content, droplet radius and number density. For further information contact David Whiteman (David.N.Whiteman@nasa.gov).

The `Cloud Physics Lidar (CPL)` measures cloud and aerosol properties from on board the high-altitude ER-2 aircraft. CPL data is often combined with data from multispectral visible and infrared imaging radiometers to enable studies of atmospheric radiative properties. During 2002, CPL participated in the CRYSTAL-FACE field campaign and a MODIS validation campaign. In 2003, the CPL will be used for GLAS validation activities. For further information, contact Matthew McGill (Matthew.J.McGill@nasa.gov).

The cloud `THickness from Offbeam Returns (THOR )` is a Lidar operating at 540 nm with Nd-YALO 250 micro Joule Laser pulses. The system detects 8 annular fields of view (FOV's) of diameters increasing by factors of 2 from a single fiber seeing 215 micro radian laser pulses, up to the full 6 degrees (0.1 radians) FOV seen by a fiber bundle containing more than 100,000 fibers connected to an array of Hamanaso single-photon counting detectors. The THOR system provides an inexpensive alternate approach to measuring cloud vertical structure, that eventually can be carried out on unmanned aircraft (UAVs) and perhaps even in space. The reflected "halo" measured by THOR is now being employed in retrieval of cloud properties, using a "nonlocal" approach that improves on the usual "independent pixel approximation" used for standard EOS products. The THOR validation campaign took place in March 2002 over the DOE ARM site in northern Oklahoma. For further information, contact Robert Cahalan (Robert.F.Cahalan@nasa.gov).

The `Leonardo Airborne Simulator (LAS)` is an imaging spectrometer (hyperspectral) with moderate spectral resolutions. LAS measures reflected solar radiation to retrieve atmospheric properties such as column water vapor amount, aerosol loadings, cloud properties, and surface characteristics. This was successfully deployed in the SAFARI-2000 campaign in the vicinity of South Africa. The instrument participated in the July 2002 CRYSTAL-FACE campaign in Florida. For further information, contact Si-Chee Tsay (Si-Chee.Tsay-1@nasa.gov).

The `Cloud Radar System (CRS)` is a W-band (94 GHz) millimeter-wave Doppler radar system for measuring cirrus clouds and precipitation regions with lower reflectivities (smaller particles) than detectable with conventional rain radars. The system is designed for high-altitude ER-2 operation and operates at the same frequency as the CLOUDSAT radar. The instrument first flew in the CRYSTAL-FACE field campaign during July 2002. For further information, contact Gerald Heymsfield (Gerald.M.Heymsfield@nasa.gov).

Ground-Based and Laboratory Instruments

The `Scanning Raman Lidar (SRL)` is a mobile, all-weather Raman lidar system that measures the water vapor aerosols and cloud structure. The SRL was deployed to western Oklahoma during May–June 2002 for the International H2O Project (IHOP). Over the course of the 6-week campaign, the SRL was used to record atmospheric evolution during the passage of drylines, fronts and low-level jets. For further information, contact David Whiteman (David.N.Whiteman@nasa.gov).

The `Goddard Lidar Observatory for Winds (GLOW)` is a mobile direct-detection Doppler lidar system that measures vertical profiles of wind from the surface to the stratosphere. The instrument measures winds using the laser energy backscattered from aerosols (wavelength=1064 nm) or molecules (wavelength=355 nm). The 1064 nm-channel data products are high spatial resolution wind profiles in the planetary boundary layer (altitudes < 2km) and the 355 nm channel provides wind profiles in the free troposphere and stratosphere (altitudes as high as 35 km). In the spring of 2002, GLOW was deployed to the Oklahoma panhandle for 8 weeks of intensive measurements as part of the International H_2O Project (IHOP). For further information, contact Bruce Gentry (Bruce.M.Gentry@nasa.gov).

The `Lightweight Rainfall Radiometer/X-band (LRR-X)` is an instrument development project supported by the Instrument Incubator Program (IIP). The radiometer employs an advanced technology design based on the use of a thinned array, synthetic aperture antenna. The antenna consists of a set of linear wave guides producing an interferrometric representation of the X-band (10.7 GHz) wave pattern over a cross-track imaging domain. MIMC receiver and digital correlator technologies are used to process the transmitted wave field. This type of design is referred to as a Synthetic Thinned-Array Radiometer (STAR) having the advantage of not requiring a scanning antenna assembly or a feed horn palette. The instrument will undergo its initial airborne flight testing campaign in the early summer of 2003. For further information, contact Eric A. Smith (Eric.A.Smith@nasa.gov).

The `Stratospheric Ozone Lidar Trailer Experiment (STROZ LITE)` measures vertical profiles of ozone, aerosols, and temperature. The system collects elastically and Raman-scattered returns using Differential Absorption Lidar (DIAL). The instrument has participated in over a dozen international measurement campaigns, and is currently deployed to Mauna Loa Observatory, Hawaii. A water vapor channel is being added for testing at this site in spring 2003. For further information, contact Thomas McGee (Thomas.J.McGee@nasa.gov).

The `Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA)` instrument, developed in the Atmospheric Chemistry and Dynamics Branch, was completed and a final report was submitted to the Earth Science Technology Office (ESTO). The primary objective was to demonstrate the capability for high-resolution measurements of NO_2, SO_2, aerosol, and O_3. The core design is a wide field-of-view (FOV) front-end telescope that illuminates a filter/focal plane array (FFPA) package. For further information, contact Scott Janz (Scott.J.Janz@nasa.gov).

The `Aerosol and Temperature Lidar (AT Lidar)` is a trailer-based instrument that makes measurements of vertical profiles of atmospheric aerosols and stratospheric temperature. Aerosol information is gathered at three wavelengths to provide particle size information. This instrument has been modified to include water vapor and in-cloud temperature capabilities. Measurements are currently being taken at GSFC. For further information, contact Thomas J. McGee (Thomas.J.McGee@nasa.gov).

The `Brewer UV Spectrometer` is an operational ground instrument for ozone and UV irradiance measurements. There are several deployed in ozone ground-based networks. The Goddard Brewer instrument has improved calibration and operability for special field campaigns for use as a reference for other network brewer instruments. The instrument is also upgraded to conduct research as part of the Skyrad program. For further information, contact Ernest Hilsenrath (Ernest.Hilsenrath-1@nasa.gov).

`Goetz Radiometer` is a ruggedized filter UV radiometer with precision filters and electronics for unattended field use for total and profile ozone and UVB irradiance measurements. The long-term objective is to collect accurate ozone and UV data with low cost, reliable and highly accurate hardware. It is also being used to conduct aerosol research as part of the Skyrad program and in conjunction with GSFC's Aeronet program. For further information, contact Ernest Hilsenrath (Ernest.Hilsenrath-1@nasa.gov).

The `Aerosol Lidar (AL)` is a collaborative effort with JPL to build and deploy a small autonomous aerosol lidar for the Network for the Detection of Stratospheric Change. This lidar will transmit 1064 and 532 nm and will retrieve ozone profiles from both those wavelengths. It will also provide depolarization information to determine the physical state of aerosol particles. The first deployment of the lidar will be to a remote site on Christmas Island, near the equator, south of Hawaii. Data will be collected as continuously as possible for a year to gather information on the cloud climatology above the island. For further information, contact Thomas McGee (Thomas.J.McGee@nasa.gov).

`L2-SVIP (Lagrange-2 Solar Viewing Interferometer Prototype)` is a new prototype instrument being developed to demonstrate the technology needed to develop large aperture (8 to 10 meters) interferometers needed for observing the Earth's atmosphere at Lagrange-2 (1.5 million kilometers behind the Earth on the Earth-Sun line). This development is being done under a new IIP project in cooperation with Code 916 and Code 930 scientists and Code 500 engineers. The goal of the spaceflight instrument is to map out the altitude, latitude and longitude distribution of the greenhouse gases (CO_2, H_2O, CH_4, HCl, O_3, O_2). For more information, contact Jay Herman (Jay.R.Herman@nasa.gov).

The `Micro-Pulse Lidar (MPL)` system is a compact and eye-safe lidar capable of determining the range of aerosols and clouds continuously in an autonomous fashion. The MPL was developed at GSFC during the early 1990s and is now a commercial product. The unique capability of this lidar to operate unattended in remote areas makes it an ideal instrument to use for a network. In 2000, the `Micro-Pulse Lidar Network (MPLNET)` was begun. MPLNET is comprised of ground-based MPL systems, co-located with sun/sky photometer sites in the NASA Aerosol Robotic Network (AERONET). The MPLNET project is discussed in more detail in section 5. For further information on MPL systems, contact James Spinhirne (James.D.Spinhirne@nasa.gov) and for questions on the MPLNET project, contact Judd Welton (Ellsworth.J.Welton@nasa.gov).

The Scanning Microwave Radiometer (SMiR) measures the column amounts of water vapor and cloud liquid water using discrete microwave frequencies. This instrument was successfully deployed in SAFARI-2000, in ACE-Asia-2001, and in CRYSTAL-FACE-2002 campaigns. For further information, contact Si-Chee Tsay (Si-Chee.Tsay-1@nasa.gov).

The Sun-Sky-Surface photometer (3S) is under development in collaboration with Biophysics Branch (Code 923) and Detector System Branch (Code 553). The 3S contains 14 discrete channels, ranging from the ultraviolet to shortwave-infrared spectral region, and scans the upper (atmosphere) and lower (surface) hemispheres during its operation. For further information, contact Si-Chee Tsay (Si-Chee.Tsay-1@nasa.gov).

COmpact Vis IR (COVIR) is an engineering model of an imaging radiometer for small satellite missions. The instrument is being developed under the Instrument Incubator Program (IIP) and will measure visible and IR wavelengths in the following ranges: 10.3-11.3 µm, 11.5-12.5 µm, 9.5-10.5 µm, and 0.67-0.68 µm. The system employs uncooled microbolometer focal plane detectors. The goal of COVIR is to enable future multisensor Earth science missions to utilize smaller and lower cost infrared and visible imaging radiometers. This will lead to improved cloud sensing through increased spatial resolution and coverage with spectral IR data. The design of COVIR is complete. Analysis was completed and a paper published on the results of infrared stereo cloud height retrieval by data acquired during the Infrared Spectral Imaging Radiometer shuttle hitchhiker experiment. For further information, contact James Spinhirne (James.D.Spinhirne@nasa.gov).

SMART-COMMIT is a new combination of two suites of instruments. The Surface-sensing Measurements for Atmospheric Radiative Transfer (SMART) is a suite of surface remote-sensing instruments developed and mobilized to collocate with satellite overpass at targeted areas for retrieving physical/radiative properties of the Earth's atmosphere and for characterizing surface properties. The SMART includes an array of broadband radiometers, a shadow-band radiometer, a sunphotometer, a solar spectrometer, a whole-sky camera, a micro-pulse lidar, and a microwave radiometer, as well as meteorological probes for atmospheric pressure, temperature, humidity, and wind speed/direction. During past years, SMART has been deployed in many NASA-supported field campaigns to collocate with satellite nadir overpass for intercomparisons, and for initializing model simulations. Built on the successful experience of SMART, we are currently developing a new ground-based in situ sampling package, Chemical, Optical and Microphysical Measurements of In situ Troposphere (COMMIT). COMMIT includes measurements of trace gas (CO, NO_x, SO_2, and O_3) concentrations, fine/coarse particle size and chemical composition, single- and three-wavelength nephelometers. The next major activities for SMART-COMMIT are scheduled for FY03–05 in BASE-ASIA (Biomass-burning Aerosols in South East-Asia: Smoke Impact Assessment) and CHINA-TEA (Climate & Health Impacts in Northeast Asia-Tropospheric Experiment on Aerosols). For further information, contact Si-Chee Tsay (Si-Chee.Tsay-1@nasa.gov).

Field Campaigns

Field campaigns typically use the resources of NASA, other agencies, and other countries to carry out scientific experiments or to conduct environmental impact assessments from bases throughout the world. Research aircraft, such as the NASA ER-2 and DC-8, serve as platforms from which remote-sensing and in situ observations are made. Ground systems are also used for soundings, remote sensing and other radiometric measurements. In 2002, Laboratory personnel supported many such activities as scientific investigators, or as mission participants, in the planning and coordination phases. The IHOP and CRYSTAL-FACE were two major campaigns supported this year by Laboratory scientists and engineers.

International H_2O Project (IHOP-2002)

The International H_2O Project (IHOP-2002) was a major field experiment conducted in May–June 2002 over the southern Great Plains to explore improved water vapor measurements and their incorporation in forecast models. The Scanning Raman Lidar (SRL), the Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE) and the Goddard Mobile Lidar Observatory for Wind (GLOW) were deployed for IHOP-2002. SRL provided profiles of water vapor mixing ratio to reveal the water vapor stratification to altitudes of 10 km or more. HARLIE provided data characterizing Atmospheric Boundary Layer structure and winds. GLOW provided measurements of wind speed and direction from the surface into the stratosphere. Further details on the IHOP campaign are found in Section 5 highlights under the Mesoscale Atmospheric Processes Branch section.

CRYSTAL-FACE

Members of the Laboratory for Atmospheres played key roles in the Cirrus Regional Study of Tropical Anvils and Layers-Florida Area Cirrus Experiment (CRYSTAL-FACE), a major NASA field experiment conducted in south Florida in July 2002. There were six aircraft participating in CRYSTAL-FACE: NASA's ER-2 and WB-57, the Proteus (contracted by IPO), the University of North Dakota Citation, Naval Research Laboratory's P-3 and CIRPAS Twin Otter. The aircraft were based at Key West Naval Air Facility where the science team of over 200 members was assembled. Important objectives were: 1) the validation of ground-based and satellite remote-sensing observations of cloud properties including observations from Terra (MODIS, MISR, CERES), Aqua (MODIS, AIRS, CERES), GOES, POES, and TRMM (Precipitation Radar); and 2) to provide data sets supporting algorithm development for future measurements from space such as lidar (CALIPSO) and millimeter wavelength radar (CloudSat)–key elements of NASA's "A-Train" that will be in place in 2004. Further details on the CRYSTAL-FACE campaign are found in Section 5 highlights under the Mesoscale Atmospheric Processes Branch section.

Scientists from Code 916 participated in two **International NDSC Comparisons** during 2002. These campaigns are part of a continuing validation protocol within the NDSC. The Network for the Detection of Stratospheric Change (NDSC) consists of a set of high-quality remote-sounding research stations for observing and understanding the physical and chemical state of the stratosphere. The first campaign was held at Lauder, New Zealand, and involved scientists from the Netherlands, New Zealand, and the United States. The second campaign was held at the NOAA facility at Mauna Loa Observatory, Hawaii, in August 2002. This campaign involved instruments from NRL, Goddard, JPL and NOAA. Goddard participants from the Atmospheric Chemistry and Dynamics branch included Tom McGee, with his stratospheric ozone lidar system, and Richard McPeters, who served as the referee for the comparison. Ozone profiles (15 to 50 km) and temperature profiles (15 to 80 km) were compared over a 16-day period. Both of these campaigns were designed to validate data quality of instruments permanently operated at the sites, and included profile measurements of ozone, temperature and aerosols. For further information, contact Thomas McGee (Thomas.J.McGee@nasa.gov), or Richard McPeters (Richard.D.McPeters@nasa.gov).

Data Sets

In the previous discussion, we examined the array of instruments and some of the field campaigns that produce the atmospheric data used in our research. The raw and processed data from these instruments and campaigns is used directly in scientific studies. Some of the data from our instruments and campaigns, plus data from additional sources, are arranged into data sets useful for studying various atmospheric phenomena. Some of these data sets are described in the following paragraphs.

TIROS Operational Vertical Sounder Pathfinder

The Pathfinder Projects are joint NOAA/NASA efforts to produce multiyear climate data sets using measurements from instruments on operational satellites. One such satellite-based instrument suite is the TIROS Operational Vertical Sounder (TOVS). TOVS is comprised of three atmospheric sounding instruments: the High Resolution Infrared Sounder-2 (HIRS-2), the Microwave Sounding Unit (MSU), and the Spectral Sensor Unit (SSU). These instruments have flown on the NOAA Operational Polar Orbiting Satellite since 1979. We have reprocessed TOVS data from 1979 to the present, using an algorithm developed in the Laboratory to infer temperature and other surface and atmospheric parameters from TOVS observations.

The TOVS Pathfinder Path A data set covers the period 1979–2002 and consists of global fields of surface skin and atmospheric temperatures, atmospheric water vapor, cloud amount and cloud height, OLR and clear sky OLR, and precipitation estimates. The data set includes data from TIROS N, NOAA 6,7,8,9,10,11,12, and 14. Equivalent future data sets will be produced from NOAA 16 and 17 ATOVS data and from AIRS data on EOS Aqua. We have demonstrated that TOVS data can be used to study interannual variability of surface and atmospheric temperatures and humidity, cloudiness, OLR, and precipitation. We have developed the 24-year TOVS Pathfinder Path A data set. The TOVS precipitation data is being incorporated in the monthly and daily GPCP precipitation data sets. We are developing improved methodologies to analyze ATOVS data to produce a future climate data set. We have also developed the methodology to be used by the AIRS science team to generate products from AIRS for weather and climate studies. In joint work with the DAO, the AIRS sounding products will be assimilated into the DAO GEOS 3 system to demonstrate how well the AIRS data will improve weather prediction skill. For more information, contact Joel Susskind (Joel.Susskind-1@nasa.gov).

Total Ozone

The merged satellite total ozone data set was recently updated. Calibration of the original six satellite instruments was transferred to the NOAA 16 SBUV/2. This allows extending the record despite issues with the calibration of the Earth Probe TOMS for the last year or so. The data sets now extend through the end of 2001. The data, and information about how they were constructed, can be found at http://code916.gsfc.nasa.gov/Data_services/merged. These data should be useful for trend analyses. For more information, contact Richard Stolarski (Richard.S.Stolarski@nasa.gov) or Stacey Hollandsworth Frith (smh@code916.gsfc.nasa.gov).

Tropospheric Ozone Data

Tropospheric column ozone (TCO) and stratospheric column ozone (SCO), gridded data products are made available from NASA Goddard Space Flight Center Code 916 via either direct ftp, World Wide Web, or electronic mail. Monthly averaged TCO and SCO data are derived in the tropics for January 1979–present using the Convective Cloud Differential (CCD) method [Ziemke et al., *J. Geophys. Res*., **103**, 22115-22127, 1998]. Specific details regarding algorithm and data are discussed in Ziemke et al. [*Bull. Amer. Meteorol. Soc*., **81**,580-583, 2000; *J. Geophys. Res*., 9853-9867, 2001]. Since 1998 and prior to year 2003, the CCD data have been used in ten published papers. The CCD data, algorithm description, and data documentation may be obtained via World Wide Web at http://hyperion.gsfc.nasa.gov/Data_services/Data.html. For more information, contact Jerry Ziemke (ziemke@jwocky.gsfc.nasa.gov).

Aerosol Products from the Total Ozone Mapping Spectrometer

Laboratory scientists are generating a unique new data set of atmospheric aerosols by reanalyzing the 17-year data record of Earth’s ultraviolet albedo as measured by the TOMS. Since 1996, Laboratory staff members have developed techniques for extracting aerosol information from measured UV radiances. The UV technique differs from conventional visible methods in that the UV measurements can reliably separate UV absorbing aerosols (such as desert dust and smoke from biomass burning) from nonabsorbing aerosols (such as sulfates, sea-salt, and ground-level fog). In addition, the UV technique can measure aerosols over land and can detect all types of aerosols over snow/ice and clouds.

TOMS aerosol data are currently available in the form of a contrast index (and now as optical depth). The aerosol index, AI, provides excellent information about sources, transport, and seasonal variation of a variety of aerosol types. The most recent version of the data based on Version 8 reprocessing has been released.

Recently, new methods have been developed to quantitatively detect aerosols using SeaWiFS visible channels over many types of land surfaces as well as the oceans. Because of the high spatial resolution (1 km) we are now able to investigate the sources of dust and smoke by combining the data with calculations from high-resolution transport models. An example of this type of analysis has been made showing dust flowing through mountain passes in Afghanistan and Iran. The aerosol data is also being used to assess the degree of radiative forcing (excess heating) in the atmosphere caused by the presence of dust. The results are used to estimate heating rates related to climate change. The dust aerosol sources and satellite derived winds have been incorporated in the GOCART model to map out trajectory plumes for any time of the day, and to give altitude distributions. One of the applications of the GOCART model to aerosol data is the estimation of air quality in the boundary layer. This is especially important in Africa where the intense boundary layer dust storms are implicated in the incidence of meningitis with epidemic proportions. The results are of intense interest to CDC and WHO. For more information, contact Jay Herman (Jay.R.Herman@nasa.gov).

Multiyear Global Surface Wind Velocity Data Set

The Special Sensor Microwave Imagers (SSM/I) aboard three Defense Meteorological Satellite Program (DMSP) satellites have provided a large data set of surface wind speeds over the global oceans from July 1987 to the present. These data are characterized by high resolution, coverage, and accuracy, but their application was limited by the lack of directional information. In an effort to extend the applicability of these data, the DAO developed methodology to assign directions to the SSM/I wind speeds and to produce analyses using these data. This methodology has been used to generate a 15-year data set (from July 1987 through June 2002) of global SSM/I wind vectors. These data are currently being used in a variety of atmospheric and oceanic applications and are available to interested investigators. For more information, contact Robert Atlas (Robert.M.Atlas@nasa.gov).

Global Precipitation

An up-to-date, long, continuous record of global precipitation is vital to a wide variety of scientific activities. These include initializing and validating numerical weather prediction and climate models, providing input for hydrological and water cycle studies, supporting agricultural productivity studies, and diagnosing intra- and inter-annual climatic fluctuations on regional and global scales.

At the international level, the Global Energy and Water Cycle Experiment (GEWEX) component of the World Climate Research Programme (WCRP) established the Global Precipitation Climatology Project (GPCP) to develop such global data sets. Scientists working in the Laboratory have led the GPCP effort to merge microwave data from low-Earth-orbit satellites, infrared data from geostationary satellites, and data from ground-based rain gauges to produce the best estimates of global precipitation.

Version 2 of the GPCP merged data set provides global, monthly precipitation estimates for the period January 1979 to the present. Updates are being produced on a quarterly basis. The release includes input fields, combination products, and error estimates for the rainfall estimates. The data set is archived at World Data Center A (located at the National Climatic Data Center in Asheville, North Carolina) and at the Goddard Distributed

Active Archive Center (DAAC). Evaluation is ongoing for this long-term data set in the context of climatology, ENSO-related variations and trends, and comparison with the new TRMM observations. Development of data sets with finer time resolution (daily and 3-hr) is proceeding. A daily, global analysis for the period 1997–present has also been completed for the GPCP and is available from the archives. A quasi-global, 3-hr resolution rainfall analysis combining TRMM and other satellite data is being produced in real-time in an experimental mode. A research version of this 3-hr data set will soon be available (in late 2003) for the TRMM observation period from January 1, 1998, to the present. For more information, contact Robert Adler (Robert.F.Adler@nasa.gov).

SHADOZ (Southern Hemisphere ADditional OZonesondes) Data Set

The SHADOZ (Southern Hemisphere Additional Ozonesondes) project was initiated in 1998 to end the lack of tropical ozone profile data. SHADOZ facilitates weekly launches at a dozen locations, collecting and disseminating data through a centralized archive at http://code916.gsfc.nasa.gov/Data_services/shadoz/. More than 1600 ozone and PTU (pressure-temperature-humidity) profiles are available in the archive. SHADOZ data are used to to enhance satellite ozone profile climatology and study tropical chemistry and dynamics. More details are given in an article in Section 5. highlights, under the Atmospheric Chemistry and Dynamics Branch section. For more information, contact Anne Thompson (Anne.M.Thompson@nasa.gov).

Multiyear Data Set of Satellite-based Global Ocean Surface Turbulent Fluxes

Information on the turbulent fluxes of momentum (or wind stress), latent heat (due to evaporation), and sensible heat at the air-sea interface is essential in understanding the interaction between the atmosphere and oceans, global energy and water cycle variability, and in improving model simulations of climate variations. In recognition of the importance of these fluxes in climate studies, the World Climate Research Program (WCRP)/Global Energy and Water Experiment (GEWEX) Radiation Panel has established an international SEA surface turbulent FLUX project, called SEAFLUX, with the primary objective of deriving the global data sets of sea surface turbulent fluxes from satellite observations.

The Special Sensor Microwave/Imager (SSM/I) on board a series of the Defense Meteorological Satellite Program (DMSP) spacecraft has provided global radiance measurements for sensing the atmosphere and the surface. Version 2 data set of Goddard Satellite-based Surface Turbulent Fluxes (GSSTF2), derived from the SSM/I radiance measurements, provides daily- and monthly-mean turbulent fluxes and some relevant parameters over global oceans for the period July 1987–December 2000 and the 1988–2000 annual- and monthly-mean climatologies of the same variables. These variables are wind stress, latent heat flux, sensible heat flux, 10-m wind speed, 10-m specific humidity, sea-air humidity difference, and the lowest 500-m bottom-layer precipitable water. Its spatial resolution is 1º x 1º lat-long. Evaluation is ongoing for this long-term data set in the context of climatology, ENSO-related variations and trends, as well as comparison with research quality in situ measurements, and other data sets of satellite retrievals and the atmospheric general circulation model (GCM) climate simulation/assimilation. The data set is archived at the Goddard Distributed Active Archive Center (DAAC) and is posted in the SEAFLUX Web site for intercomparison and climate studies. For more information, contact Shu-Hsien Chou (Shu-Hsien.Chou-1@nasa.gov).

Data Analysis

A considerable effort by our scientists is spent in analyzing the data from a vast array of instruments and field campaigns. This section details some of the major activities in this endeavor.

Atmospheric Ozone Research

The Clean Air Act Amendment of 1977 assigned NASA major responsibility for studying the ozone layer.

Data from many ground-based, aircraft, and satellite missions are combined with meteorological data to understand the factors that influence the production and loss of atmospheric ozone. Analysis is conducted over different temporal and spatial scales, ranging from studies of transient filamentary structures that play a key role in mixing the chemical constituents of the atmosphere to investigations of global-scale features that evolve over decades.

The principal goal of these studies is to understand the complex coupling between natural phenomena, such as volcanic eruptions and atmospheric motions, and human-made pollutants, such as those generated by agricultural and industrial activities. These nonlinear couplings have been shown to be responsible for the development of the well-known Antarctic ozone hole.

An emerging area of research is to understand the transport of chemically active trace gases across the tropopause boundary. It has been suggested that changes in atmospheric circulation caused by greenhouse warming may affect this transport and, thus, delay the anticipated recovery of the ozone layer in response to phase-out of CFCs. For more information, contact Paul A. Newman (Paul.A.Newman@nasa.gov).

Total Column Ozone and Vertical Profile

Laboratory for Atmospheres scientists have been involved in measuring ozone since April 1970 when a satellite instrument, the Backscatter Ultraviolet (BUV) Spectrometer, was launched on NASA's Nimbus-4 satellite to measure the column amount and vertical distribution of ozone. These measurements are continuing aboard several follow-on missions launched by NASA, NOAA, and, more recently, by the ESA.

An important activity in the Laboratory is developing a high-quality, long-term ozone record from these satellite sensors and comparing that record with ground-based and other satellite sensors. This effort, already more than a quarter century in duration, has produced ozone data sets that have played a key role in identifying the global loss of ozone due to certain human-made chemicals. This knowledge has contributed to international agreements to phase out these chemicals by the end of this century. For more information, contact Pawan K. Bhartia (Pawan.K.Bhartia@nasa.gov).

Surface UV Flux

The primary reason for measuring atmospheric ozone is to understand how the UV flux at the surface might be changing and how this change might affect the biosphere. The sensitivity of the surface UV flux to ozone changes is calculated using atmospheric models and the measured values of ozone, aerosol, and cloud amounts. Yet, until recently, we had no rigorous test of these models, particularly in the presence of aerosols and clouds. By comparing a multiyear data set of surface UV flux generated from TOMS data and high-quality ground-based measurements, especially those from a cooperative effort with the U.S. Department of Agriculture, we are increasingly successful in quantifying the respective roles of ozone, aerosols, and clouds in controlling the surface UV flux over the globe. The better agreement between satellite estimations of UV irradiance and ground-based measurements has improved confidence in UV flux estimates for regions that are not accessible to ground instruments (e.g., deserts, oceans, etc.). There are 5 new UV products available, the noontime irradiances at 305, 310, 324, 380 nm, and erythemal, in addition to the traditional erythemal daily exposure. We have recently extended the analysis of UV flux for penetration into the deep oceans and coastal regions using a newly developed UV radiative transfer model. For more information, contact Jay Herman (Jay.R.Herman@nasa.gov).

Data Assimilation

The DAO has taken on the challenge of providing to the research community a coherent, global, near real-time picture of the evolving Earth system. The DAO is developing a state-of-the-art Data Assimilation System (DAS) to extract the usable information available from a vast number of observations of the Earth system's many components, including the atmosphere, the oceans, the Earth's land surfaces, the biosphere, and the cryosphere (ice sheets over land or sea).

The DAS is made of several components including an atmospheric prediction model, a variational physical space analysis scheme, and models to diagnose unobservable quantities. Each of these components requires intense research, development, and testing. Much attention is given to ensuring that the components interact properly with one another to produce meaningful, research-quality data sets for the Earth system science research community. (See later section on Modeling). For more information, contact Robert Atlas (Robert.M.Atlas@nasa.gov).

Observing System Simulation Experiments

Since the advent of meteorological satellites in the 1960s, considerable research effort has been directed toward designing spaceborne meteorological sensors, developing optimum methods for using satellite soundings and winds, and assessing the influence of satellite data on weather prediction. Observing system simulation experiments (OSSE) have played an important role in this research. Such studies have helped in designing the global observing system, testing different methods of assimilating satellite data, and assessing the potential impact of satellite data on weather forecasting.

At the present time, OSSEs are being conducted to (1) provide a quantitative assessment of the potential impact of currently proposed space-based observing systems on global change research, (2) evaluate new methodology for assimilating specific observing systems, and (3) evaluate tradeoffs in the design and configuration of these observing systems. Specific emphasis over the past year has been on space-based lidar winds and other advanced passive sensors. For more information, contact Robert Atlas (Robert.M.Atlas@nasa.gov).

Seasonal-to-Interannual Climate Variability and Prediction

One of the main thrusts in climate research in the Laboratory is to identify natural variability on seasonal, interannual, and interdecadal time scales, and to isolate the natural variability from the human-made global-change signal. Climate diagnostic studies use a combination of remote-sensing data, historical climate data, model outputs, and assimilated data. Climate diagnostic studies will be combined with modeling studies to unravel physical processes underpinning climate variability and predictability. The key areas of research include the El Niño Southern Oscillation (ENSO), monsoon variability, intraseasonal oscillation, and water vapor and cloud feedback processes. A full array of standard and advanced analytical techniques, including wavelets transform, multivariate empirical orthogonal functions, singular value decomposition, canonical correlation analysis, and nonlinear system analysis are used.

The Laboratory, in conjunction with the Laboratory for Hydrospheric Processes (Code 970), plays a lead role in NASA's Seasonal-to-Interannual Prediction Project (NSIPP). NSIPP promotes and facilitates collaboration between NASA and outside scientists in developing coupled ocean-atmosphere-land modeling system to predict El Niño events, and their impacts on climate of North America and other regions of the extratropics by utilizing a combination of satellite and in situ data. NSIPP will also employ a high-resolution atmosphere-land data assimilation system that will capitalize on a host of new high-resolution satellite data from MODIS/TERRA, AQUA and Landsat. This capability will allow scientists to better characterize the global and regional water cycles, and local and remote physical processes that control regional climates predictability. Another important activity is the use of satellite data for model validation and improving physical parameterizations, in particular with respect to clouds, radiation, and rainfall processes.

Promoting the use of satellite data for better interpretation, modeling and eventually prediction of geophysical and hydroclimate system is a top priority of research in the Laboratory. Satellite-derived data sets for key hydroclimate variables will be used extensively for diagnostic and modeling studies. Examples of such data sets are rainfall, water vapor, clouds, surface wind, sea surface temperature, sea level heights, land surface characteristics from the EOS TERRA, AQUA series, from TRMM, QuikSCAT and TOPEX/Poseidon and Jason-1, as well as from the Earth Radiation Budget Experiment (ERBE), the International Satellite Cloud Climatology (ISCCP), Advanced Very High Resolution Radiometer (AVHRR), SSM/I, MSU, and TOVS Pathfinder data. For more information, contact William Lau (William.K.Lau@nasa.gov).

Rain Measurements

Rain Estimation Techniques from Satellites

Rainfall information is a key element in studying the hydrologic cycle. A number of techniques have been developed to extract rainfall information from current and future spaceborne sensor data, including the TRMM satellite and the Advanced Microwave Scanning Radiometer (AMSR) on EOS Aqua.

The retrieval techniques include the following: (1) A physical, multifrequency technique that relates the complete set of microwave brightness temperatures to rainfall rate at the surface. This multifrequency technique also provides information on the vertical structure of hydrometeors and on latent heating through the use of a cloud ensemble model. The approach has recently been extended to combine spaceborne radar data with passive microwave observations. (2) An empirical relationship that relates cloud thickness and other parameters to rain rates, using TOVS sounding retrievals. (3) An analysis technique that uses TRMM, other low-orbit microwave, geosynchronous infrared, and rain gauge information to provide a merged, global precipitation analysis. The merged analysis technique is now being used to produce global daily and quasi-global (50N-50S) 3-hourly analyses.

The satellite-based rainfall information has been used to study the global distribution of atmospheric latent heating, the impact of ENSO on global-scale and regional precipitation patterns, the climatological contribution of tropical cyclone rainfall, and the validation of global models. For more information, contact Robert Adler (Robert.F.Adler@nasa.gov).

Rain Measurement Validation for the TRMM

The objective of the TRMM Ground Validation Program (GVP) is to provide reliable, instantaneous area- and time-averaged rainfall data from several representative tropical and subtropical sites worldwide for comparison with TRMM satellite measurements. Rainfall measurements are made at Ground Validation (GV) sites equipped with weather radar, rain gauges, and disdrometers. A range of data products derived from measurements obtained at GV sites is available via the Goddard DAAC. With these products, the validity of TRMM measurements is being established with accuracies that meet mission requirements. For more information, contact Robert Adler (Robert.F.Adler@nasa.gov).

Predicting Errors in Satellite Rainfall Measurements

A statistical model for the variability of rain in time and space, previously used to help understand the uncertainty in averages of satellite estimates of rainfall, can help with understanding the level of disagreement to be expected between satellite observations over areas containing rain gauges and the average rainfall measured by the gauges themselves. Such comparisons are desirable because they help to evaluate the accuracy of satellite rain estimates. The model suggests how best to choose the area around the gauges over which the satellite observations are averaged and the time intervals over which the gauge data are averaged in order to minimize the magnitude of the difference between the two averages. This was possible because the model captures an aspect of rain variability that many simpler models do not handle so well [T.L. Bell and P.K. Kundu, 2002]. An improved method of choosing the parameters in the model was also developed, and used to fit the model behavior to radar observations of rain in a major experimental campaign over the western equatorial Pacific, TOGA COARE [P.K. Kundu and T.L. Bell, 2003].

In a collaboration with researchers at Princeton, a simple method of estimating the error levels for maps of satellite average rainfall, previously developed and tested with rain observations from the Defense Meteorological Satellite Program satellites [T.L. Bell, P.K. Kundu, and C.D. Kummerow, 2001], was tested using ground-based observations of rain over the United States, and found to work quite well [M. Steiner, T.L. Bell, Y. Zhang, and E.F. Wood, 2003]. An effort is now under way to implement the method for the monthly rainfall maps produced by TRMM. For more information, contact Thomas L. Bell (Thomas.L.Bell@nasa.gov).

Aerosols/Cloud Climate Interactions

Theoretical and observational studies are being carried out to analyze the optical properties of aerosols and their effectiveness as cloud condensation nuclei. These nuclei produce different drop size distributions in clouds, which, in turn, will affect the radiative balance of the atmosphere.

We developed algorithms to routinely derive aerosol loading, aerosol optical properties, and total precipitable water vapor data products from the EOS-Terra Moderate Resolution Imaging Spectroradiometer (MODIS). These algorithms are being evaluated, modified, and verified using the global MODIS data and information from the Aerosol Robotic Network (AERONET) of sun/sky radiometers. MODIS and AERONET data are being used to evaluate the global distribution of aerosols, their properties, and their radiative forcing of climate. Evaluation of the MODIS aerosol data with AERONET shows that they are as accurate as predicted in papers from 1997. Further evaluation involving monthly mean values of MODIS and AERONET, in conjunction with output from the GOCART aerosol transport model provides a comprehensive picture of the global aerosol system, and demonstrates a lack of bias in the MODIS monthly mean aerosol properties. MODIS and AERONET data used together enables the derivation of empirical phase functions without assumption of particle shape. These phase functions are fundamentally different from those derived from the common assumption of particle sphericity and will alter our perception of how irregularly shaped aerosol particles such as desert dust affect the amount of solar radiation back-scattered to space.

Laboratory scientists are actively involved in analyzing data recently obtained from national and international campaigns. These campaigns include the Puerto Rico Dust Experiment (PRiDE) which observed transported Saharan dust in the Caribbean, the Southern Africa Fire-Atmosphere Research Initiative (SAFARI) 2000 which characterized aerosols from southern African biomass burning, and the Chesapeake Lighthouse Aircraft Measurements for Satellites (CLAMS) which was an excellent opportunity to characterize both aerosol and various ocean surface conditions off the east coast of the United States. For more information, contact Lorraine Remer (Lorraine.A.Remer@nasa.gov).

Hydrologic Processes and Radiation Studies

Scientists in the Climate and Radiation Branch of the Laboratory are developing methods to estimate atmospheric water and energy budgets. These methods include calculating the radiative effects of absorption, emission, and scattering by clouds, water vapor, aerosols, CO_2, and other trace gases. Algorithms for global measurements of aerosol thickness are developed from MODIS data. Calibration/validation and scientific experiments on aerosols and clouds are conducted in various climatic regions of the world, with ground-based and airborne instruments, e.g., the SAFARI experiment in South Africa, PRiDE in Puerto Rico, ACE-Asia in central Asia. Also developed are arrays of highly mobile and versatile measurement platforms for direct measurements of surface radiation, water vapor and cloud properties for deployments in field campaigns, e.g., Surface Measurement of Atmospheric Radiation Transfer (SMART) and the off-beam lidar (THOR) for cloud thickness measurements.

Using long-term satellite and satellite-blended data and four-dimensional assimilated data, Laboratory scientists study the response of radiation budgets to changes in water vapor and clouds during El Niño events in the Pacific basin and during westerly wind-burst episodes in the western tropical Pacific warm pool. Also investigated are the relative importance of large-scale dynamics and local thermodynamics on clouds and radiation budgets and modulating sea surface temperature. In addition, research effort is devoted to understanding and predicting the impacts of basin-scale sea surface temperature fluctuations such as the El Niño on regional climate variability over the Indo-Pacific region, North America, and South America. For more information, contact William Lau (William.K.Lau@nasa.gov).

Unified Onboard Processing and Spectrometry

Increasingly, scientists agree that spectrometers are the wave of the future in passive Earth remote sensing. But the difficulty stems from the vast volume of data generated by an imaging spectrometer sampling in the spatial and spectral dimensions. The data volume from an advanced spectrometer could easily require 10 times the present EOSDIS capacity—something NASA simply cannot afford. A group of scientists and engineers at GSFC, led by Si-Chee Tsay, is funded by ESTO/ACT, a new project to unify onboard processing techniques with compact, low-power, low-cost, Earth-viewing spectrometers being developed for eventual space missions. The philosophy is that spectrometry and its onboard processing algorithms must advance in lockstep, and eventually unite in an indistinguishable fashion. We envision a future in which archives of the spectrometer output will not be a monstrous data-dump of spectra, but rather the information content of those spectra, undoubtedly a much smaller and more valuable data stream. In the meantime, we must quickly find ways to losslessly onboard-compress spectra to the maximum extent possible. Our estimates indicate compressions of 10 to 100 are possible using a combination of physics-based removal and proximal differencing. For further information, contact Si-Chee Tsay (Si-Chee.Tsay-1@nasa.gov).

Modeling

Modeling is an important aspect of our research, and is the path to understanding the physics and chemistry of our environment. Models are intimately connected with the data measured by our instruments: models are used to interpret the data, the data is combined with the models in data assimilation. Our modeling activities are highlighted below.

Coupled Atmosphere-Ocean-Land Models

To study climate variability and sensitivity, we must couple the atmospheric GCM with ocean- and land-surface models. Much of the work in this area is conducted in collaboration with Goddard’s Laboratory for Hydrospheric Processes, Code 970. The ocean models predict the global ocean circulation—including the sea surface temperature (SST)—when forced with atmospheric heat fluxes and wind stresses at the sea surface. Land-surface models are detailed representations of the primary hydrological processes, including evaporation; transpiration through plants; infiltration; runoff; accumulation, sublimation, and melt of snow and ice; and groundwater budgets.

One of the main objectives of coupled models is forecasting seasonal-to-interannual anomalies such as the El Niño phenomenon. Laboratory scientists are involved in the NASA Seasonal-to-Interannual Prediction Project (NSIPP), which was established in collaboration with Goddard's Laboratory for Hydrospheric Processes. NSIPP's main goal is to develop a system capable of assimilating hydrologic data and using that data with complex, coupled ocean-atmosphere models to predict tropical SST with lead times of 6–14 months. A second goal is to use the predicted SST in conjunction with coupled atmosphere-land models to predict changes in global weather patterns.

NSIPP is currently producing routine seasonal forecasts. Each month surface and subsurface hydrographic data are assimilated to produce initial conditions for the ocean component of a coupled ocean-atmosphere-land forecast system. An ensemble of forecasts is then integrated for 1 year. In addition to this coupled forecast of SST, NSIPP also performs monthly "Tier 2" forecasts, using SSTs, predicted at other centers, to force more detailed atmospheric models. NSIPP's forecasts are available on the Internet at http://nsipp.gsfc.nasa.gov and are used by prediction centers for guidance in their assessments.

In addition to its forecasting work, NSIPP is engaged in research activities in land surface modeling, coupled processes, low-frequency atmospheric phenomena, and various aspects of data assimilation. More on this work can be found at the above Web site, together with a large archive of model-simulated data. For information, contact Max Suarez (Max.J.Suarez@nasa.gov).

Global Modeling and Data Assimilation

Development of the Data Assimilation System

In October 2002, the Data Assimilation Office transitioned to operations GEOS-4, its next generation data assimilation system for supporting the EOS Terra and Aqua missions. This new system consists of a completely redesigned state-of-the-art general circulation model based on the finite-volume dynamical core developed at DAO, coupled to physical parameterizations from National Centers for Atmospheric Research (NCAR). The system employs an adaptive statistical quality control, which examines the quality of the input data stream taking into consideration the "flow of the day." The system ingests data from a variety of conventional and remotely sensed data including rawinsondes, TOVS Level 1B radiances and scatterometers. In the core of the assimilation algorithm is DAO's Physical-space Statistical Analysis System (PSAS), a global 3-D VAR class solver that combines model short-term forecast with observations to provide an optimal estimate of the atmospheric state. Compared to the previous GEOS-3.2 operational system, the next generation system has superior forecasts skills, has an improved stratospheric circulation, realistically captures the evolution of synoptic systems, and has a competitive climate. For more information, contact Robert Atlas (Robert.M.Atlas@nasa.gov).

Cloud and Mesoscale Modeling

The mesoscale (MM5) and cloud-resolving (Goddard Cumulus Ensemble-GCE) models are used in a wide range of studies, including investigations of the dynamic and thermodynamic processes associated with cyclones and frontal rainbands, tropical and mid-latitude deep convective systems, surface (i.e., ocean and land, and vegetation and soil) effects on atmospheric convection, cloud-chemistry interactions, cloud-aerosol interactions, and stratospheric-tropospheric interaction. Other important applications include assessment of the potential benefits of assimilating satellite-derived water vapor, winds and precipitation fields into tropical and extra-tropical regional-scale (i.e., hurricanes and cyclones) weather simulations, and climate applications. The latter involves long-term integrations of the models that allow for the study of air-sea and cloud-radiation interactions and their role in cloud-radiation-climate feedback mechanisms. Such simulations provide an integrated system-wide assessment of important factors such as surface energy and radiative exchange processes, and diabatic heating and water budgets associated with tropical, subtropical and mid-latitude weather systems.

Data collected during several major field programs, GATE (1974), PRESTORM (1985), TOGA COARE (1992–1993), ARM (1997), SCSMEX (1998), TRMM LBA (1999), TRMM KWAJEX (1999) and CAMEX3/4 (2000/2001), were used to improve as well as to validate the GCE and MM5 model. The MM5 was also improved in order to study regional climate variation, hurricanes and severe weather events (i.e., flash floods in the central United States and China). The models also are used to develop retrieval algorithms. For example, GCE model simulations are being used to provide TRMM investigators with four-dimensional cloud data sets to develop and improve TRMM rainfall and latent heating retrieval algorithms and moist processes represented in large scale models (i.e., weather forecast model and climate model). Four-dimensional latent heating structures (1º by 1º, monthly) were retrieved from December 1997 to November 2002.

The scientific output of the modeling activities was again exceptional in 2002 with 15 new papers published and many more submitted. For more information, contact Wei-Kuo Tao (Wei-Kuo.Tao-1@nasa.gov).

Physical Parameterization in Atmospheric GCMs

The development of submodels of physical processes (physical parameterizations) is an integral part of climate modeling activity. Laboratory scientists are actively involved in developing and improving physical parameterizations of the major radiative transfer moist processes, clouds and cloud radiation interaction and Earth-atmosphere interaction processes. All of these areas are extremely important for eliminating climate-model biases, which leads to a better understanding of the global water and energy cycles.

For atmospheric radiation, we are developing efficient, accurate, and modular longwave and shortwave radiation codes. The radiation codes allow efficient computation of climate sensitivities to water vapor, cloud microphysics, and optical properties. The codes also allow us to compute the global warming potentials of carbon dioxide and various trace gases.

For atmospheric hydrologic processes, we are evaluating and improving a prognostic cloud liquid water scheme, which includes representation of source and sink terms as well as horizontal and vertical advection of cloud water substance. This scheme incorporates attributes from physically based cloud life cycles, including the effects of convective updrafts and downdrafts, cloud microphysics within convective towers and anvils, cloud-radiation interactions, and cloud inhomogeneity corrections. The boundary-layer clouds are consistently derived from and linked to boundary-layer convection. We are evaluating coupled radiation and the prognostic water schemes with in situ observations from the ARM-CART and TOGA-COARE IOPs as well as satellite data. For land-surface processes, a new snow physics package has been developed and evaluated with GEWEX GSWP data sets. It is currently in the GEOS/fv-NCAR GCMs. Moreover, the soil moisture prediction is extended down to 5m, which often goes through the groundwater table. All these improvements have been found to better represent the hydrologic cycle in a climate simulation. Currently, we are performing objective intercomparisons of different parameterization concepts applied to both models and satellite data retrievals within GSFC laboratories. NCAR/GISS scientists are our active collaborators. For more information, contact Yogesh Sud (Yogesh.C.Sud@nasa.gov).

Trace Gas Modeling

The Atmospheric Chemistry and Dynamics Branch has developed two- and three-dimensional models to understand the behavior of ozone and other atmospheric constituents. We use the two-dimensional models primarily to understand global scale features that evolve in response to both natural effects, such as variations in solar luminosity in ultraviolet, volcanic emissions, or solar proton events, and human effects, such as changes in chlorofluorocarbons (CFCs), nitrogen oxides, and hydrocarbons. Three-dimensional stratospheric chemistry and transport models (CTMs) simulate the evolution of ozone and trace gases that affect ozone. The constituent transport is calculated utilizing meteorological fields (winds and temperatures) generated by the DAO or using meteorological fields that are output from a general circulation model (GCM). These calculations are appropriate to simulate variations in ozone and other constituents for time scales ranging from several days or weeks to seasonal, annual, and multiannual. The model simulations are compared with observations, with the goal of improving our understanding of the complex chemical and dynamical processes that control the ozone layer, thereby improving our predictive capability.

The modeling effort has evolved in four directions: (1) Lagrangian models are used to calculate the chemical evolution of an air parcel along a trajectory. The Lagrangian modeling effort is primarily used to interpret aircraft and satellite chemical observations. (2) Two-dimensional (2-D) noninteractive models have comprehensive chemistry routines, but use specified, parameterized dynamics. They are used in both data analysis and multidecadal chemical assessment studies. (3) Two-dimensional interactive models include interactions among photochemical, radiative, and dynamical processes, and are used to study the dynamical and radiative impact of major chemical changes. (4) Three-dimensional (3-D) CTMs have a complete representation of photochemical processes and use input meteorological fields from either the data assimilation system or from a general circulation model for transport. The constituent fields calculated using winds from a new GCM developed jointly by the DAO and the National Center for Atmospheric Research exhibit many observed features. We are coupling this GCM with the stratospheric photochemistry from the CTM with the goal of developing a fully interactive 3-D model that is appropriate for assessment calculations. We are also using output from this GCM in the current CTM for multidecadal simulations. A pending improvement to the CTM is implementation of a chemical mechanism suitable for both the upper troposphere and lower stratosphere. This capability will be needed for interpretation of data from EOS Aura, to be launched in early 2004.

The Branch uses trace gas data from sensors on the UARS, on other satellites, from ground-based platforms, from balloons, and from various NASA-sponsored aircraft campaigns to test model processes. The integrated effects of processes such as stratosphere troposphere exchange, not resolved in 2-D or 3-D models, are critical to the reliability of these models. For more information, contact Anne Douglass (Anne.R.Douglass@nasa.gov).

Support for National Oceanic and Atmospheric Administration Operational Satellites

In the preceding pages, we examined the Laboratory for Atmosphere's work in measurements, data sets, data analysis, and modeling. In addition, Goddard supports NOAA's remote sensing requirements. Laboratory project scientists support the NOAA Polar Orbiting Environmental Satellite (POES) and the Geostationary Operational Environmental Satellite (GOES) Project Offices. Project scientists assure scientific integrity throughout mission definition, design, development, operations, and data analysis phases for each series of NOAA platforms. Laboratory scientists also support the NOAA SBUV/2 ozone measurement program. This program is now operational within the NOAA/National Environmental Satellite Data and Information Service (NESDIS). A series of SBUV/2 instruments flies on POES. Post-doctoral scientists work with the project scientists to support development of new and improved instrumentation and to perform research using NOAA's operational data.

Laboratory members are actively involved in the NPOESS Internal Government Studies (IGS) and support the Integrated Program Office (IPO) Joint Agency Requirements Group (JARG) activities. Likewise, the Laboratory is supporting the formulation phase for the next generation GOES mission, known as GOES-R. One scientist is involved in specifying the requirements for the advanced GOES-R atmospheric sounder, called High Resolution Environmental Suite (HES), writing the RFP, and serving on the Source Evaluation Board (HES).

Geostationary Operational Environmental Satellites

NASA GSFC project engineering and scientific personnel support NOAA for the GOES operational satellites. GOES supplies images and soundings to monitor atmospheric processes in real time, such as moisture, winds, clouds, and surface conditions. GOES observations are used by climate analysts to study the diurnal variability of clouds and rainfall and to track the movement of water vapor in the upper troposphere. The GOES satellites also carry an infrared multichannel radiometer that NOAA uses to make hourly soundings of atmospheric temperature and moisture profiles over the United States to improve numerical forecasts of local weather. The GOES project scientist at Goddard provides free public access to real-time weather images via the World Wide Web (http://rsd.gsfc.nasa.gov/goes/). For more information, contact Dennis Chesters (Dennis.F.Chesters@nasa.gov).

Polar-Orbiting Environmental Satellites

Algorithms are being developed and optimized for the HIRS-3 and the Advanced Microwave Sounding Unit (AMSU) first launched on NOAA 15 in 1998. Near real-time analysis will be carried out thereafter, as was done with HIRS2/MSU data. For more information, contact Joel Susskind (Joel.Susskind-1@nasa.gov).

Solar Backscatter Ultraviolet/2

NASA has the responsibility to determine and monitor the prelaunch and post-launch calibration of the SBUV/2 instruments that are included in the payload of the NOAA polar-orbiting satellites. We further have the responsibility to continue the development of new algorithms to determine more accurately the concentration of ozone in the atmosphere.

The NOAA 16 SBUV/2 instrument was launched and has gone through testing. It has now been operational since March 2001. Because the EP TOMS instrument is undergoing a degradation of its scanning mirror, the NOAA 16 SBUV/2 is now our primary measurement for the long-term ozone record. We are in the process of integrating the data from this instrument into our long-term record. This is being accomplished by comparing its data to both EP TOMS and the NOAA 11 SBUV/2 to evaluate their relative calibrations.

We have previously produced a single merged data set with a common calibration that extends from November 1978 through the end of 2000. We will soon be updating this record to include the NOAA 16 data that can continue into and beyond 2000. The data are available on the Web at http://code916.gsfc.nasa.gov/Data_services/merged/. For more information, contact Richard Stolarski (Richard.S.Stolarski@nasa.gov).

National Polar-Orbiting Environmental Satellite System

The first step in instrument selection for NPOESS was completed with Laboratory personnel participating on the Source Evaluation Board, acting as technical advisors. Laboratory personnel were involved in evaluating proposals for the OMPS (Ozone Mapper and Profiler System) and the Crosstrack Infrared Sounder (CrIS), which will accompany ATMS, an AMSU-like crosstrack microwave sounder. Collaboration with the IPO continues through the Sounder Operational Algorithm Team (SOAT) and the Ozone Operational Algorithm Team (OOAT), which will provide advice on operational algorithms and technical support on various aspects of the NPOESS instruments. In addition to providing an advisory role, members of the Laboratory are conducting internal studies to test potential technology and techniques for NPOESS instruments. We have conducted numerous trade studies involving CrIS and ATMS, the advanced IR and microwave sounders, which will fly on NPP and NPOESS. Simulation studies were conducted to assess the ability of AIRS to determine atmospheric

CO_2, CO, and CH_4. These studies indicate that total CO_2 can be obtained to 2 ppm (0.5%) from AIRS under clear conditions, total CH_4 to 1%, and total CO to 15%. This shows that AIRS should be able to produce useful information about atmospheric carbon. For more information, contact Joel Susskind (Joel.Susskind-1@nasa.gov).

For OMPS, Laboratory scientists continue to support the IPO through the OOAT. The team conducts algorithm research and provides oversight for the OMPS developer. An algorithm is being developed to analyze SAGE III data when SAGE III operates in a limb-scattering mode, which will simulate retrievals expected from the OMPS profiler. This work is an extension of the retrievals used for the SOLSE/LORE shuttle mission conducted in 1997. The SOLSE/LORE payload was developed in the Laboratory for Atmospheres. The retrievals from this shuttle mission demonstrated the feasibility of employing limb scattering to observe ozone profiles with high vertical resolution down to the tropopause. This research is enabled by the advanced UV and visible radiative transfer models developed in the Laboratory. Laboratory scientists also participate in the Instrument Product Teams to review all aspects of the OMPS instrument development. The IPO supported a reflight of SOLSE/LORE on the space shuttle, in July 2002, as a risk mitigation effort related to the OMPS. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath-1@nasa.gov).

CrIS is a high-spectral-resolution interferometer infrared sounder with capabilities similar to those of the Atmospheric Infrared Sounder (AIRS). AIRS was launched with AMSU A and HSB on the EOS Aqua platform on March 5, 2002. Scientific personnel have been involved in developing the AIRS Science Team algorithm to analyze the AIRS/AMSU/HSB data. Preliminary results with AIRS/AMSU/HSB data indicate that the temperature sounding goals for AIRS, i.e., RMS accuracy of 1K in 1 km layers of the troposphere under partial cloud cover, will be met. The AIRS soundings will be used in a pseudo-operational mode by NOAA/NESDIS and NOAA/NCEP. Simulation studies were conducted for the IPO to compare the expected performance of AIRS/AMSU/HSB with that of CrIS, as a function of instrument noise, together with AMSU/HSB. The simulations will help in assessing the noise requirements for CrIS to meet the NASA sounding requirements for the NPOESS Preparatory Project (NPP) bridge mission in 2005. Trade studies have also been done for the Advanced Technology Sounder (ATMS), which will accompany CrIS on the NPP mission and replace AMSU/HSB. For more information, contact Joel Susskind (Joel.Susskind-1@nasa.gov).

Tropospheric wind profile measurements are the number one priority in the unaccommodated Environmental Data Records (EDR) identified in the NPOESS Integrated Operational Requirements Document (IORD-1). The Laboratory is using these requirements to develop new technologies and Direct Detection Doppler Lidar measurement techniques to measure tropospheric wind profiles from ground, air and spaceborne platforms. The IPO is supporting the effort through their IGS program. For more information, contact Bruce Gentry (Bruce.M.Gentry@nasa.gov).

The IPO supports the development of Holographic Scanning Lidar Telescope technology as a risk reduction for lidar applications on NPOESS, including direct detection wind lidar systems. Currently used in ground-based and airborne lidar systems, holographic scanning telescopes operating in the visible and near infrared wavelength region have reduced the size and weight of scanning receivers by a factor of three. We are currently investigating extending the wavelength region to the ultraviolet, increasing aperture sizes to 1 meter and larger, and eliminating all mechanical moving components by optically addressing multiplexed holograms in order to perform scanning. This last development should reduce the weight of large aperture scanning receivers by another factor of three. For more information on the Holographic Optical Telescope and Scanner (HOTS) technology, visit the Web site at http://virl.gsfc.nasa.gov/lazer/index.html or contact Geary Schwemmer (Geary.K.Schwemmer@nasa.gov).

Project Scientists

Spaceflight missions at NASA depend on cooperation between two upper-level managers, the project scientist and the project manager, who are the principal leaders of the project. The project scientist provides continuous scientific guidance to the project manager while simultaneously leading a science team and acting as the interface between the project and the scientific community at large. Table 3 lists project and deputy project scientists for current missions.

Table 3. Laboratory for Atmospheres Project and Deputy Project Scientists

Project Scientists		**Deputy Project Scientists**	
Name	**Project**	**Name**	**Project**
Pawan K. Bhartia	TOMS	Anne R. Douglass	EOS Aura, UARS
Dennis Chesters	GOES	Ernest Hilsenrath	EOS Aura
Jay Herman	Triana	Arthur Hou	TRMM
	(renamed DSCOVR)	Si-Chee Tsay	EOS Terra
Robert Adler	TRMM	Marshall Shepherd	GPM
Charles Jackman	UARS		
Joel Susskind	POES		
Robert Cahalan	EOS		
	SORCE		
Eric Smith	GPM		

EOS Validation Scientist		**Field/Aircraft Campaign Co-Project/Mission Scientists**	
Name	**Project**	**Name**	**Project**
David O’C Starr	EOS	Matt McGill	Cloud Sat
		Matt McGill	CALIPSO
		Robert Atlas	GTWS
		Judd Welton	MPLNET
		Si-Chee Tsay	ACE Asia II
		Robert Cahalan	THOR Validation
		Thomas McGee	N.Z. Intercomparison
		Geary Schwemmer	SERDR
		Bruce Gentry/Geary Schwemmer	HARGLO-2
		David Starr	CRYSTAL-FACE
		Belay Demoz	IHOP
		Paul Newman/Mark Schoeberl	SOLVE II

Interactions with Other Scientific Groups

Interactions with the Academic Community

The Laboratory relies on collaboration with university scientists to achieve its goals. Such relationships make optimum use of government facilities and capabilities as well as those of academic institutions. These relationships also promote the education of new generations of scientists and engineers. Educational programs include summer programs for faculty and students, fellowships for graduate research, and associateships for postdoctoral studies. A number of Laboratory members teach courses at nearby universities and give lectures and seminars at U.S. and foreign universities (see section 6 for more details on the education and outreach activities of our Laboratory). The Laboratory frequently supports workshops on a wide range of scientific topics of interest to the academic community, as shown in Appendix 5.

NASA and non-NASA scientists work together on NASA missions, experiments, and instrument and system development. Similarly, several Laboratory scientists work on programs residing at universities or other Federal agencies.

The Laboratory routinely makes its facilities, large data sets, and software available to the outside community. The list of refereed publications, presented in Appendix 7, reflects our many scientific interactions with the outside community; 70% of the publications involve co-authors from institutions outside the Laboratory.

A prime example of the collaboration between the academic community and the Laboratory is given in this list of collaborative relationships via memoranda of understanding or cooperative agreements. The Directorate list of these collaborations is given at the Web site http://webserv.gsfc.nasa.gov/ESD/collab.html.

- Center for Earth-Atmosphere Studies (CEAS), with Colorado State University;
- Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA), with Howard University;
- Cooperative Center for Atmospheric Science and Technology (CCAST), with the University of Arizona;
- Cooperative Institute for Atmospheric Research (CIFAR) Graduate Student Support, with UCLA;
- Cooperative Institute of Meteorological Satellite Studies (CIMSS) with the University of Wisconsin, Madison;
- Earth System Science Interdisciplinary Center (ESSIC), with the University of Maryland, College Park;
- Goddard Earth Sciences and Technology Center (GEST Center), with the University of Maryland, Baltimore County, (and involving Howard University);
- Joint Center for Earth Systems Technology (JCET), with the University of Maryland, Baltimore County;
- Joint Center for Geoscience (JCG) at MIT;
- Joint Center for Observation System Science (JCOSS) with the Scripps Institution of Oceanography, University of California, San Diego; and,
- Joint Interdisciplinary Earth Science Information Center (JIESIC) with George Mason University.

These collaborative relationships have been organized to increase scientific interactions between the Earth Sciences Directorate at GSFC and the faculty and students at the participating universities. One means of increasing these interactions is a new initiative the Earth Sciences Directorate has established that will increase our sponsorship of graduate students. The Laboratory for Atmospheres is participating in this program, which will partner Laboratory scientists with graduate students. Our scientists will advise the student, serve on the thesis committee, visit the university, host the student at GSFC, and collaborate with the student’s thesis advisor.

In addition, university and other outside scientists visit the Laboratory for periods ranging from 1 day to as long as 2 years. (See Appendix 1 for a list of recent visitors and Appendix 4 for seminars.) Some of these appointments are supported by Resident Research Associateships offered by the National Research Council (NRC) of the National Academy of Sciences; others, by the Visiting Scientists and Visiting Fellows Programs currently managed by the Goddard Earth Sciences and Technology (GEST) Center. Visiting Scientists are appointed for up to 2 years and carry out research in preestablished areas. Visiting Fellows are appointed for up to 1 year and are free to carry out research projects of their own design. (See Appendix 3 for a list of NRC Research Associates, GEST Center Visiting Scientists, Visiting Fellows, and Associates of the Joint Institutes during 2002.)

Interactions with Other NASA Centers and Federal Laboratories

The Laboratory maintains strong, productive interactions with other NASA Centers and Federal laboratories.

Our ties with the other NASA Centers broaden our knowledge base. They allow us to complement each other's strengths, thus increasing our competitiveness while minimizing duplication of effort. They also increase our ability to reach the Agency's scientific objectives.

Our interactions with other Federal laboratories enhance the value of research funded by NASA. These interactions are particularly strong in ozone and radiation research, data assimilation studies, water vapor and aerosol measurements, ground truth activities for satellite missions, and operational satellites. An example of inter-agency interaction is the NASA/NOAA/NSF Joint Center for Satellite Data Assimilation (JCSDA), which is building on prior collaborations between NASA and NCEP to exploit the assimilation of satellite data for both operational and research purposes.

Interactions with Foreign Agencies

The Laboratory has cooperated in several ongoing programs with non-U.S. space agencies. These programs involve many of the Laboratory scientists.

Major efforts include the TRMM Mission, with the Japanese National Space Development Agency (NASDA); the Huygens Probe GCMS, with the ESA CNES; the TOMS Program, with NASDA and the Russian Scientific Research Institute of Electromechanics (NIIEM); the Neutral Mass Spectrometer (NMS) instrument, with the Japanese Institute of Space and Aeronautical Science (ISAS); and climate research with various institutes in Europe, South America, Africa, and Asia. Another example of international collaboration was in the SOLVE II (SAGE III Ozone Loss and Validation Experiment) campaign, which was conducted in close collaboration with the VINTERSOL (Validation of International Satellites and study of Ozone Loss) campaign sponsored by the European Commission. More than 350 scientists from the United States, the European Union, Canada, Iceland, Japan, Norway, Poland, Russia, and Switzerland participated in this joint effort.

Laboratory scientists interact with about 20 foreign agencies, about an equal number of foreign universities, and several foreign companies. The collaborations vary from extended visits for joint missions to brief visits for giving seminars or working on joint science papers. As a result of the joint U.S.-Japan Workshop on Relationships and Intercomparison of Monsoon Climate Systems, held in our Laboratory in 2000, participants have agreed to develop pilot research projects involving the U.S. Global Change Research Program and the Japanese Frontier Research System for Climate Variability to enhance studies of teleconnections or globally connected climate systems.

Commercialization and Technology Transfer

The Laboratory for Atmospheres fully supports Government/industry partnerships, SBIRs, and technology transfer activities. In recent years two members of the Laboratory received the annual James J. Kerley Award for outstanding contributions to technology commercialization. Successful technology transfer has occurred on a number of programs in the past and new opportunities will become available in the future. Past examples include the micro-pulse Lidar and holographic optical scanner technology. Industry now uses these innovations for topographic mapping, medical imaging, and for multiplexing in telecommunications.

During the past year, two patents were issued to members of the laboratory. Matthew McGill and V. Stanley Scott were co-inventors of a novel Holographic Circle-to-Point Converter (HCPC). This invention has been awarded a patent (U.S. Patent #6,313,908) through GSFC. The HCPC is used to convert the output of Fabry-Perot interferometers into an easily measurable pattern. Specific applications include direct-detection Doppler lidar, airglow, and other measurements using Fabry-Perot interferometers as spectral resolving elements. The HCPC has been successfully demonstrated in a ground-based Doppler lidar system. The HCPC has been licensed through the GSFC Commercial Technology Office. For his work with the Commercial Technology Office in developing, licensing, and patenting the HCPC, Matthew McGill received the James J. Kerley Award for Technology Commercialization and Tech Transfer in 2000.

The United States Patent and Trademark Office issued a patent for Geary Schwemmer's invention titled "Methods and Systems for Collecting Data from Multiple Fields of View." This invention utilizes holographic optics to perform the function of a large aperture lidar receiver telescope that has several focal planes, each looking in a different direction with widely separated fields of view, as much as 90 degrees apart, and each obtaining use of the full aperture for photon collection. This system may eliminate or greatly minimize any mechanically moving systems to perform scanning of large angles, and will greatly reduce the weight of large aperture scanning lidar telescopes such as what is needed for atmospheric wind lidar measurements. This work followed on Geary's very successful previous work using rotating single holograms as conical scanning telescopes. The full text and figures of the patent are available on the Patent Office's Web page at http://www.uspto.gov/. Search for Schwemmer or the patent number: U.S. Patent No. 6,479,808 B1.

New research proposals involving technology development will have strong commercial partnerships wherever possible. The Laboratory hopes to devote at least 10% to 20% of its resources to joint activities with industry on a continuing basis.

5 HIGHLIGHTS OF LABORATORY FOR ATMOSPHERES ACTIVITIES

This section highlights some of the Laboratory's research accomplishments for 2002. The section is partitioned by Branch. A Branch summary, written by the respective Branch Head is followed by one or more science highlight articles. The Branch Web sites can be accessed from the Laboratory for Atmospheres Web site at http://atmospheres.gsfc.nasa.gov/.

Data Assimilation Office (DAO), Code 910.3

Branch Summary

The DAO's accomplishments in 2002 include:

1. An upgraded MPI GEOS-3 operational system, with improved computational performance, provided daily first-look and late-look assimilation data products to EOS instrument teams. In July 2002, this upgraded system was used to begin the production of a unique multiyear GEOS-3 TRMM reanalysis incorporating TRMM and SSM/I tropical precipitation data from November 1997, and onwards.

The implementation of the GEOS-4 operational system was successfully completed. The data assimilation engine in the GEOS-4 system is fvDAS, the DAO next-generation data assimilation system. The DAO worked closely with EOS Instrument Teams, DAO data users, and external elements, such as the ECS and DAAC, to define the new interfaces for the GEOS-4 products and to coordinate the implementation schedules and system test planning. The DAO has started working with the Aura Instrument Teams (MLS, TES, HIRDLS, and OMI) to define data and operational requirements in preparation for the Aura launch. The DAO completed both the stand-alone tests of GEOS-4 data at user sites and the end-to-end data flow test with no significant discrepancies encountered. The GEOS-4 data products file specification incorporates all the critical user feedback collected during the user review cycle. The GEOS-4 system commenced operations with data from October 1, 2002. GEOS-3 operations stopped at the end of October 2002. The DAO also started the Reanalysis for the Stratospheric Trace gas Study (ReSTS) using the GEOS-4 system. The data period planned for ReSTS is 1991 through 1995. The GEOS-4 reprocessing in support of MODIS, spanning the whole EOS/Terra period with a fixed system, started in late October 2002.

In April 2002, the SAGE III project joined as a new operational user of the GEOS DAS data products. SAGE III uses temperature profile information in the GEOS first-look data products to support validation efforts during field campaigns and to aid in instrument performance evaluation.

2. DAO research pursuing innovative ways to assimilate TRMM and SSM/I precipitation measurements has highlighted NASA's role in the U.S. Weather Research Program (USWRP) by providing observations from space that have the potential of significantly improving operational hurricane track and landfall predictions to mitigate human and economic losses. Results showed that GEOS analyses incorporating microwave-based satellite rainfall data yielded better track predictions for Hurricanes Bonnie and Floyd, and notably higher scores for quantitative precipitation forecasts up to 5 days.

3. The DAO has tested and evaluated a number of new observation types in the context of fvDAS, namely wind observations from the EOS MODIS and MISR instruments, and in situ wind observations obtained on board commercial aircraft (GADS). Initial tests with the MODIS winds were highly promising, and important feedback on data quality to the GADS and MISR teams have been obtained from assimilation experiments using these data. A comprehensive set of Observing System Experiments (OSEs) has been carried out in order to apportion the respective contributions between the various components of the observing system. The satellite

data were shown to be crucial to the performance in the Southern Hemisphere, but recent versions of fvDAS have shown a much stronger sensitivity to satellite data in both hemispheres.

Two examples are given of the science activities of the DAO in the following short articles. The first is on the assimilation and validation of ozone data by Ivanka Stajner; the second is on Observing System Experiments by Robert Atlas.

Ozone Assimilation: Validation in the Tropical Troposphere

Ivanka Stajner (istajner@dao.gsfc.nasa.gov)

An ozone data assimilation system at the Data Assimilation Office (DAO) provides global ozone fields. This system is being used in preparation for EOS Aura with a series of experiments investigating the use of column ozone from either TOMS or SBUV, and vertical ozone profiles from SBUV. Initial application of the system and its design have been focused on stratospheric ozone.

Here we show the sensitivities of the assimilated ozone to the total column ozone data source and to the meteorological atmospheric assimilation system that provides the winds. Validation is focused on tropical ozone and uses the Southern Hemisphere ADditional Ozonesondes (SHADOZ) measurements from 1998. Figure 5-1 shows that the annual mean of the assimilation using SBUV total column (blue) is in better agreement with SHADOZ sondes (black) than the assimilation using TOMS total ozone column data (green). Even though the assimilated ozone remains high biased in the lower stratosphere and troposphere, the shape of the profile is improved with the capture of the characteristic “S” shape. The shape is further improved with the use of winds from a newer (GEOS-4) data assimilation system, which includes the DAO’s finite volume general circulation model (red curve in Figure 5-1). Figure 5-2 illustrates good agreement in the temporal variability of the sonde and assimilated profiles in a region controlled by the dynamical variability. Lower ozone values are seen in the first half of the year, and highest values are in September and October. Vertical extent and altitude of many anomalies are captured well. For example, a profile on October 30 shows two positive anomalies: around 300 and 700 hPa. These anomalies are captured in the assimilation, despite the lack of information about the shape of the tropospheric profile from the SBUV and TOMS data that were used in the assimilation.

The upcoming online implementation of the transport that will include convection, and the incorporation of the Harvard parameterized chemistry in the troposphere, are expected to reduce the bias and capture the temporal variability caused by the pollutants.

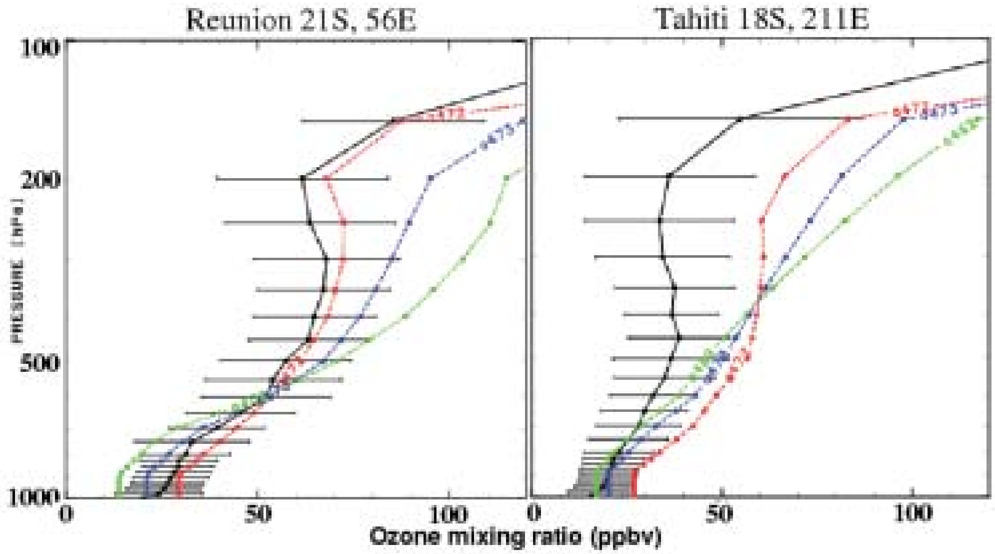

Figure 5-1. Three ozone assimilation experiments are compared with independent SHADOZ ozone sondes using annual mean of the profiles collocated with sondes. Assimilation using SBUV total column (blue) is in better agreement with SHADOZ sondes than the assimilation using TOMS total column (green). Transport in both these experiments used GEOS-2 winds. The shape of the assimilated profile improves further with the use of GEOS-4 winds in the transport (red). Note that the last experiment captures the characteristic "S" shape in the profile with relatively low ozone values around 250 hPa. The length of a black horizontal line denotes the size of the standard deviation of the sonde measurements at each pressure level in the annual time series.

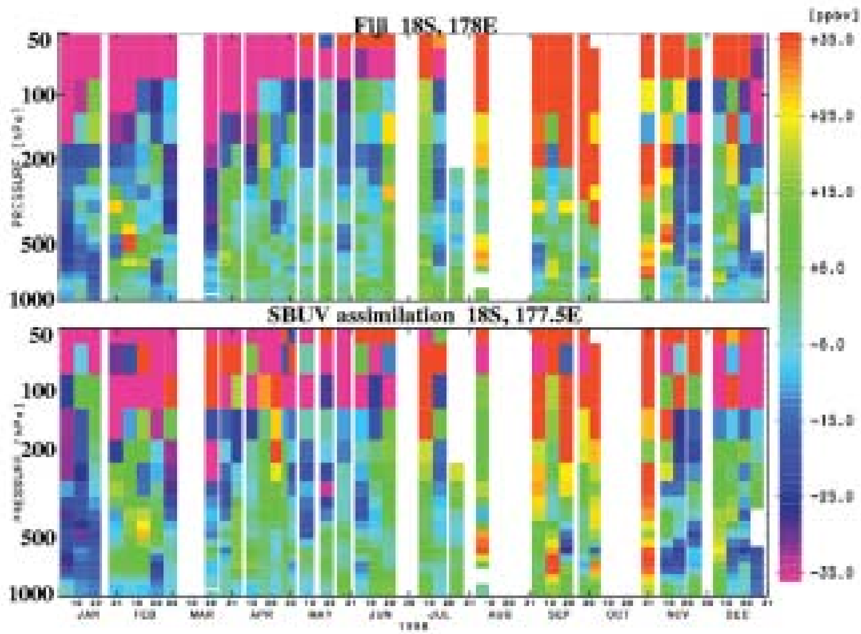

Figure 5-2. Time series of ozone anomalies are shown: for the independent sonde measurements in the upper panel, and for the ozone assimilation in the lower panel.

Observing System Simulation Experiments

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Since the advent of meteorological satellites in the 1960’s, numerous experiments have been conducted in order to evaluate the impact of these and other data on atmospheric analysis and prediction. Such studies have included both OSEs (Observing System Experiments) and OSSEs (Observing System Simulation Experiments). The OSEs were conducted to evaluate the impact of specific observations or classes of observations on analyses and forecasts. Such experiments have been performed for selected types of conventional data and for various satellite data sets as they became available. The OSSEs were conducted to evaluate the potential for future observing systems to improve Numerical Weather Prediction (NWP) and to plan for the Global Weather Experiment and more recently for EOS. In addition, OSSEs have been run to evaluate trade-offs in the design of observing systems and observing networks, and to test new methodology for data assimilation.

OSSEs are currently being conducted at the NASA Data Assimilation Office (DAO) in order to determine the potential impact of space-based lidar wind profiles in current data assimilation/numerical weather prediction systems and to evaluate tradeoffs in lidar instrument design. In the first of these experiments, the nature run (reference atmosphere) was generated using an early version of the Finite Volume General Circulation Model (fvGCM) at .5 degree resolution, and the assimilation and forecast system was the current operational version of the GEOS 3 Data Assimilation System at 1 degree resolution. This nature run is substantially longer than earlier nature runs and covers a three-and-one-half month period. In addition, the nature run contains very interesting and important meteorological features, including tropical cyclones and very realistic representations of atmospheric fronts and extratropical cyclone evolution.

Following a very detailed assessment of the realism of the nature run and the differences between the nature run model and the assimilation/forecasting model, the entire OSSE system was validated through a comparison of parallel real data and simulated data impact experiments. Then parallel assimilation experiments and 14 five-day forecasts were performed with this system to evaluate the impact of idealized space-based lidar wind profiles. As in earlier OSSEs (Atlas, 1997, Lord et al., 2001), one of the major metrics for assessing the potential impact of lidar winds was the anomaly correlation for sea level pressure and 500 mb height forecasts. In addition, a number of additional metrics, such as impact on the central pressure and displacement of cyclones or the landfall of hurricanes was also evaluated.

The results of this evaluation showed a very substantial improvement in forecast accuracy resulting from the assimilation space-based lidar winds. In the Southern Hemisphere, average forecast skill was extended by 12–18 hours, while in the Northern Hemisphere, average forecast skill was extended by 3–6 hours. This was associated with a meaningful (10%) reduction in position error for all cyclones averaged over the globe and all time periods. For very intense cyclones (those with central pressure less than 945 hPa), the reduction of position error exceeded 200 km. A meaningful impact on the prediction of hurricane landfall is shown in Figure 5-3, which illustrates the improvement in hurricane landfall prediction as a result of assimilating wind lidar data. This result was obtained for the first hurricane in the nature run. The predicted landfall position error for the two tropical cyclones to hit the U.S. mainland in the nature run was improved by approximately 150 miles for both storms. These results demonstrate considerable potential for space-based lidar wind profile measurements; however, further experiments are needed to evaluate the specific characteristics of proposed lidars.

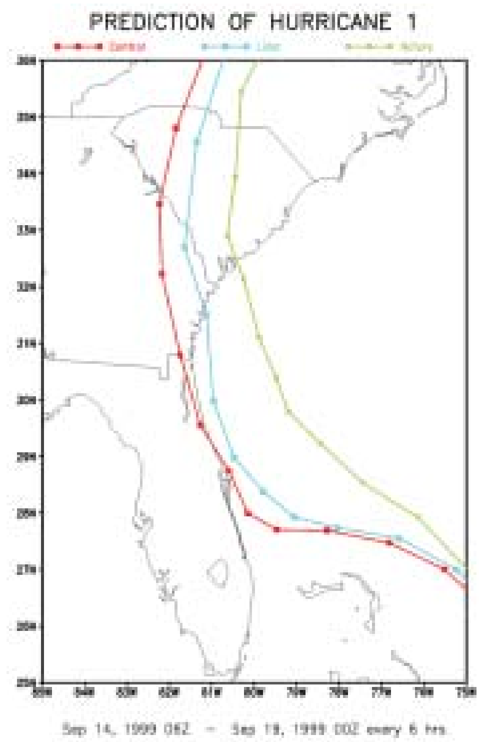

Figure 5-3. Potential impact of new space-based observations on Hurricane Track Prediction based on OSSEs at NASA Data Assimilation Office. Tracks: green is the actual track; red is the forecast beginning 63 hours before landfall with current data; and blue is the improved forecast for the same time period with simulated wind lidar. The dollar savings is ~ $1M/mile per hurricane for improved landfall forecast. Thus the wind lidar in this one case reduces landfall prediction error by 66% and would potentially save > $165M.

Mesoscale Atmospheric Processes Branch, Code 912

Branch Summary

The Mesoscale Atmospheric Processes Branch seeks to understand the contributions of mesoscale atmospheric processes to the global climate system. Research is conducted on the physical and dynamical properties, structure and evolution of meteorological phenomena ranging from synoptic scale down to micro scales, with a strong focus on the initiation, development and effects of cloud systems. A major emphasis is placed on understanding energy exchange and conversion mechanisms, especially cloud microphysical development and latent heat release associated with atmospheric motions. The research is inherently focused on defining the atmospheric component of the global hydrologic cycle, especially precipitation, and its interaction with other components of the Earth system. Branch members participate in satellite missions and develop advanced remote-sensing technology with strengths in the active remote sensing of aerosols, water vapor, winds, and convective and cirrus clouds. There are also strong research activities in cloud system modeling, and in the analysis, application and visualization of a great variety of data.

1) Branch scientists develop retrieval techniques to estimate precipitation using satellite observations from the Tropical Rainfall Measurement Mission (TRMM) and other satellites such as GOES and the new AMSR-E sensor on EOS Aqua. The accompanying article on TRMM describes recent accomplishments including new 3-hourly rainfall fields in near real time, development of a new effective El Niño predictor, and application of TRMM data to study of the urban heat island effect. The TRMM Ground Validation team processes and applies data from rain gauge networks, and ground-based radars. TRMM and other precipitation data are used within the branch for a wide spectrum of studies on precipitating cloud systems and global water cycle. Increasingly, these activities integrate global or regional data sets with modeling. Research is conducted on the assimilation of TRMM observations into models to explore the potential benefits to weather forecasting, such as for hurricanes, and to improve understanding of precipitating cloud systems. Branch scientists are also an integral part of the developing Global Precipitation Measurement (GPM) mission, presently in formulation phase. GPM seeks to establish an international calibrated satellite network for high-resolution (space and time) global precipitation measurements.

2) Development of *lidar technology* and *application of lidar data* for atmospheric measurements are also key areas of research. Systems have been developed to characterize the vertical profile structure of cloud systems (Cloud Physics Lidar–CPL), atmospheric aerosols (Micro-Pulse Lidar–MPL), water vapor (Scanning Raman Lidar–SRL) and winds (Goddard Lidar Observatory for Winds–GLOW) at fine temporal and/or spatial resolution from ground-based, airborne and satellite platforms. In addition, the Cloud Radar System (CRS), a new millimeter-wavelength radar for profiling cloud systems has been developed and integrated on NASA's high-altitude ER-2 research aircraft for use in sensing the microphysical properties of cirrus and other cloud types, and complements the existing ER-2 Doppler (EDOP) radar that has been extensively used to study precipitating cloud systems.

The ground-based SRL, GLOW and HARLIE systems participated in the International H2O Project (IHOP) in May–June 2002. The CPL, CRS and EDOP were all deployed on NASA's ER-2 aircraft for the Cirrus Regional Study of Tropical Anvils and Cirrus Layers-Florida Area Cirrus Experiment (CRYSTAL-FACE) in July 2002. More detailed descriptions of the participation of branch scientists and observing systems in these major field experiments may be found in the following IHOP and CRYSTAL-FACE highlights.

Branch scientists developed atmosphere-sensing capabilities of the Geoscience Laser Altimeter System (GLAS) system that was launched on ICESat early in 2003. The GLAS will be used to profile the vertical distributions of cloud and aerosol layers. Branch scientists also serve as Project Scientists for the Earth System Science Pathfinder (ESSP) CALIPSO (lidar) and CloudSat (mm-radar) missions that are planned for launch in 2004.

The Micro-Pulse Lidar Network (MPLNET) is comprised of ground-based MPL systems, co-located with sun/sky photometer sites in the NASA Aerosol Robotic Network (AERONET). MPLNET data, together with the co-located AERONET results, provides information on aerosol and cloud vertical structure, optical depth, particle size and shape, aerosol absorption, and sky radiance. Notable accomplishments for 2002 include publication of data processing algorithms and papers derived from observations taken during INDOEX-99, ARREX, and SAFARI-2000. In addition, MPL systems were deployed in support of CRYSTAL-FACE and the Brazil-based Smoke Aerosols, Clouds, Rainfall and Climate (SMOCC) experiment during the past year. MPLNET observations have also proven very useful for modeling GLAS algorithm performance and accuracy. MPLNET data products are documented and available to the scientific community via the project Web site (http://mplnet.gsfc.nasa.gov).

3) Cloud-resolving (Goddard Cumulus Ensemble, GCE) and mesoscale (MM5) models are used in investigations of the dynamic and thermodynamic processes associated with tropical and extratropical cyclones and rainbands, and tropical and mid-latitude deep convective systems. The models are also used to research cloud-chemistry interactions, stratospheric-tropospheric interactions, and the effects of the ocean surface (sea surface temperature) and land surface (vegetation and soil moisture) on atmospheric convection and weather systems. Other important applications include assessment of the potential benefits of assimilating satellite-derived water vapor and precipitation fields on simulations and forecasting of tropical and extra-tropical regional-scale weather systems (i.e., hurricanes, and cyclones). Long-term integrations of the models are used to investigate climate feedback mechanisms, such as cloud-radiation interactions. The simulations provide a basis for integrated systemwide assessment of important factors such as surface energy and radiative exchange processes, and diabatic heating and water budgets associated with tropical and mid-latitude weather systems. The models are also used to develop retrieval algorithms. For example, the GCE model is providing TRMM investigators with four-dimensional data sets for developing and improving TRMM rainfall and latent heating retrieval algorithms. The scientific output of the modeling activities was again exceptional in 2002 with 15 new papers published and many more submitted. Further details can be found in the accompanying GCE Model article.

Branch scientists have active participation and leadership in various international model comparison and evaluation activities of the GEWEX Cloud System Study for the purpose of increasing confidence in the cloud-resolving models and facilitating research on the development and testing of cloud parameterizations used in large-scale climate and forecast models (GCMs). Of particular note is a model comparison study of microphysical development in cirrus clouds that identifies key parameters, such as deposition coefficient, to which the models are highly sensitive and for which additional information is required (e.g., laboratory studies).

4) The Branch has developed a world-class visualization lab that is being increasingly used in high profile settings to reach out to scientists and, very importantly, to citizens and Government organizations to stimulate understanding and support of NASA's Earth Science Enterprise and its missions. The TRMM Outreach Office, Earth Observing System (EOS) Project Science Office, Earth Sciences Directorate and NASA Earth Science Enterprise (HQ) heavily utilize these capabilities in bringing the value of NASA missions and science accomplishments to the forefront of U.S. Global Change Research.

Tropical Rainfall Measurement Mission (TRMM)

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Now in its fifth year since launch, NASA and NASDA's Tropical Rainfall Measurement Mission (TRMM) satellite continues to collect a variety of measurements designed to answer an array of climate and weather questions related to Earth's water cycle. The primary objectives are to provide distributions of rainfall and latent heating in the tropics, understand how tropical rainfall influences the global circulation, improve the initialization of 24-hour to short-range climate forecasts, and diagnose and predict the development of climate-varying phenomenon like the El Niño Southern Oscillation (ENSO).

One of the great achievements of the TRMM program is the breadth of its science, and the diversity of its potential societal applications. In 2002, scientists in the Mesoscale Atmospheric Processes Branch (Code 912) continued to be active in virtually every component of the TRMM program, including algorithm development, research analysis, ground validation, educational outreach, and transfer to societal applications.

Branch scientists, led by Robert Adler and George Huffman, continue to develop algorithms in support of the TRMM mission. A multisatellite, near real-time, 3-hourly rainfall product has been developed using a combination of TRMM, polar orbit microwave, and geosynchronous infrared (IR) data. The product is available at the TRMM Web site (http://trmm.gsfc.nasa.gov) and has shown skill at accurately retrieving rainfall totals associated with extreme weather events. In addition, Scott Curtis and Robert Adler have developed an ENSO precipitation index (ESPI) using TRMM satellite estimates to predict the onset of the El Niño/La Niña cycle. Large values of the ESPI occur when rapid fluctuations in the Indian Ocean precipitation gradient (and accompanying westerly wind bursts) drive the ocean towards an El Niño state (Figure 5-4a). On February 7, 2002, an El Niño was predicted to begin between July and October 2002 (as seen by a rapid increase in ESPI in Figure 5-4a). At the same time other institutions produced forecast-probabilities of ~ 50%. Figure 5-4b shows the validation of the 2002 El Niño forecast with the conventional Niño 3.4 index.

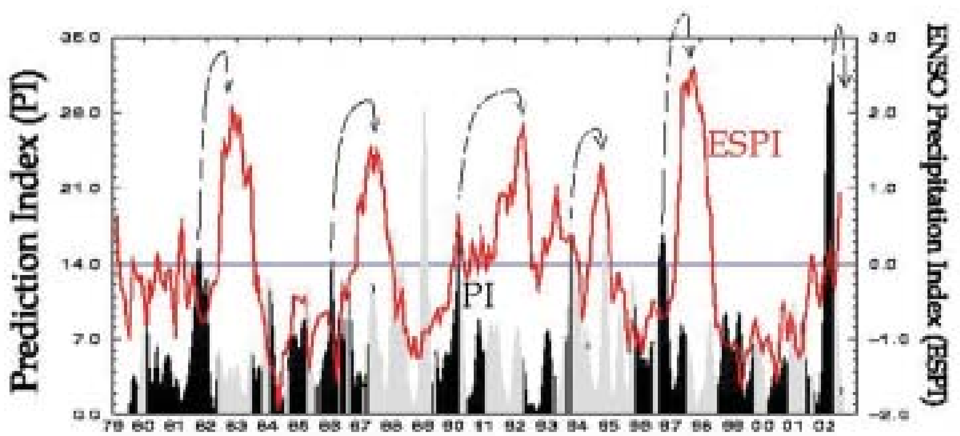

Figure 5-4a. ENSO Precipitation index.

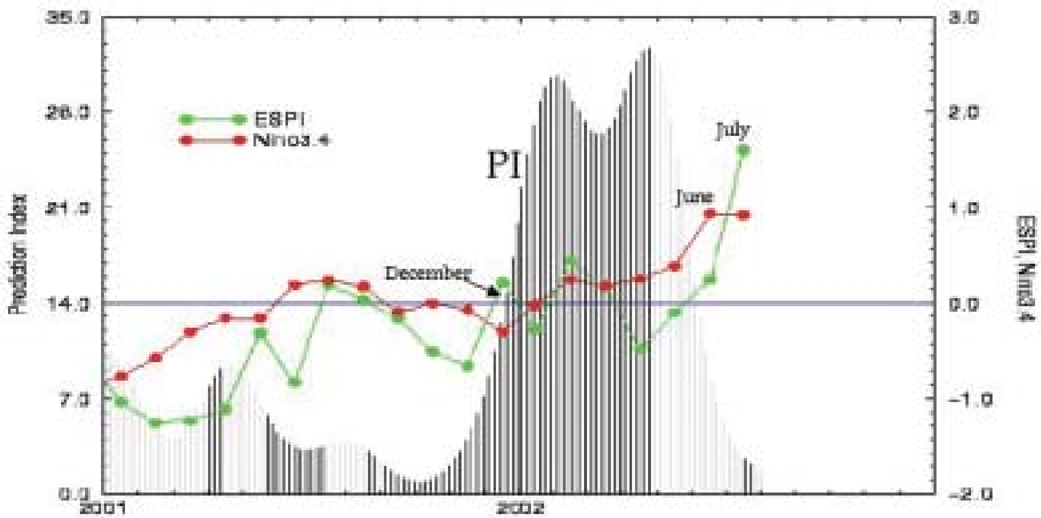

Figure 5-4b. 2002 ESPI prediction.

Wei-Kuo Tao and colleagues continue to progress towards the first generation of latent heating algorithms. Tao's group uses TRMM precipitation radar and the Goddard Convective-Stratiform Heating (CSH) algorithm to retrieve latent heating values at different atmospheric levels. Wei-Kuo Tao's cloud model work is a critical component of TRMM's latent heating retrieval and microphysical validation efforts.

Marshall Shepherd and colleagues used data from the TRMM precipitation radar to identify rainfall anomalies downwind of cities (Shepherd et al. 2002). It is hypothesized that urban land use/change impacts convective processes that produce rainfall. Recent work by Shepherd and Steve Burian (University of Arkansas) identified rainfall anomalies over and downwind of Houston, Texas, (Figure 5-5) that correspond to recently published lightning anomalies (Orville et al. 2001). NASA funding has been received to extend this work to other cities and incorporate coupled land-atmosphere models.

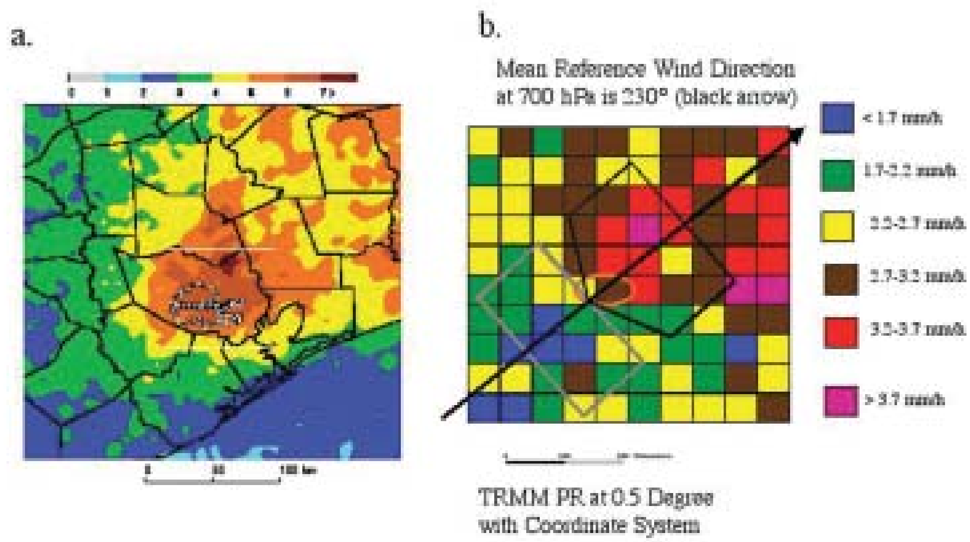

Figure 5-5. Rainfall from TRMM, 5-5a, and lightning anomalies, 5-5b, (Orville et al., 2001) over and downwind of Houston Texas. Orange oval is the central Houston urban district.

International H_2O Project (IHOP-2002)

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Accurate forecasting of the rainfall in the summer months is difficult. This limitation has important consequences to society. As an example, flash floods, which may result from heavy rainfall in a very localized area, are responsible for more deaths than hurricanes, tornadoes, windstorms, or lightning. Atmospheric moisture is a key ingredient for convective precipitation and there have been significant improvements in measurement capability over the last decade. The International H_2O Project (IHOP-2002) was a major field experiment conducted in May–June 2002 over the southern Great Plains to explore the possible improvements in forecasting convective precipitation that could result from improved water vapor measurements and their incorporation in forecast models. Members of the Mesoscale Atmospheric Processes Branch were key participants in IHOP-2002, which involved a diverse collection of scientists from universities, NOAA, DOE, and other organizations. Integration of the observations with models is fundamental to the IHOP-2002 strategy.

IHOP-2002 was comprised of four main research foci: Quantitative Precipitation Forecasting (QPF), Convection Initiation (CI), Atmospheric Boundary Layer (ABL), and Instrumentation. Under QPF, IHOP will determine if better humidity measurements improve the performance of weather forecast models for rainfall prediction. IHOP will also assess if humidity and wind measurements can help in forecasting the timing and location of new storms (CI). A key concern is the relationship between land surface variations and air moisture variations (ABL). Humidity is a difficult quantity to measure, and a combination of instruments may be needed to obtain the most useful set of measurements. Determining the best combination of humidity-measuring instruments to better predict rainfall amounts is being addressed under Instrumentation. Central to understanding convective precipitation in this region is the dryline phenomena. Characterizing the dryline and its evolution is integral to IHOP-2002.

The Scanning Raman Lidar (SRL), the Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE) and the Goddard Mobile Lidar Observatory for Wind (GLOW) were deployed for IHOP-2002. SRL provided profiles of water vapor mixing ratio to reveal the water vapor stratification to altitudes of 10 km or more. HARLIE provided data characterizing ABL structure and winds. GLOW provided measurements of wind speed and direction from the surface into the stratosphere. All these active remote-sensing measurements have excellent vertical and temporal resolution and provide a vastly more detailed picture than conventional observations.

The lidars were co-located at a remote ground site in the western panhandle of Oklahoma together with the NCAR S-Pol radar, profilers, sodars (sound detection and ranging), and many other instruments. This location is highly favored for airmass convergence and drylines.

One of the objectives is to examine the link between ABL processes, water vapor, wind and convection. An example of data that would allow us to accomplish this is shown in Figures 5-6a,b,c. It shows the evolution of a dryline over our site on 22 May 2002. The dryline was better defined after sunset (0025 UTC) compared to its daytime structure, which is modified by the convectively active boundary layer. The vertical mixing by the updraft plumes caused by surface heating, together with the terrain slope in this area, is hypothesized as the cause for an apparent eastward movement of the dryline after sunrise. We plan to quantify this mesoscale variability and test the theory. Characterization of these updraft plumes is also important in convective initiation modeling. Cumulus clouds form on top of updraft columns, which can be seen best from the HARLIE measurements. If these clouds are to be correctly modeled, one needs to know the profile of moisture within the updraft plumes. We are in the process of identifying and analyzing updraft plumes using HARLIE, SRL and other instruments that were co-located at our site, like the University of Massachusetts Frequency Modulated Continuous Wave (FMCW) radar, NCAR Integrated Sounding System (ISS), Multiple Antenna Profiling Radar (MAPR), S-Pol radar, and many others.

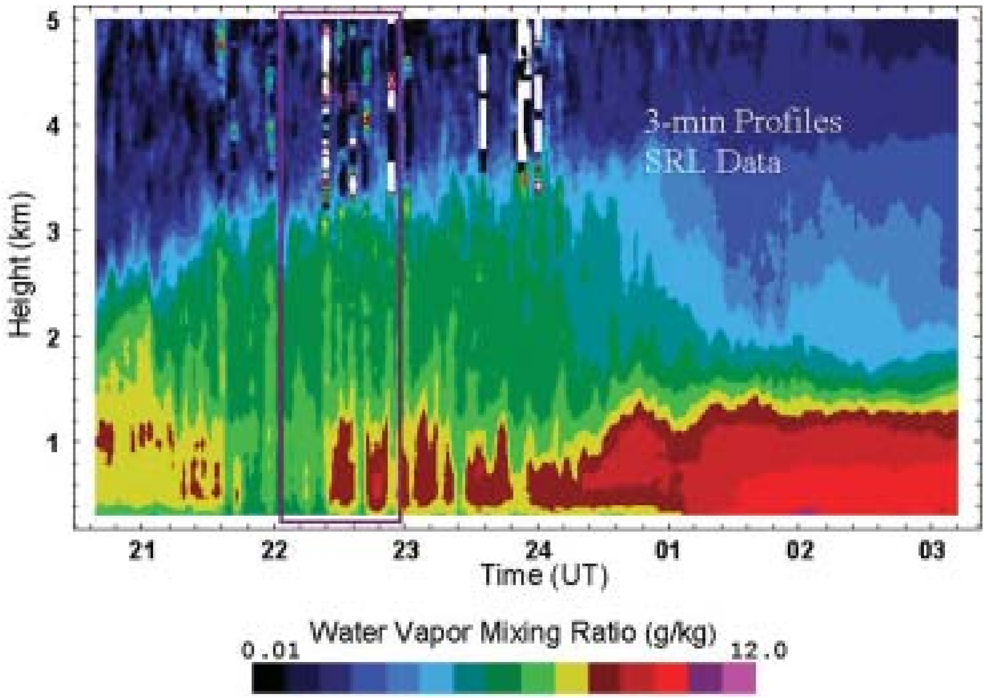

Figure 5-6a. Time-height plot of the Scanning Raman lidar measured water vapor mixing ratio for the 22 May 2002 dryline case at Homestead, Oklahoma. It shows cloud locations (vertical white strips), evolution of the water vapor mixing ratio and hence the dryline, day and nighttime characteristics of the boundary layer, and the well-defined contours of the dry line boundary in late afternoon and after sunset (0025 UTC).

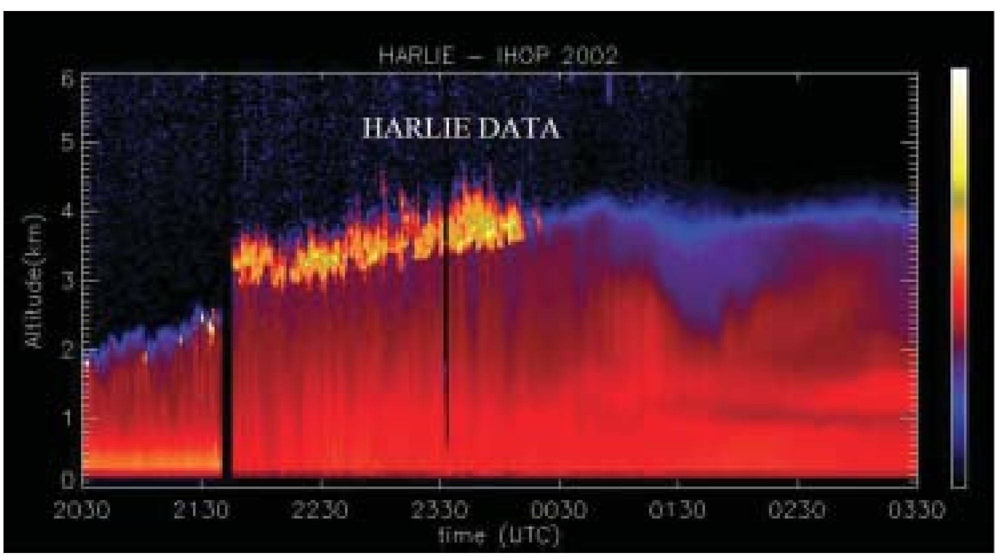

Figure 5-6b. Time-height plot of the HARLIE-measured aerosol backscatter profile data for the 22 May 2002 dryline case at Homestead, Oklahoma. The daily evolution of the atmospheric boundary layer (formation in the daytime and its demise after sunset, at about 0100 UTC) and location of cumulus clouds present is revealed. The gap near 2130 is data lost due to time delay in switching between modes of operation, from staring at an angle to conical scan. The profiles shown in the figure after this gap are averages of every 360-scan, leading to an apparently continuous cloud deck. Note that the day-night transition in the HARLIE and the SRL data reveal the sudden decrease in BL height and no cumulus clouds after the Sun sets—a manifestation of the absence of the surface forcing.

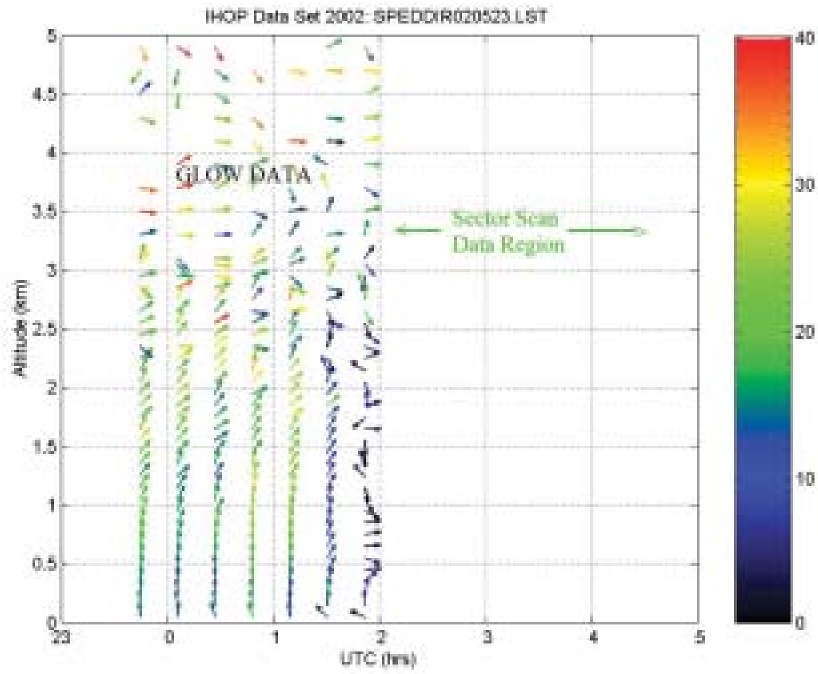

Figure 5-6c. Time-height plot of the GLOW-measured wind speed and direction for the 22 May 2002 dryline case at Homestead, Oklahoma. Low-level wind shifts associated with the dryline are noticeable. This information will be integrated with data from the other sensors to describe the complete evolution of the dryline. These data sets will also be augmented with vertical wind and other data of ABL properties for the Homestead site. Location of the updrafts will be determined from the radars (e.g., the FMCW) and mapped to the wind, aerosol backscatter and moisture observations to determine the mesoscale and convective scale ABL variability.

Goddard Cumulus Ensemble (GCE) Model

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The Goddard Cumulus Ensemble (GCE) model, a 3-dimensional model that explicitly resolves cloud and mesoscale processes, was used to simulate convection that occurred during the TRMM LBA field experiment in Brazil. Convection in this region can be categorized into two different regimes: low-level *easterly* or low-level *westerly* flow. Low-level easterly flow results in moderate to large CAPE (convective available potential energy) and a relatively dry environment. The resulting convection is more intense, like that seen over mid-latitude continents. Conversely, low-level westerly flow results in smaller CAPE and a moist environment. Convection is weaker and more widespread, similar to oceanic or monsoon-like systems. The GCE model was recently used to study both regimes in order to provide cloud data sets representative of both environments in support of TRMM rainfall and heating algorithm development. Two different cases were examined: January 26, 1999, an easterly regime case, and February 23, 1999, a westerly regime case. The January 26 case is an organized squall line and the February 23 case is less organized with only transient lines. The results show latent heating distributed over a deeper layer with a less pronounced peak for the January 26 easterly regime case. Also, reinforced is the notion that ice processes are more important in this regime, consistent with the observed electrical activity. Figure 5-7 shows the observations (provided by Drs. S. Rutledge and R. Cifelli/CSU) and the 3-D GCE model results. In addition, the GCE model has been linked to a passive radiative transfer model developed by C. Kummerow (CSU) to utilize satellite data in order to modify and improve the “cloud microphysics” used in cloud-resolving models as shown in Figure 5-8.

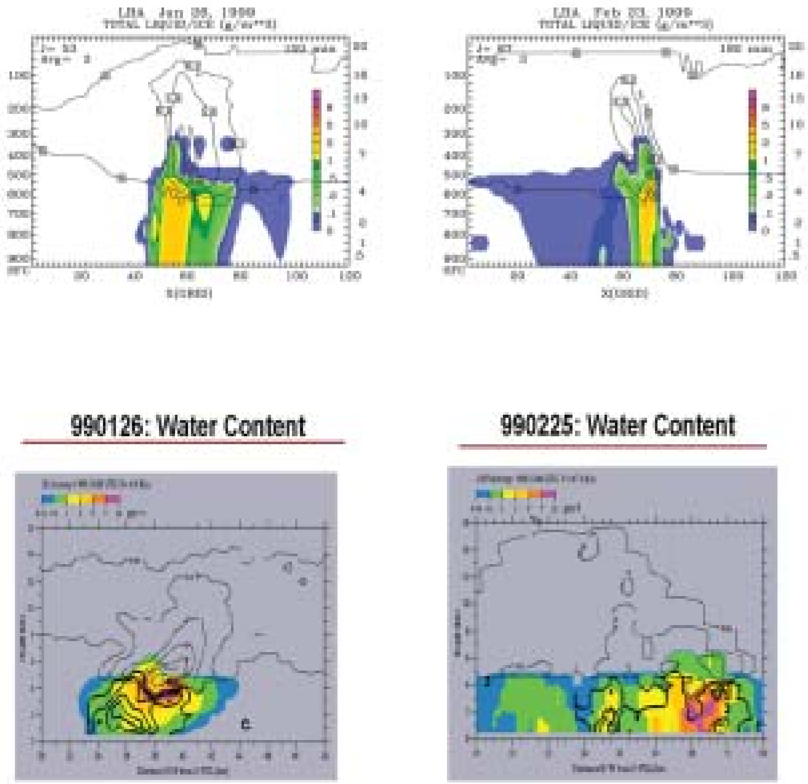

Figure 5-7. Liquid and ice water contents (g m-3) for cases typical of two different convective regimes from radar observations (top) and 3-D GCM model simulations (bottom) for January 26 (left) and February 23/25 (right) during TRMM LBA in 1999. The January case is an easterly flow regime while the February cases are a westerly regime. Note the differences in organization and scale of the convective cores, as well as in the extent of the stratiform precipitation regions, which are well captured by the model. Radar analysis courtesy of S. Rutledge and R. Cifelli of Colorado State University.

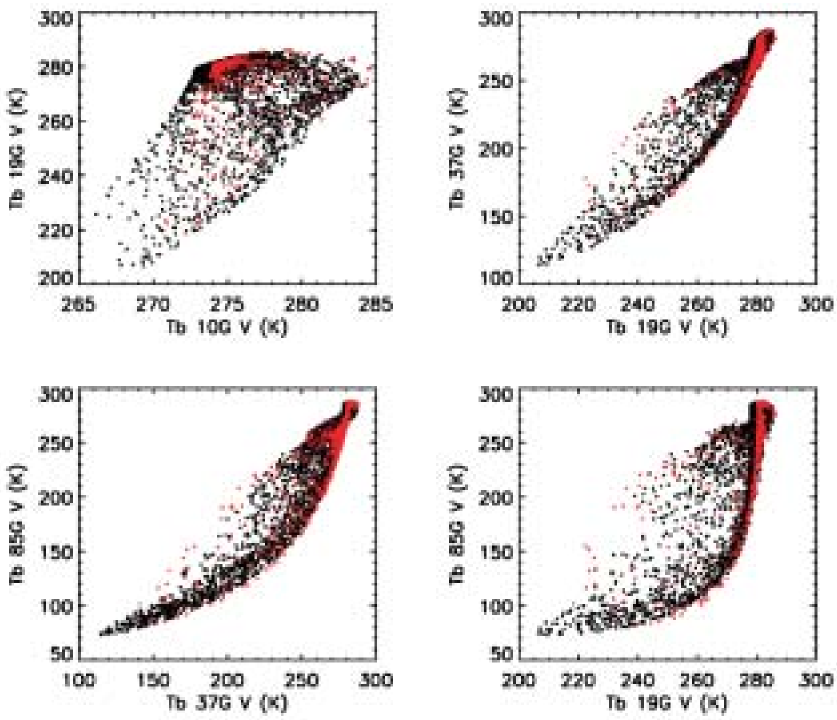

Figure 5-8. Simulated brightness temperature scatter plots at different TMI channels using GCE model outputs. Black squares are January 26, 1999, case and red squares are February 23, 1999, LBA case. January 26 case has stronger convection and more ice.

Of the main types of extratropical cyclone-related mesoscale rainbands, the most intense rainfall rates are usually associated with Narrow Cold Frontal Rainbands (NCFRs). A NOAA P-3 instrumented aircraft observed an intense, fast-moving NCFR as it approached the Pacific Northwest coast on 19 February 2001 during the Pacific Coastal Jets Experiment. The NCFR produced hail along the California coast when it made landfall. An outstanding feature of the NCFR was the breaks (gaps) observed along the rainband by Doppler Radar. A mesoscale model, MM5, was used to simulate this NCFR. The numerical simulations were conducted using nested grids with resolutions of 36 km, 12 km, 4 km and 1.3 km. The high-resolution domain was able to reproduce the main structural features of the observed NCFR Figure 5-9 (provided by Dr. D. Jorgensen/NOAA). The breaks (gaps) along the rainband are well represented. Based on the simulated results, many aspects of NCFR structure depicted in previous studies were confirmed.

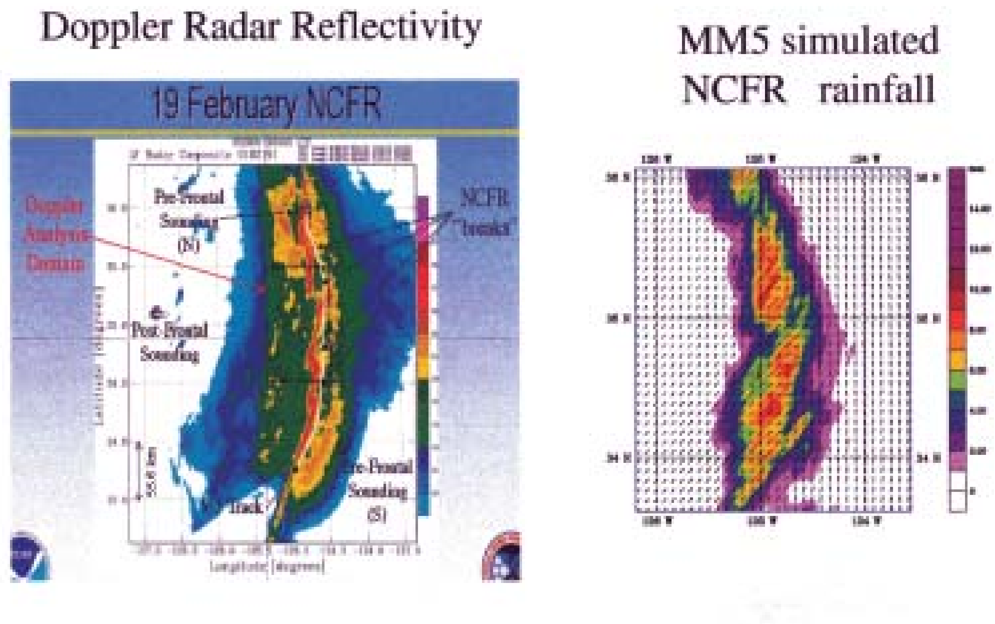

Figure 5-9. MM-5 simulation (right) of precipitation field for Narrow Cold Frontal Rainband (NCFR) observed (left) on February 19 during PACJET 2001. The simulations were conducted with nested grids of 36, 12, 4 and 1.3 km. With the high-resolution inner domain, the simulation reproduced the main structural features of the NCFR. The breaks (gaps) in the rainband were well represented. The results of this study confirmed many aspects of NCFR structure described in prior studies.

In addition, regional scale model experiments were conducted to quantify the water cycle over the South China Sea and its impact on mid-latitude water vapor transport during different climate regimes (1997 and 1998). We also conducted cloud-resolving (process) model simulations of convective systems that developed over different geographic locations (i.e., S. China Sea, W. Pacific, E. Atlantic, and central U.S.) to provide a better understanding of the precipitation efficiency and surface energy budget, and their system-to-system differences.

CRYSTAL-FACE

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Members of the Laboratory for Atmospheres played key roles in the Cirrus Regional Study of Tropical Anvils and Layers-Florida Area Cirrus Experiment (CRYSTAL-FACE), a major NASA field experiment conducted in south Florida in July 2002. The experiment sought to:

1) Improve understanding of cirrus anvil properties in relationship to the properties and strength of deep convection.
   Does stronger convection imply a larger longer-lived anvil; more anvil ice mass; larger ice crystals; more complex ice crystals?
2) Provide a direct basis for improvement of large-scale models used for numerical weather prediction and climate studies by quantitatively linking anvil properties to convective mass flux, a parameter predicted in such models.
3) Improve understanding of the physical factors that control lifetime and area coverage of cirrus anvils and tropical cirrus layers.
   What are the roles of microphysical, radiative and dynamical processes in cirrus cloud development and lifecycle and what are the effects of environmental factors such as humidity and stability?
4) Improve understanding of how deep convection affects tropical upper tropospheric and lower stratospheric humidity, a key climate-radiation variable, and also a key factor in stratospheric chemistry.

These objectives support the evaluation and improvement of state-of-the-art, high-resolution, cloud system models that account for the full range of cloud physical processes and provide another path for improvement of global circulation models (GCMs).

An additional objective was the validation of ground-based and satellite remote sensing observations of cloud properties including observations from Terra (MODIS, MISR, CERES), Aqua (MODIS, AIRS, CERES), GOES, POES, and TRMM (Precipitation Radar) as well as to provide data sets supporting algorithm development for future measurements from space such as lidar (CALIPSO) and millimeter wavelength radar (CloudSat)—key elements of NASA's "A-Train" that will be in place in 2004.

CRYSTAL-FACE was principally sponsored by NASA under the Code Y Radiation Sciences Program, the Upper Atmosphere Research Program, the EOS Validation Program, and the Atmospheric Chemistry Modeling and Analysis Program. Additionally, CRYSTAL-FACE was also sponsored by the National Science Foundation, the Department of Energy Atmospheric Radiation Program (ARM), the Office of Naval Research, and the NASA-NOAA-DOD Integrated Program Office. The National Weather Service (NOAA) was a cooperating agency.

There were six aircraft participating in CRYSTAL-FACE: NASA's ER-2 and WB-57, the Proteus (contracted by IPO), the University of North Dakota Citation, Naval Research Laboratory's P-3 and CIRPAS Twin Otter, as shown on the cover of this report. The aircraft were based at Key West Naval Air Facility where the science team of over 200 members was assembled.

There were two cloud-observing ground sites, located at Tamiami Airport, near Miami, and at Everglade City on the west coast of southern Florida. Goddard provided and staffed the Surface Measurements for Atmospheric Radiative Transfer (SMART, Tsay/913) system at the eastern site that included a Micropulse Lidar (MPL, Welton/912) and a suite of radiometers. In addition, a sophisticated polarmetric precipitation radar (Goddard's NPOL radar from Wallops Flight Facility, Gerlach/972) was operated at Ochopee, 5 km east of Everglades City. In-flight aircraft operations were directed from this location, Figure 5-10. Multiaircraft science missions were conducted on 12 days with the ER-2 flying 11 missions. Underflights of Terra (3) and Aqua (5) were performed and good coordination was often achieved with the ground sites. On many occasions, all six aircraft flew simultaneous coordinated patterns.

Figure 5-10. (Left) David Starr/912 (back) and ex-ER-2 pilot Jan Nystrom direct CRYSTAL-FACE aircraft operations from the NPOL site. Also shown are Paul Cucera of University of North Dakota and John Gerlack/972 at Ochopee using real-time displays of GOES imagery (provided by team at NASA LaRC), NPOL and NWS NEXRAD data, FAA flight-tracking data, and information from the ground sites. (Right) NPOL site at Ochopee, Florida. Photos courtesy of Ed Zipser, University of Utah.

Goddard investigators played key roles in the successful execution of the mission, serving as ER-2 Platform Scientist (Platnick/913, King/900, Newman/916) and as the co-Mission Scientist responsible for real-time direction of in-flight aircraft operations (Starr/912). In addition, daily regional forecasts of convective activity and chemical transport (Figure 5-11) were generated to support mission planning using MM5 (Wang/JCET/912 and Pickering/ESSIC/916). Other 910 scientists supported the daily mission planning cycle in various ways.

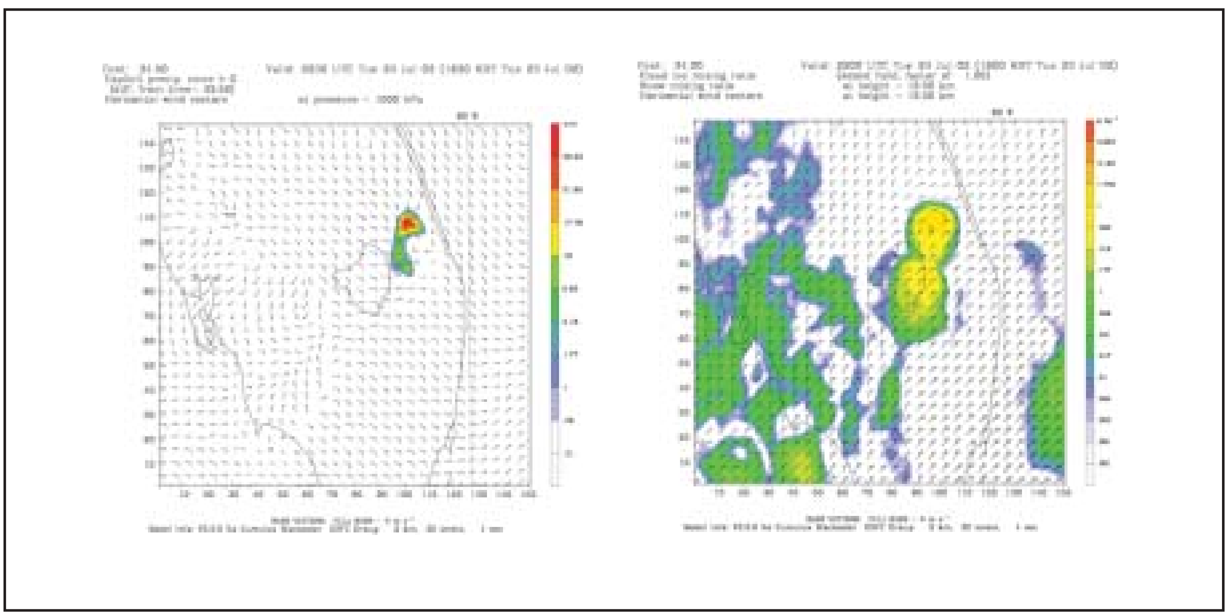


Figure 5-11. Forecasts using nested MM5 for CRYSTAL-FACE on July 23, 2002. Shown are examples of (left) precipitation and low-level wind fields; and (right) upper level cloud mass and winds at 2200 UTC over southern Florida. Compare the forecasts with the GOES image of the convective system (Figure 5-13).

Goddard instruments constituted the core of sensors carried on the ER-2 (Figure 5-12), including the MODIS Airborne Simulator (MAS, Platnick/913 and King/900), the Cloud Physics Lidar (CPL, McGill/912), the 95 GHz (3 millimeter) Cloud Radar System (CRS, Heymsfield/912), the 3-cm wavelength (precipitation) ER-2 Doppler radar (EDOP, Heymsfield/912) system and Conical Scanning Sub-mm wave Imaging Radiometer (COSSIR, Wang/975)—a microwave sensor for detection of ice and precipitation. MAS, CPL and CRS provided an effective simulation of key elements of NASA's planned "A-Train" satellite constellation, especially as regards sensing of upper tropospheric clouds, i.e., Aqua/MODIS, CALIPSO and CloudSat.

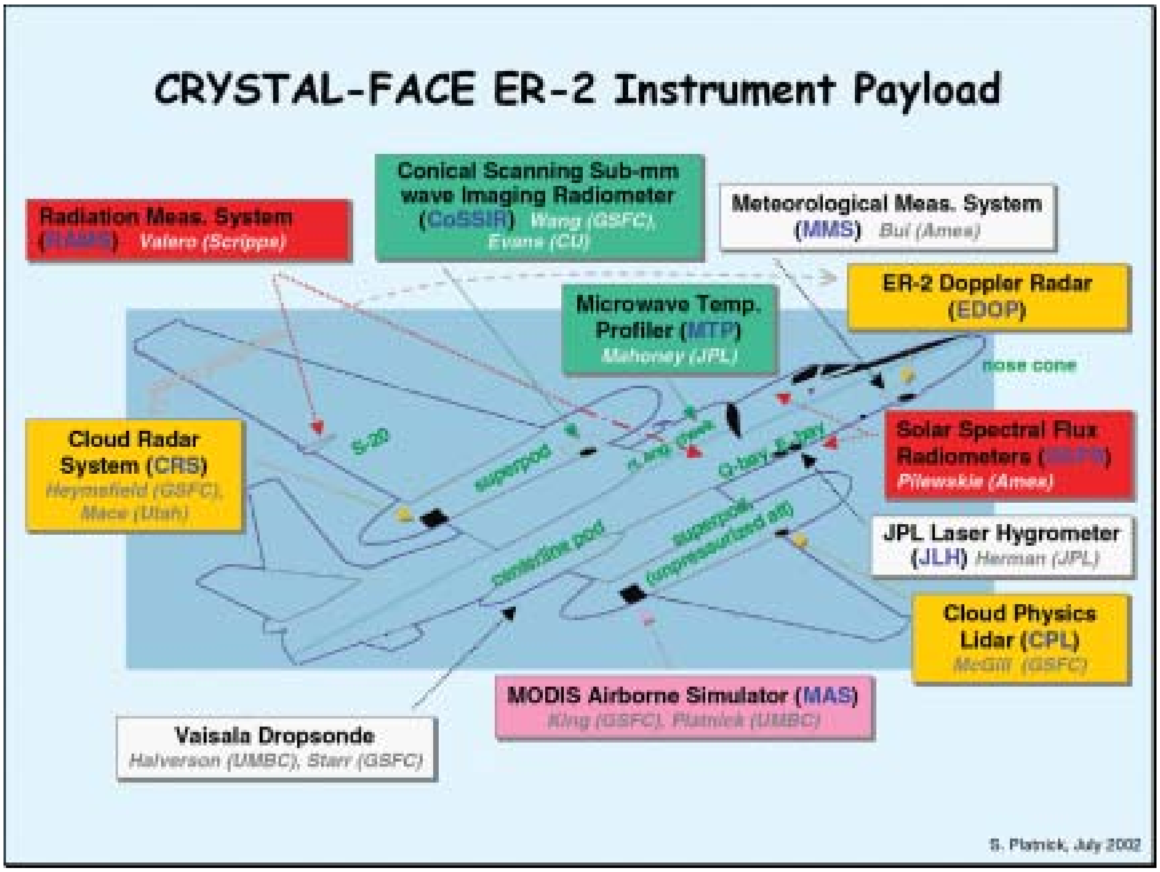


Figure 5-12. Instrument layout on NASA's ER-2 for CRYSTAL-FACE field deployment in July 2002.

Coincident data from the instruments are shown in Figure 5-13, where the complementary nature of the observations is readily apparent. Cirrus clouds are a particularly difficult remote-sensing target due to their lack of optical opacity and great variability. Combination of multiwavelength observations from active and passive sensors holds the greatest promise of enabling detailed accurate retrievals of cirrus cloud properties. This was the first CRS mission and the first time coincident MAS, CPL and CRS data have been obtained.

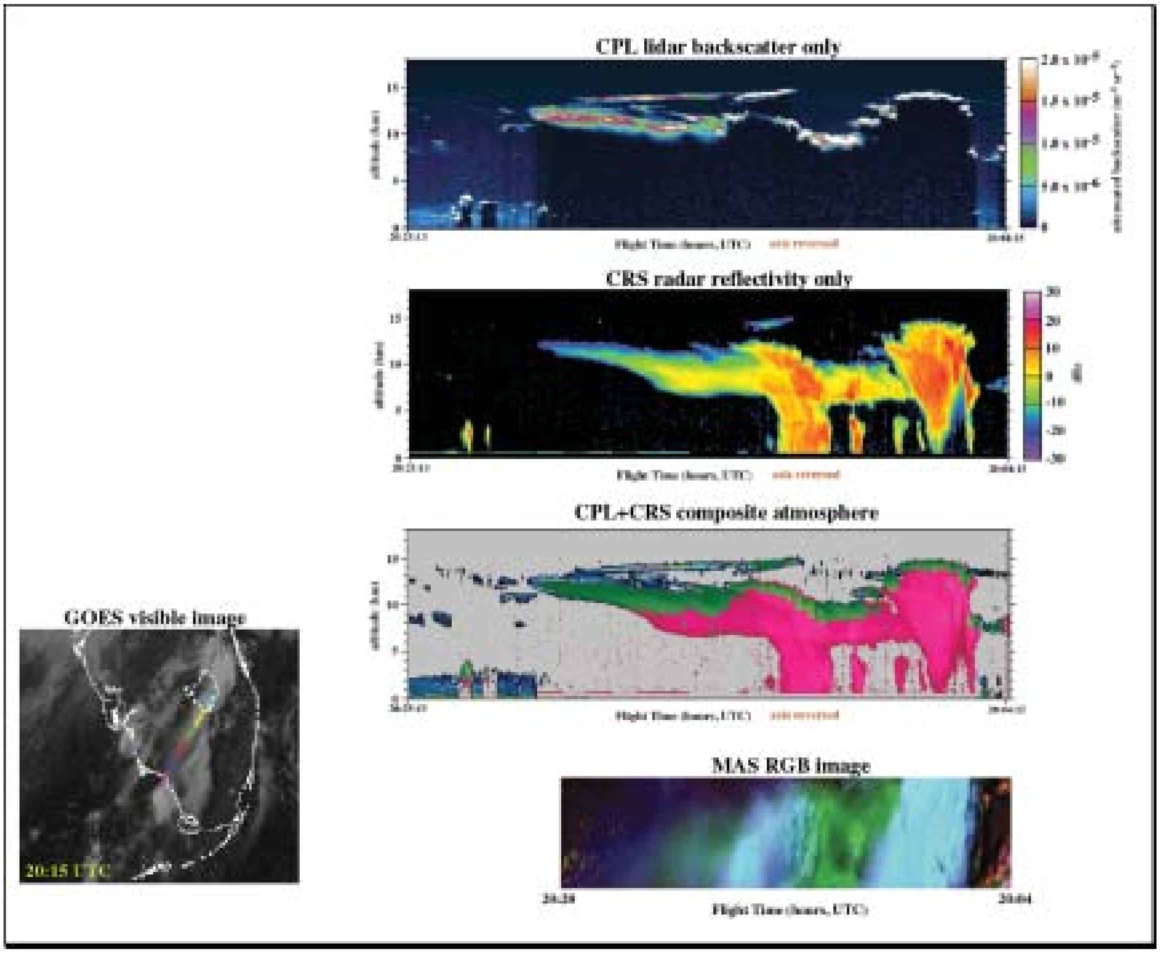


Figure 5-13. GOES image (lower left) shows generating convective system on July 23, 2002, near Lake Okeechobee with cirrus anvil streaming to southwest and overlaid 15-minute aircraft tracks at about this time. Shown are concurrent CPL and CRS profile images of cloud properties along the ER-2 flight track, as well as combined image. The latter depicts the cloud regions detected only by lidar (blue), by both lidar and radar (green), and only by radar (pink). A concurrent MAS image of the scene is shown at the bottom.

Special radiosonde observing support (3-hourly soundings on operational days) by the National Weather Service Forecast Offices at Tampa, Miami, and Key West was arranged and coordinated by Goddard (Starr/912). Special arrangements were also made to acquire a very complete NWS NEXRAD data set for the experiment from these same sites, as well as from the NWS Melbourne site, using a new system to enable real-time data transmission to GSFC (Rickenbach/JCET/912). A new ER-2 dropsonde system (Halverson/JCET/912), developed and operated by NCAR in collaboration with NASA, was used to obtain profiles of atmospheric state when the aircraft was far from operational sites (missions were flown to the deep tropics southeast of the Yucatan Peninsula (Figure 5-14)), and to characterize the offshore preconvective and anvil environments. A mobile radiosonde system (Halverson/JCET/912) was also operated in the interior of southern Florida by staff from the University of Central Florida, and sondes were provided for the western Everglades City remote-sensing site manned by scientists from PNNL (DOE).

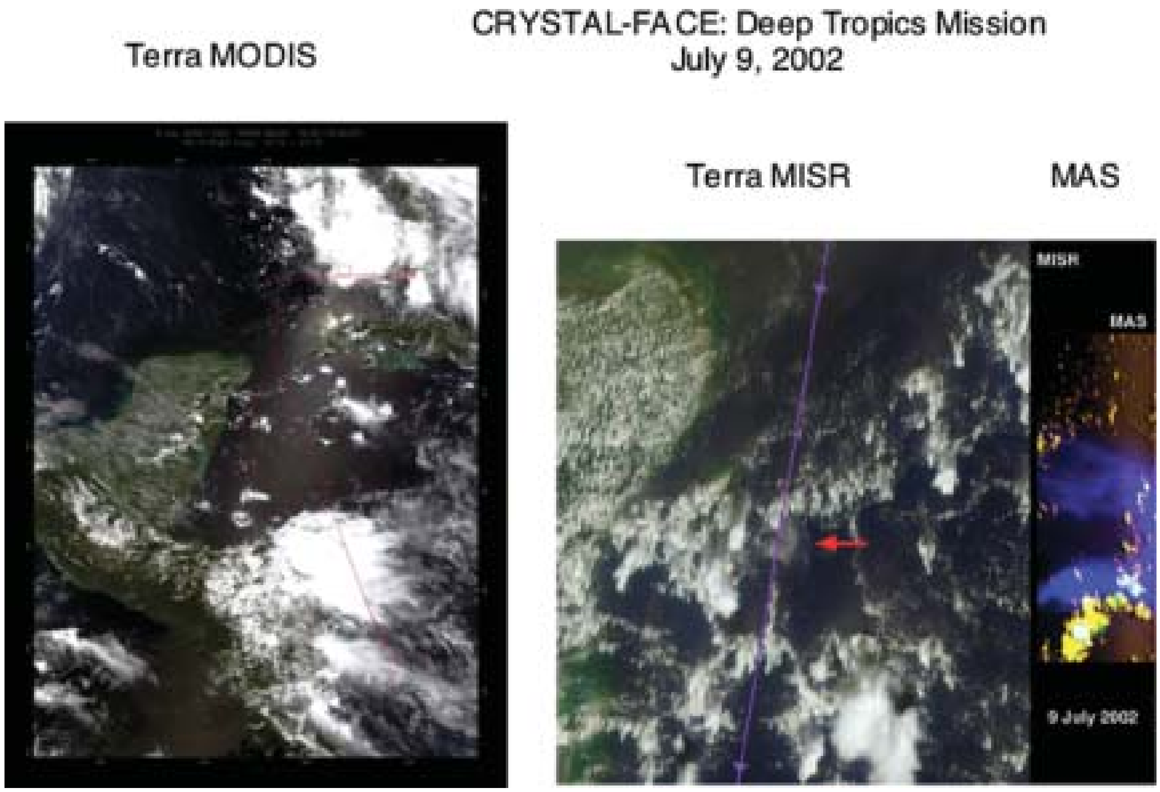


Figure 5-14. MODIS, MISR and MAS imagery during deep tropics mission to study tropical tropopause transition layer. MISR image courtesy of Ralph Kahn/JPL.

Additional information on CRYSTAL-FACE may be found at the following Web sites: http://cloud1.arc.nasa.gov/crystalface/index.html and http://angler.larc.nasa.gov/crystal/

Climate and Radiation Branch, Code 913

Branch Summary

As we embark upon the new millennium, one of the most pressing issues we face is to understand the Earth's climate system and how it is affected by human activities now and in the future. This has been the driving force behind much of the activities of the climate and radiation branch. We have made major scientific contributions in five key areas: hydrologic processes and climate, aerosol-climate interaction, clouds and radiation, model physics improvement, and technology development. They are highlighted at the end of this section.

Besides scientific achievements, we have made great strides in many areas of science leadership, as well as science enabling, education, and outreach. Thanks to the organization efforts of Yoram Kaufman and Lorraine Remer, the Aerocenter visitor program has been established and is in full operation. The Aerocenter seminar series is running well and is very well attended. We have over 10 visitors already planning to visit and interact with scientists at the Lab during 2002–2003. The processing of MODIS aerosol and cloud products, including the development of cloud masks for aerosols, cloud optical thickness and cloud microphysics are going well. The MODIS aerosol group has produced the first quantitative, accurate, operational aerosol product over most land surfaces. The MODIS aerosol retrieval over oceans reduces the standard error by half when compared to the product accuracy of heritage satellite retrievals (e.g., AVHRR). The availability of MODIS cloud and aerosol products has opened many pathways of research in climate modeling and data assimilation in the Laboratory.

We actively participated and played lead roles in the Cirrus Regional Study of Tropical Anvils and Cirrus Layers-Florida Area Experiment (CRYSTAL-FACE) field campaign held in Key West, Florida, during July 2002. CRYSTAL-FACE studied the life cycle and radiative and microphysical properties of anvil cirrus, and involved 6 aircraft, 2 ground stations, and several hundred scientists. The ER-2 logged over 70 flight hours and flew several new instruments. The combined instrument payload of the ER-2 and Proteus aircraft constituted an "A-train" simulator for the upcoming series of satellites (Aqua, CloudSat, Calypso, Parasol). CRYSTAL-FACE objectives also included relating anvil properties to convective intensity, understanding the exchange of water vapor in the upper troposphere and lower stratosphere, and validation of remote-sensing techniques.

We continued to serve in key leadership positions on international programs, panels and committees. Si-Chee Tsay leads a group of scientists from NASA and universities in initiating a new project, BASE-ASIA, to study impacts of smoke aerosols on tropospheric chemistry, water and carbon cycles, and their interactions in the Southeast Asia monsoon region, using multiplatform observations from satellites, aircraft, networks of ground-based instruments and dedicated field experiments. Robert Cahalan has served as project scientist of SORCE (SOlar Radiation and Climate Experiment), which was launched in December 2002, and will measure both TSI (Total Solar Irradiance, formerly "solar constant") and SSI (Spectral Solar Irradiance) with unprecedented accuracy and spectral coverage (1–2000 nm for SSI, 1–100,000 nm for TSI) during a 5-year nominal mission lifetime. During the past year, Warren Wiscombe has been appointed as Science Lead for the Earth Science Vision 2025 activity commissioned by NASA Headquarters. This involves forming science workgroups drawn from NASA Centers and the community at large to decide on specific science questions for NASA's far future in Earth science.

The Earth Observatory Web site (http://earthobservatory.nasa.gov) has continued to provide the science community with direct communication gateways to the latest breaking news on NASA Earth sciences. It provides the news media and other communications outlets with a "one-stop shopping" resource for publication quality images and data visualizations from NASA Earth science satellite missions such as Terra, Aqua, and many others. The Earth Observatory Web site now boasts over 27,000 subscribers, with roughly 1 million page views per month worldwide. The contents of the Web site are increasingly syndicated by NASA Headquarters and other public sites.

Science Highlights

Atmospheric Hydrologic Processes and Climate

Summertime climate teleconnection

Using NCAR/NCEP reanalysis and GPCP rainfall data, we have identified recurrent climate modes associated with sea surface temperature (SST) variability in the North Pacific and the North Atlantic that are distinct from El Niño. Simultaneous high/dry (or cool/wet) summers were found over Japan/Southern Korea, northwestern North America, and the northern Great Plains, and reverse conditions over the Atlantic coasts. These modes may be instrumental in simultaneously altering the probability distribution of extreme temperature and rainfall events in Eurasia and North America, and providing potential predictability of flood and drought occurrence over the two continents.

Canonical Ensemble Predictions

We have developed a canonical ensemble prediction (CEC) scheme for the seasonal rainfall over the U.S. continent to maximize the predictive information from a variety of sources, e.g., SST from various ocean basins and soil moisture. In benchmark hindcast experiments, CEC shows an overall increase in potential predictability of 15–20% over traditional methods, with most gain in the summer season, when the El Niño influence is weakest. The CEC methodology is being adopted at NCEP for seasonal forecasts. CEC can also be incorporated into multimodel statistical-dynamical forecasts to achieve overall better forecast skills.

Rainfall retrieval

Simultaneous observations of reflectivity made by TRMM Precipitation Radar (PR) and brightness temperature, Tb, made by Microwave Imager (TMI) radiometer over tropical land are being analyzed with the help of theoretical models to understand the relationship between these two data sets. TRMM PR data analyses over land reveal that there is a significant variability in the strength of convection over different geographical regions. We are investigating this regional variability in convection and its impact on rain retrievals with the TRMM TMI data. Preliminary results from our study indicate that it is possible to deduce a parameter from Tb that can account for regional variability in convection. This study can enhance the capability of satellite-borne microwave remote sensors.

Rainfall sampling

A statistical model for the variability of rain in time and space has been applied to gain better understanding of the level of disagreement to be expected between satellite observations over areas containing rain gauges and the average rainfall measured by the gauges themselves. The model suggests how best to choose the area around the gauges over which the satellite observations are averaged and the time intervals over which the gauge data are averaged in order to minimize the magnitude of the difference between the two averages. The results are very helpful in evaluating the accuracy of satellite rain estimates with surface gauges.

Regional effects of global warming

Using the NCAR regional climate model, we are studying the elevation dependence of the surface temperature warming over the Tibetan Plateau (TP) due to doubling CO_2. In the eastern TP, when CO_2 is doubled, the cloud amount increases at lower elevations and decreases at higher elevations in the winter half year. As a consequence, at lower elevations the short wave solar radiation absorbed at the surface declines and the downward long wave flux reaching the surface enhances; on the other hand, at higher elevations the surface solar radiative flux increases and the surface infrared flux shows a more uniform increase. The net effect of the changes in both radiative fluxes is an enhanced surface warming at higher elevations, which is the primary cause of the elevation dependency in the surface warming. In the southwestern TP, the most significant factor affecting the surface energy budget is the depletion of snow cover at higher elevations, which leads to a reduction of the surface albedo, and increase in surface temperature.

Climate variability of South America

The submonthly variability of atmospheric circulation and organization of convection in South America during JFM98 and JFM99 was studied (January-February-March). According to the NCEP reanalysis, the South America Low Level Jet (SALLJ) was nearly twice as strong during JFM of the 1998 El Niño episode than during JFM of the 1999 La Niña episode. The difference in SALLJ strength between these two years translated into stronger transport of moist tropical air into the subtropics during JFM98 than during JFM99. An objective analysis technique was used to identify large, long-lived convective cloud systems in infrared imagery. The stronger SALLJ resulted in larger and more numerous long-lived convective cloud systems and nearly twice as much rainfall in subtropical South America during JFM98 than during JFM99. While the SO (Southern Oscillation) modulates the SALLJ in interannual timescales, the SACZ (South Atlantic Convergence Zone) modulates the SALLJ in submonthly timescales. Both time scales are found in rainfall variability in the South America subtropical region.

Regulation of warm pool SST

The sea surface temperature (SST) of the tropical western Pacific (Pacific warm pool) is very high but rarely greater than 30ºC. It is very important to understand the physical processes that prevent the temperature from increasing to a value higher than 30½, as it will shed light on the possible scenarios of global warming of the tropical oceans. By analyzing the surface wind, clouds, and the surface heat fluxes in the warm pool, we have found that regions of the highest SST have the largest surface heating, primarily due to the weak evaporative cooling associated with weak winds. Results show that an enhanced surface heating in an enhanced convection region is not sustainable and must be interrupted by variations in large-scale atmospheric circulation.

Aerosol-Climate Interactions

Distinguishing man-made vs. natural sources of aerosol

Plumes of smoke and regional pollution are distinguished by their large concentrations of small particles (less than 1 micrometer) downwind of biomass burning sites and urban areas. New analysis of 2 years of daily global data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument flying aboard NASA's Terra and Aqua satellites is allowing us to distinguish small from large aerosol particles by measuring precisely the aerosols' reflection of sunlight across most of the solar spectrum (from 0.41 to 2.2 micrometers). These measurements of pollution and smoke airborne particles are important because, depending upon the type of particles produced, human pollution can either have a warming or cooling influence on climate, and they can either increase or decrease regional rainfall. The results were reported in the September issue of Nature in a review paper on the satellite view of aerosol effect on climate

Validation of MODIS aerosol optical thickness

A preliminary evaluation of the MODIS aerosol products had been completed in 2000, using a limited data set of just 2–3 months of data, consisting of less than 400 points. Those results suggested that MODIS was retrieving aerosol optical thickness to within the prelaunch expected accuracy. MODIS has now been collecting data and producing an aerosol product for over 2 years. Recently, we completed a more thorough evaluation. The MODIS satellite-derived products are co-located with ground-based AERONET sunphotometers, and the aerosol optical thickness produced by each type of instrument are compared. AERONET is expected to be accurate to within 0.01 of optical thickness units, and is taken to be the ground "truth." Over two full years of data consisting of 2052 ocean points from 44 coastal and island AERONET stations and 5908 land points from 96 land AERONET stations have been compared.

Clouds and Radiation

Atmospheric radiative transfer

A simple approach has been developed that uses theoretical simulations to estimate the uncertainties that arise in cloud optical thickness retrievals due to neglect of cloud horizontal variability. For the first time, preliminary error bounds have been set to estimate the resulting errors for stratocumulus clouds. Another approach was proposed that combines visible and thermal infrared images to see whether 3-D radiative effects make clouds appear asymmetric. These results help us understand the uncertainties that horizontal cloud variability introduces into retrievals of cloud optical thickness, an important product of MODIS.

Shortwave radiation in cloudy atmosphere

Using an improved geometric-optics method, Yang et al. [2000] had computed the single-scattering optical properties of individual ice particles as a function of particle habit (shape), particle size, and wavelength. Based on these precomputed single-scattering optical properties, we have computed the mean effective particle size, mass absorption coefficient, single-scattering albedo, and asymmetry factor for 30 sample cirrus clouds in both the tropics and middle latitudes. Each sample cloud is identified with a particle size distribution, a composition of particle habits, and the aspect ratios of particle size dimension. We then developed parameterizations for the bulk mass absorption coefficient, single-scattering albedo, and asymmetry factor as a function of the mean effective particle size. The new fast and accurate parameterization has been implemented into the Goddard radiation scheme for use in cloud and climate models.

International intercomparison of 3-dimensional Radiation Codes (I3RC)

I3RC is an ongoing joint activity of NASA and DOE that encourages development and testing of multiangle atmospheric radiative transfer codes. This activity involves 32 research groups in 6 countries, who met for workshops in 1999 and 2000, and are now developing an “open source” 3-D Monte Carlo code for general distribution. An executive committee of I3RC participants, chaired by Robert Cahalan of the Branch, and other 3-D modelers, are now organizing a 3-DRT (3-dimensional Radiative Transfer) Working Group, under the auspices of the IRC (International Radiation Commission).

Physical Parameterizations

Cumulus and stratiform cloud parameterization

Three major upgrades to the cumulus parameterization scheme in the new NASA/NCAR climate model have been implemented. First, the cloud-base mass flux in moist convection was assumed to ensue with saturated as opposed to grid-averaged specific humidity. Second, the conditionally unstable clouds were forced to rise, depleting some of the excess specific humidity as cloud water and precipitation. Third, Relaxed Arakawa-Schubert Scheme (RAS) was reconfigured to simulate atmospheric boundary layer (BL) eddies to transport heat and moisture up into the inversion layer. The results show that these upgrades represent a significant step in the right direction. The GCM simulated some of the key features of the Indian drought of 1987 and North American drought of 1988 with some useful skill.

Shallow convection scheme in AGCM

Major modifications were undertaken in the physical parameterizations used by the NSIPP atmospheric general circulation model. These modifications were aimed primarily at improving the model’s simulation of boundary layer clouds over ocean, especially maritime stratus decks and the stratus-trade cumulus transition. A prognostic cloud condensate scheme was implemented, as well as a shallow convection/PBL entrainment parameterization scheme. Along with the introduction of these new physical processes, changes to pre-existing parameterization schemes, including convection, radiation and turbulence schemes were also made. Recent results with the NSIPP AGCM suggest that vigorous transport of water vapor between 800mb to 500mb may be the key to eliminating the spurious, southern ITCZ.

Technology Development

THOR (THickness from Offbeam Returns)

THOR had its initial validation flights on the NASA P3B, over the Oklahoma ARM site in March 2002, demonstrating THOR's ability to measure physical thickness of dense cloud layers. THOR's capabilities are now being extended to measure thickness of sea ice layers, with the addition of several angular channels. THOR is expected to fly over Antarctic sea ice in August 2003. THOR development is being led by Robert Cahalan (913), with co-investigator Matthew McGill (912) and chief engineer John Kolasinski (565).

Aerosol detection instrumentations

We have also designed and built two new instruments in the aerosol group: 1) Aerosol Multiple Reflection Extinction Cell, in response to the lack of standard in situ measurements of aerosol absorption, and 2) the Cloud Scanner Spectrometer, aimed at studying the interaction between aerosols and clouds. The first prototype of the multiple reflection extinction cell has been built and is being tested and calibrated, and the Cloud Scanner Spectrometer was tested for the first time during the SMOCC/LBA experiment in Brazil, in October 2002.

SMART (Surface Measurement of Atmospheric Radiative Transfer)–COMMIT (Chemical, Optical and Microphysical Measurements of in situ Troposphere)

The GSFC SMART consists of a suite of remote-sensing instruments, including many commercially available radiometers, spectrometer, interferometer, and three in-house developed instruments: micro-pulse lidar (MPL), scanning microwave radiometer (SMiR), and sun-sky-surface photometer (S3). During past years, SMART has been deployed in many NASA-supported field campaigns to collocate with satellite nadir overpass for intercomparisons, and for initializing model simulations. Built on the successful experience of SMART, we are currently developing a new ground-based in situ sampling package, COMMIT, including measurements of trace gases (CO, SO_2, and O_3) concentrations, fine/coarse particle sizers and chemical composition, single- and three-wavelength nephelometers, and surface meteorological probes. The next major activities for SMART-COMMIT are scheduled for FY03–05 in BASE-ASIA (Biomass-burning Aerosols in South East-Asia) and CHINA-TEA (Climate & Health Impacts in Northeast Asia-Tropospheric Experiment on Aerosols)

Unified Onboard Processing and Spectrometry (UniOPS)

A group of scientists and engineers at GSFC, led by Si-Chee Tsay, is funded by ESTO/ACT in a new project to unify onboard processing techniques with compact, low-power, low-cost, Earth-viewing spectrometers being developed for eventual space missions. The philosophy is that spectrometry and its onboard processing algorithms must advance in lockstep, and eventually unite in an indistinguishable fashion. A future is envisioned in which archives of the spectrometer outputs will not be a monstrous data-dump of spectra, but rather an entity that contains the full information content of the spectra, compressed on board into much smaller and more valuable data streams. Preliminary results show that compression factors of 10 to 100 are possible using a combination of physics-based removal and proximal differencing.

In the next few short articles we highlight some of the science achievements of the Branch.

Shallow Convection Scheme in AGCM

By Julio Bacmeister (bacmj@janus.gsfc.nasa.gov)

Low-level stratus and stratocumulus (St/Sc) cloud decks are a persistent feature over the relatively cool waters of eastern subtropical oceans. Well-known examples are the “fog banks” off the coasts of California and Peru. These cloud decks can be extensive, covering areas the size of the continental U.S. They reflect incoming sunlight much more effectively than the ocean underneath, and for this reason reduce the amount of solar radiation that is absorbed by the Earth. The combination of their persistence, large size, and strong radiative effect means that marine St/Sc decks are a critical component of the Earth’s net radiation budget. Modest changes in stratus deck extent could enhance (or mitigate) changes in climate induced by greenhouse gases.

Unfortunately, correctly simulating the cloud-topped marine boundary layer (MBL) in atmospheric general circulation models (AGCMs) remains a vexing problem. To begin with, stratus decks though very extensive in the horizontal, are thin, often no more than 100 to 200 meters thick. This represents a severe challenge to AGCMs whose vertical grid spacing is normally larger than this. Even with sufficient vertical resolution the creation and destruction of marine St/Sc decks involves processes that are poorly represented in AGCMs: moist turbulence and shallow convection, cloud/radiation interaction, and cloud microphysics. Numerous scientists have suggested that the key to simulating realistic St/Sc decks lies in correctly diagnosing the rate of entrainment at the top of the MBL (e.g., Grenier and Bretherton 2001). Moisture and potential temperature gradients at the top of the stratus-capped MBL are strong, so that small differences in turbulent transport can have a large impact on cloud distributions. Standard dry turbulence schemes tend to underestimate PBL-top entrainment, leading to overly wet, cool marine BLs and excessive low cloud cover. Proposed explanations for insufficient entrainment are that physical processes such as radiative destabilization in cloud decks (e.g., Stevens et al. 1999), evaporatively driven downdrafts (e.g., Deardorff 1980), and overshooting moist thermals (e.g., Stull 1989) are not included in most dry turbulence schemes.

The NSIPP AGCM includes a simple 1st-order, dry PBL scheme (Louis et al. 1983). The scheme appears to perform well in many respects, such as in its overall reproduction of tropical temperature and moisture profiles. However, without modification, the scheme leads to excessive low-level cloudiness throughout the subtropics. In order to overcome this problem, a relatively simple, plume-based entrainment calculation was added to the basic Louis scheme. This calculation is accomplished using a 1-D linearly entraining moist plume model to estimate the strength of overshooting moist thermals originating from the surface layer. The vertical momentum equation used for the plume includes condensational buoyancy production as well as liquid water loading. The vertical velocity w_u within the plumes is used to calculate an additional diffusivity,

$$K_{zz,u}(z) = a_u\, w_u(z)\, \delta_{BL}\ ,$$

which is applied near the MBL top. The parameter, a_u, is a constant representing roughly the areal fraction of a gridbox covered by moist updrafts, δ_{BL} is a length scale determined from the depth of the boundary layer. For definiteness we take δ_{BL} to be 20% of the boundary layer depth, defined as the level where the entraining plume becomes neutrally buoyant, and regard a_u. as a tunable constant.

Figure 5-15a shows low-level (below 700 mb) cloud fraction for June 1989 from a simulation using a “reasonable” value of a_u=0.03, that is 3% of a typical gridbox covered by moist updrafts. The basic structure of the cloud fields compares reasonably well with ISCCP observations (Fig. 5-15b), with dense, low-level cloud decks found off the coasts of California, Peru, and Namibia as well sparser cloud decks off of Australia and near the Azores. Cross sections of cloud fraction (Fig. 5-15c) and cloud condensate (Fig. 5-15d) are shown along 26N (California stratus). The simulation in Fig. 5-15 appears to underestimate cloudiness, except in the arctic. The cloud cross sections in Figs. 5-15c and 5-15d, exhibit cloud decks that have a generally realistic appearance. The decks are too low, reaching only 900 mb before dissipating, whereas in reality Sc cloud top heights reach 800 mb or higher before dissipating. The highest cloud fractions in the simulated California St/Sc deck are found near the coast, but are found somewhat further out over ocean in reality. The primary mechanism for cloud production in the simulated California stratus deck is found to be large-scale condensation. However, west of 150W and above 900 mb, the primary source of condensate is from detraining convection. This is encouraging because it may be analogous to the stratocumulus to trade cumulus transition in nature, which occurs as shallow convection rather than moist turbulence becomes the source of condensate (e.g., Wyant et al. 1996). The secondary cloud deck in the simulation is sparse with fractions only between 10% and 30%, but reaches heights more consistent with observed Sc and trade cumulus tops.

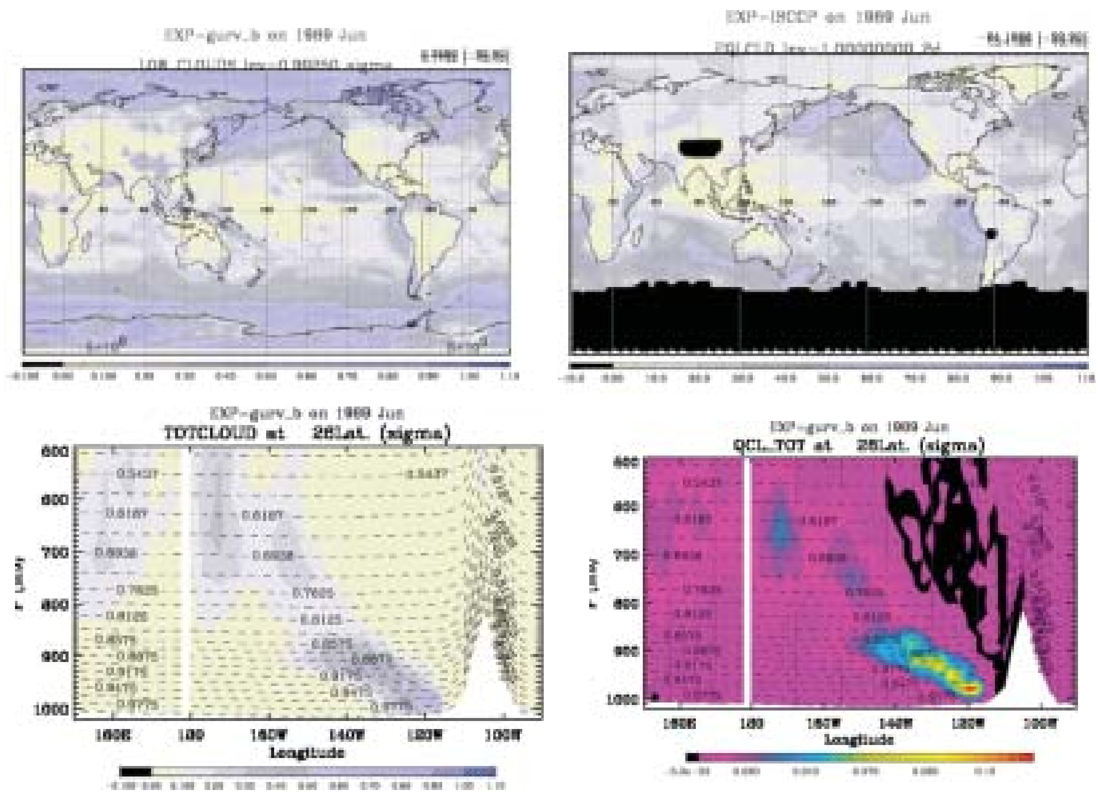
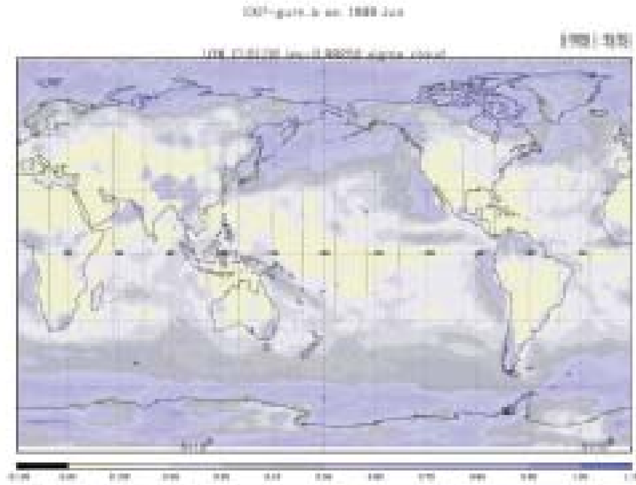
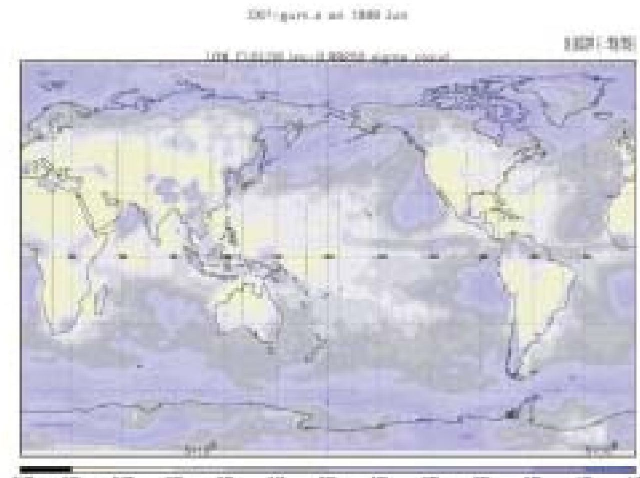


Figure 5-15. (a, upper left) low level (>700mb) cloud cover for June 1989 from the NSIPP AGCM with prognostic clouds and PBL entrainment; (b, upper right) ISCCP low cloud fraction for June 1989; (c, lower left) longitude-pressure section along 26N—California stratus region—of cloud fraction from the model; and (d, lower right) longitude-pressure section along 26N of cloud condensate mixing ratio (g/kg).

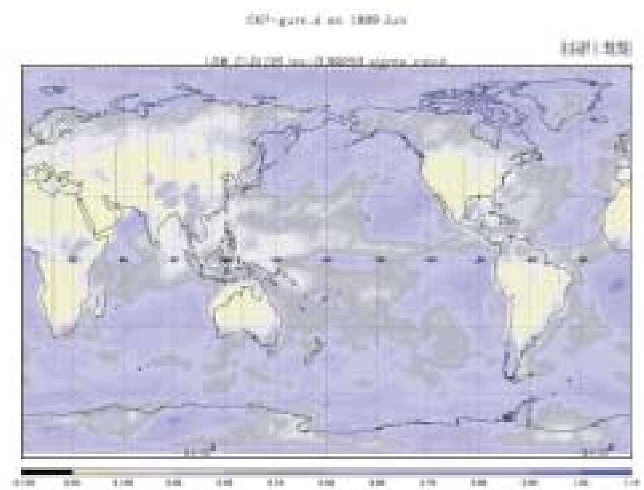
Figure 5-16 shows the sensitivity of the simulated low-level cloudiness to the assumed updraft areal fraction a_u. Figure 5-16a repeats results for a_u=0.03. Figures 5-16b and 5-16c show that, as expected, the effect of reducing a_u. is to increase the amount of low-level cloudiness. In Figure 5-16c with $a_u=1\times10^{-5}$ dense low-level clouds occur almost everywhere above the boundary layer. With $a_u=1\times10^{-2}$ (Figure 5-16b) low-level cloudiness distributions are in good agreement with observations. However, cross sections of the cloud fields in Figure 5-16b reveal similar defects to those shown in Figures 5-15c, d, i.e., cloud tops near 900 mb, and weak production of clouds by convective detrainment. It should be emphasized that the "best" choice for a_u. will probably depend on other choices made in the model physics parameterizations. The basic point of Figure 5-16 is simply to illustrate the control of a_u. on low-level cloudiness for a given set of model parameters.



5-16a



5-16b



5-16c

Figure 5-16. Sensitivity of low-level cloudiness to entrainment parameter a_u ; a) strong entrainment $a_u=3\times10^{-2}$, b) moderate entrainment $a_u=1\times10^{-2}$, and c) weak entrainment $a_u=1\times10^{-5}$. Cloud fields for June 1989 are shown.

The results shown above are encouraging in that they show that reasonable cloud simulations may be obtained in a model using a relatively simple extension to a 1st-order PBL scheme. However, the results are somewhat unsatisfying in that they require a separate ad hoc moist plume model. Similar results should be possible by modifying the model's existing convection scheme –RAS (Moorthi and Suarez 1992) to better simulate shallow convection. Such an effort is now underway, and appears promising.

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A New Satellite View of Aerosols in the Climate System
By Yoram J. Kaufman (Yoram.J.Kaufman@nasa.gov)

Manmade aerosols reflect sunlight to space, cooling the Earth's surface; at the same time they absorb solar radiation thereby warming the atmosphere. Aerosols affect cloud properties and precipitation patterns. High concentrations of aerosols with varying compositions are found downwind of urban and industrial areas, regions of domestic and forest fires, and deserts. Study of this global heterogeneous aerosol requires continuous observations from satellites, networks of ground-based instruments, and dedicated field experiments. These measurements show that aerosols have large radiative impacts downwind of polluted continental regions and deserts. Future trends in aerosol composition and concentration driven by industrialization and population expansion may adversely affect the Earth's climate, water supply, and human health.

During the last century, the Earth's surface temperature increased by 0.6°C, reaching the highest levels in the last millennium. This rapid temperature change is attributed to a shift of less than 1% in the energy balance between absorption of incoming solar radiation and emission of thermal radiation from the Earth system. Among the different agents of climate change, anthropogenic greenhouse gases and aerosols play the larger roles. While greenhouse gases reduce the emission of thermal radiation to space, thereby warming the surface, aerosols mainly reflect and absorb solar radiation (the aerosol direct effect) and modify cloud properties (the aerosol indirect effect), cooling the surface. These impacts on the radiation balance are very different and therefore require different research approaches.

Greenhouse gases, such as carbon dioxide and methane, have a long lifetime in the atmosphere of 100 years and a rather homogeneous distribution around the globe, in contrast to the heterogeneous spatial and temporal distribution of tropospheric aerosols due to their short lifetime of about a week. As a result, the global increase in the carbon dioxide concentration of 1–2 ppm per year was measured half a century ago using a single ground-based instrument, while daily satellite observations and continuous ground-based measurements are needed to observe the emission and transport of dense aerosol plumes downwind of populated and polluted regions (urban haze), regions with vegetation fires (smoke), and deserts (dust). The effect of greenhouse gases on the energy budget occurs everywhere around the globe. Aerosols have both regional and global impacts on the energy budget, requiring frequent global measurements tied to elaborate aerosol models that realistically represent the atmospheric aerosols.

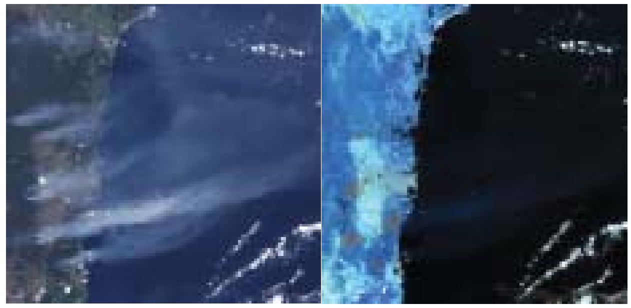
Aerosol effects on climate differ from those of greenhouse gases in two additional critical ways. Because most aerosols are highly reflective, they raise our planet's albedo, thereby cooling the surface and effectively offsetting greenhouse gas warming by anywhere from 25% to 50%. However, aerosols containing black graphitic and tarry carbon particles (present in smoke and urban haze), are dark and therefore strongly absorb incoming sunlight. The effects of this type of aerosol are twofold, both warming the atmosphere and cooling the surface before a redistribution of the energy occurs in the column. During periods of heavy aerosol concentrations over the Indian Ocean and Amazon Basin, for example, measurements revealed that the black carbon aerosol warmed the lowest 2–4 km of the atmosphere while reducing by 15% the amount of sunlight reaching the surface. Heating the atmosphere and cooling the surface below reduces the atmosphere's vertical temperature gradient and therefore is modeled to cause a decline in evaporation and cloud formation over the Mediterranean region. On the other hand, global circulation models show that the aerosol warming can change the regional and global circulation, bringing moisture and floods to Southern China due to the presence of the nearby Pacific Ocean.

The second way in which aerosols differ from greenhouse gases is through the aerosol effect on clouds and precipitation. In polluted regions, the numerous aerosol particles share the condensed water during cloud formation, therefore reducing cloud droplet size by 20%–30%, causing an increase in cloud reflectance of sunlight by up to 25%, and cooling the Earth's surface. The smaller, polluted cloud droplets are inefficient in producing precipitation, so they may ultimately modify precipitation patterns in populated regions that are adapted to present precipitation rates. The cooling effect due to polluted clouds is still poorly characterized with an uncertainty 5 to 10 times larger than the uncertainty in the predicted warming effect of greenhouse gases. The effect of aerosols on precipitation is even less well understood.

To assess the aerosol effect on climate we first need to distinguish natural from anthropogenic aerosols. Satellite data and aerosol transport models show that plumes of smoke and regional pollution have distinguishably large concentrations of fine (submicron) size aerosols (see Figures 5-17,5-18,5-19). In contrast, natural aerosol layers may have concentrated coarse dust particles and only widespread fine aerosols from oceanic and continental sources. The new ability of satellites to observe the spatial distribution of aerosol and to distinguish fine from coarse particles (Figure 5-17) can be exploited to separate natural from anthropogenic aerosols. In situ measurements of aerosol composition and size, models that assimilate the measurements and information on population density and economic activities are needed to further quantify the anthropogenic aerosol component, and to relate it to specific aerosol sources.

Aerosol research is in transition from an exploratory phase to a global quantitative phase. In the exploratory phase, new aerosol related processes are discovered, i.e., the large concentration of black carbon emitted from vegetation fires and found in regional pollution in the tropics and its effect on slowing down the hydrological cycle; the effect of aerosol on reducing precipitation efficiency and counteracting regionally the greenhouse warming. In this phase models are used to assess the potential of aerosol processes to affect the global climate. Because aerosols vary widely from region to region, a multiple-measurement approach is necessary to assess their impacts on global climate. Specifically, we require the use of long-term, detailed global measurements from satellites, distributed networks of ground-based instruments, and comprehensive regional experiments in clean and polluted environments, that feed global aerosol and climate models.

Smoke from fires in Australia—Dec. 25, 2001



Dust emitted from West Africa—Jan. 7, 2002

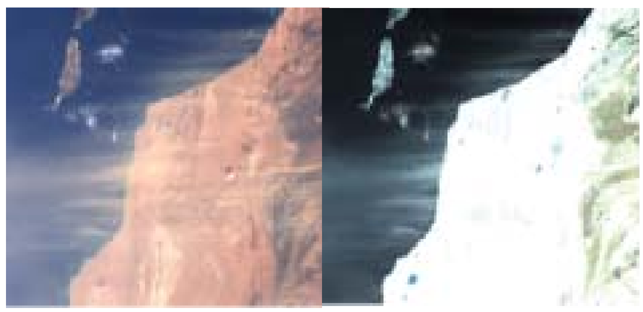
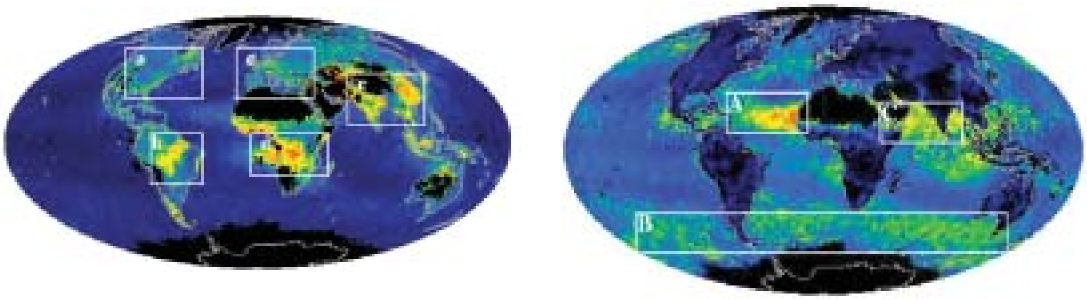
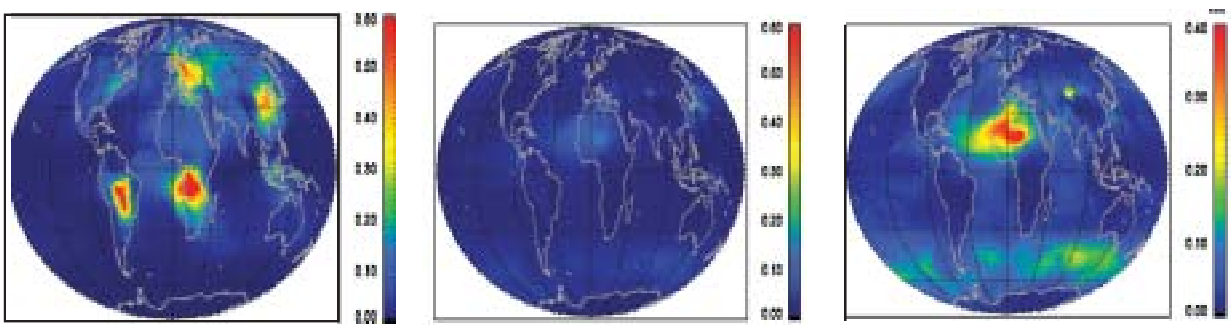


Figure 5-17. Spectral aerosol reflectance measured by MODIS: On the left, color composite of channels in the visible spectrum and on the right for near IR spectrum. Top: Fine smoke particles from fires in Australia (Dec. 25, 2001) invisible over the ocean in the near IR. Bottom: Coarse dust particles emitted from West Africa (Jan. 7, 2002) visible in both panels over the ocean. While dust is clearly visible in the visible and near IR part of the spectrum, the fine smoke particles are mostly transparent in the near IR.



a) Measured fine aerosol optical thickness   b) Measured coarse aerosol optical thickness

Figure 5-18. Global analysis of the fine (left) and coarse (right) aerosol optical thickness (0.55 µm) measured from the MODIS instrument on the NASA Terra spacecraft, for September 2000. The optical thickness presented by the color scale, is a measure of the aerosol column concentration. Black regions have surface properties inappropriate for MODIS aerosol retrievals or very low solar elevations. The white boxes indicate regions with high aerosol concentrations. The image shows fine particles in (a) and (c) pollution from North America and Europe, (b) vegetation fires in South America and (d) Southern Africa and (e) pollution in South and East Asia. Coarse dust from Africa (A), salt particles in the windy Southern Hemisphere (B) and desert dust (C).



Man-made fine aerosol optical thickness   **Natural fine aerosol optical thickness**   **Coarse aerosol optical thickness**

Figure 5-19. Model results of Chin et al., 2001 that correspond to the MODIS data of September 2000: (a) anthropogenic fine aerosols, (b) natural fine aerosols, and (c) coarse aerosols composed of natural dust and salt. The relationship between the spatial structure between fine anthropogenic aerosol in the model and MODIS is used as indication of the presence of the anthropogenic aerosol.

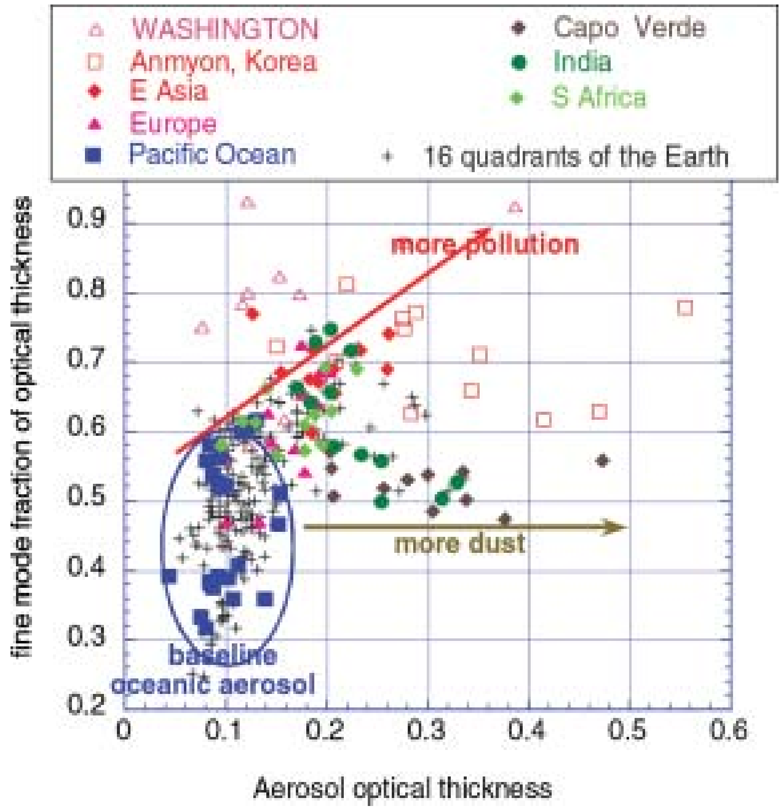


Figure 5-20. Classification of aerosol measured from MODIS over the ocean in 2 dimensions: fraction of the optical thickness due to the fine aerosol versus aerosol optical thickness. The color symbols are for specific locations as indicated and the crosses are for 16 quadrants of the Earth. Each location is represented by one point per month. The baseline aerosol is associated with optical thickness of 0.05–0.10 and fraction of the fine aerosol less than 50%. Dust is associated with higher optical thicknesses and equal fraction of fine and coarse aerosol, while pollution aerosol is associated both with high optical thickness and fine fraction. Note that the data from India are split into the winter pollution group and into the summer dust group.

Kaufmann, Y.J., D. Tanre, O. Bourcher, 2002: A satellite view of aerosols in the climate system. *Nature*, **419**, 215-223.

A New Look into the Effect of Large Droplets on Radiative Transfer Process

By Alexander Marshak (Alexander.Marshak-1@nasa.gov)

Recent studies indicate that a cloudy atmosphere absorbs more solar radiation than any current 1-D or 3-D radiation model can predict. The excess absorption is not large, perhaps 5–15 W/m2 or less, but any such systematic bias is of concern since radiative transfer models are assumed to be sufficiently accurate for remote-sensing applications and climate modeling. The most natural explanation would be that models do not capture real 3-D cloud structure and, as a consequence, their photon path lengths are too short. However, extensive calculations, using increasingly realistic three-dimensional cloud structures, have failed to produce photon paths long enough to explain the excess absorption. Other possible explanations have also been unsuccessful, thus at this point, conventional models seem to offer no solution to this puzzle.

The weakest link in conventional models is the way a size distribution of cloud particles is mathematically handled. Basically, real particles are replaced with a single average particle. This “ensemble assumption” assumes that all particle sizes are well represented in any given elementary volume. But the concentration of larger particles can be so low that this assumption is significantly violated. We show how a different mathematical route, using the concept of a cumulative distribution, avoids the ensemble assumption. The cumulative distribution has jumps, or steps, corresponding to the rarer sizes. These jumps result in an additional term, a kind of Green’s function, in the solution of the radiative transfer equation.

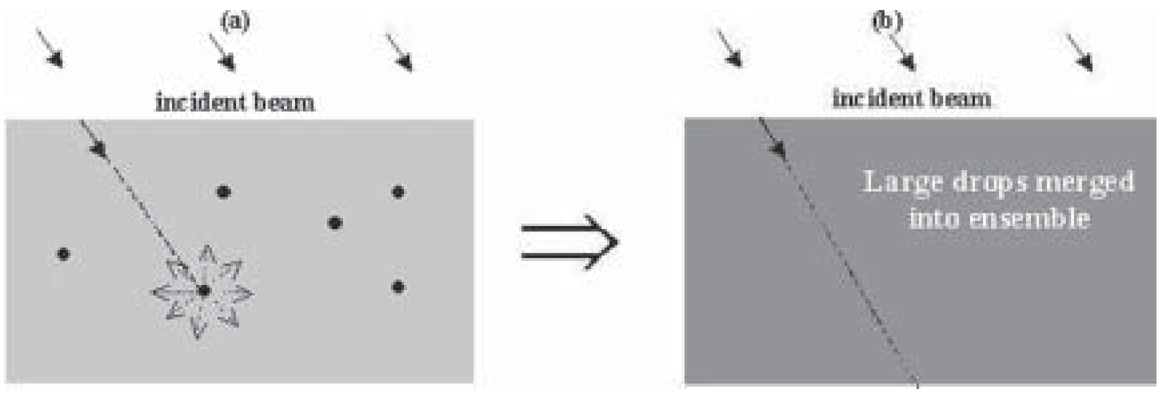


Figure 5-21. (a) Schematic representation of a small cloud piece containing an enormous number of small particles (gray area) and a tiny number of large ones (black dots); and (b) ensemble approach, where the large particles are artificially fractionated and homogenized over space. The true solution to the radiative transfer equation for (a) includes photon interactions with those particles actually present in the cloud, while the ensemble-based approximation (b) accounts for photon interactions with fictitious rare particles included in extremely small concentrations in every elementary volume. The difference between the true solution and the ensemble-based approximation is the Green’s function, which describes the radiation field generated by photons scattered from rare, large particles.

This true solution also exhibits a jump-like behavior, involving two different mathematical mechanisms in the accumulation of energy absorbed by particles. The first one integrates absorption over the photon path, so that the longer the photon path, the larger the amount of energy absorbed by particles. The second mechanism, missed in the ensemble approach, adds up jumps in the true solution corresponding to the rarer particle sizes, each corresponding to a negligible photon path. Solving the cloud radiative transfer equation with the measured particle distributions, described in a cumulative rather than an ensemble fashion, may lead to increased cloud absorption of the magnitude observed.

These results are reported in the paper, “A Missing Solution to the Transport Equation and its Effect on Estimation of Cloud Absorptive Properties,” by Y. Knyazikhin, A. Marshak, W. Wiscombe, J. Martonchik, and R. Myneni published in the *Journal of Atmospheric Sciences*.

Biomass-burning Aerosols in South East-Asia: Smoke Impact Assessment (BASE-ASIA)

Si-Chee Tsay (Si-Chee.Tsay-1@nasa.gov)

Biomass burning has been a regular practice for land clearing and land conversion in many countries, especially those in Africa, South America, and Southeast Asia. However, the unique climatology of Southeast Asia is very different than that of Africa and South America, such that large-scale biomass burning causes smoke to interact extensively with clouds during the peak-burning season of March to April. Every boreal spring the indigenous populations of Laos, Thailand, Vietnam, Myanmar, and southern China clear the ground needed to plant agricultural crops by setting fires. While the fires are often set in areas that are relatively dry with little cloud cover (particularly in Myanmar, Thailand, and Laos), the smoke plumes they generate can stretch hundreds of kilometers into areas of heavy cloud cover (Vietnam and southern China), as depicted in Figure 5-22. During the springtime, this cloud cover is generally composed of stratiform, low-altitude clouds associated with frontal systems that originate in China. Because both smoke and clouds converge over Vietnam and southern China, darkened (brown colored) clouds are often seen in satellite images during this season as smoke gets transported to areas that contain the low-lying cloud deck.

Figure 5-22. Interaction of smoke aerosols with extended cloud layer, observed by SeaWiFS on 21 March 1999 in Southeast Asia.

It is imperative that we combine measurements from multisensors to obtain optimal information for determining the impact of smoke aerosols on the radiative budget of the Earth-atmosphere system. We have estimated quantitatively the radiative effect, in the presence of clouds, of smoke aerosols from biomass burning activities in Southeast Asia during boreal spring using such technique. We combined the TOA SW and total (SW+LW) flux from CERES with the AI from TOMS and cloud reflectivity from SeaWiFS. We generated a collocated data set by averaging the daily Level-2 data from these three sensors into 0.5º latitude by 0.5º longitude bins (Hsu et al., 2003). Two types of histograms over cloudy regions were then calculated from this data set: one for relatively smoke-free clouds (AI< 0.1) and one for smoke-laden clouds (AI>1.5). The results for SW flux and total (SW+LW) flux are depicted in Figures 5-23a and 5-23b, respectively.

Apparently during boreal spring in Southeast Asia, when smoke aerosols are present in cloudy regions, the peak SW flux is observed to shift from 720–740 Wm^{-2} over relatively smoke-free clouds to 620–640 Wm^{-2} over smoke-laden clouds. Such a reduction (~ 100 Wm^{-2}) in outgoing SW flux is substantial in the radiative budget of the atmosphere. This would, in turn, cause a strong warming in the smoke layer above the cloud deck. The corresponding TOA upwelling total flux peaks at about 960–980 W m^{-2} over smoke-free clouds for this region during March, while the total flux over smoke-laden clouds peaks at 880–920 W m^{-2}. The reduction in the total flux due to the presence of smoke aerosols is around 70–80 W m^{-2}. This is because the LW flux increases by about 20–30 W m^{-2} over the smoke-laden clouds when compared to that over smoke-free clouds, and thus compensates for some of the reduction in the SW flux, resulting in a slightly smaller net reduction in the total flux. One of the processes that leads to an increase in LW emission, due to the presence of smoke aerosols in cloudy areas, could be an enhancement of the temperature inversion by SW absorption. Such large perturbations in radiation fields (SW + LW) will induce an imbalance in the terrestrial heat budget that could affect local wind circulation patterns and cloud dynamics. This, in turn, may lead to drastic change when the Southeast Asian monsoon begins, currently in the late boreal spring and early summer. Perturbations in the onset of the Southeast Asian monsoon are believed to have great influence on the development of full-scale Asian summer monsoons during the subsequent months [Lau and Yang, 1997]. Therefore, better quantification of the smoke effect on clouds in the radiative budget is crucial to the improvement of the predictability of the tropical climate system during the boreal spring.

Since this observed radiation perturbation may be a combination of direct effects (absorption of sunlight above the cloud) and indirect effects (mixing and interacting with low clouds), more ground-based and aircraft measurements are urgently needed to fully understand and partition the contributions from both. We are currently initiating a pilot study, BASE-ASIA, in seeking a better understanding of the impact of the biomass burning aerosols on regional-to-global climate, hydrological and carbon cycles, and tropospheric chemistry in Asia.

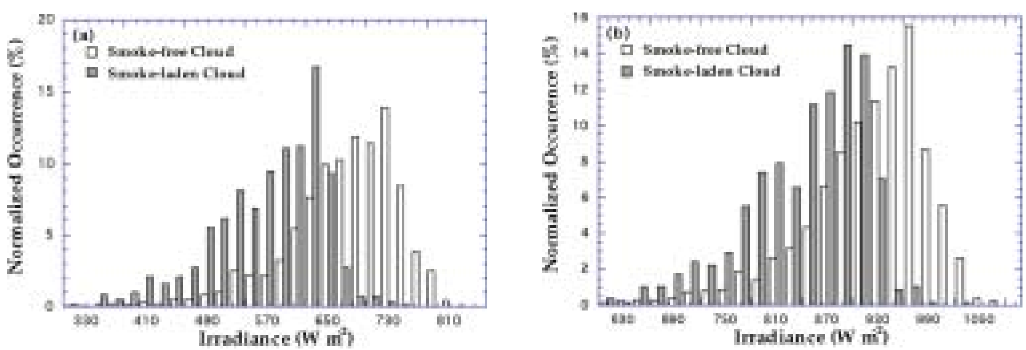


Figure 5-23. Normalized (unity) histograms of the CERES TOA upwelling (a) shortwave, and (b) total (shortwave + longwave) flux for the domain region of (15–30° N, 100–125° E) during the month of March 2000 over smoke-free clouds (nonshaded), and over smoke-laden clouds (shaded). To prevent subpixel (broken) cloud contamination, we adopt a criterion that cloud reflectivity derived from the SeaWiFS 865 nm channel has to be greater than 0.7.

Lau, K.-M., and S. Yang, Climatology and interannual variability of the Southeast Asian summer monsoon, *Adv. In Atmos. Sci*., **14**, 141-162, 1997.

Hsu, N.C., J.R. Herman, and S.-C. Tsay, Radiative impacts from biomass burning in the presence of clouds during boreal spring in Southeast Asia, *Geophys. Res. Lett*., **30**, doi:10.1029/2002GL016485, 2003.

Atmospheric Experiment Branch, Code 915

Branch Summary

The Atmospheric Experiment Branch conducts experimental studies to increase our understanding of the chemical environment in our solar system during its formation and to study the physical processes that have continued to shape solar system bodies through time. To achieve this goal, the Branch has a comprehensive program of experimental research, developing instruments to make detailed measurements of the chemical composition of solar system bodies such as comets, planets, and planetary satellites that can be reached by space probes or satellites.

The Branch's accomplishments for 2002 include:

1) The Branch continued participation in the CONTOUR mission that was planned to rendezvous with multiple comets and provide a more detailed understanding of the cometary nuclei and the diversity among comets. CONTOUR was a mission in NASA's Discovery line of small mission program for planetary studies. The CONTOUR PI is Professor Joseph Veverka of Cornell University, and the Applied Physics Laboratory (APL) in Laurel, Maryland, managed the development of this spacecraft. The Neutral Gas and Ion Mass Spectrometer (NGIMS) is one of four instruments on this mission. NGIMS was designed and fabricated inhouse at GSFC with collaboration on the analog portion of the flight electronics with the University of Michigan. The instrument was delivered in December 2001 to the Johns Hopkins APL for integration with the CONTOUR spacecraft. CONTOUR was launched in July 2002. Unfortunately, the Solid Rocket Motor failed near the end of its scheduled 50-sec burn causing an explosion that apparently rendered the spacecraft inoperable. Significant activities for the NGIMS instrument team, however, were the completion of the instrument's final processing, assembly, environmental testing and delivery to APL. The NGIMS team also carried out significant participation during spacecraft integration at APL. A replacement mission, CONTOUR II, is being discussed as a possible new mission for the next Discovery proposal opportunity.

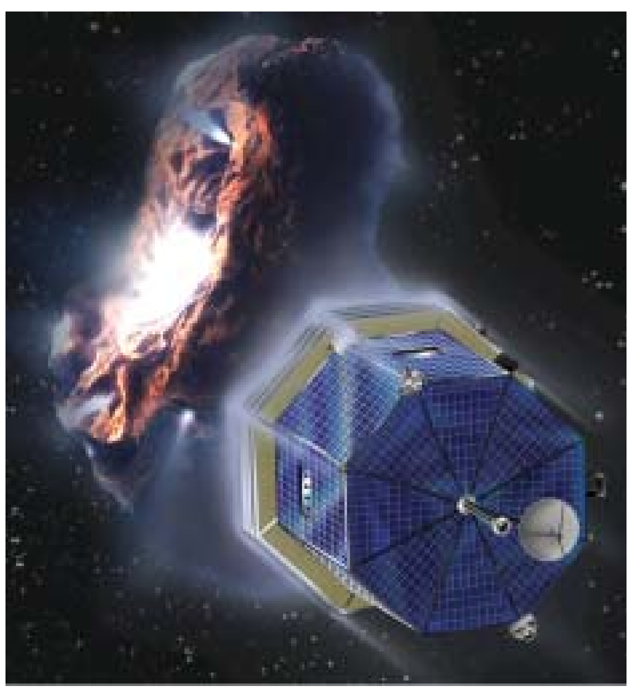


Figure 5-24. Artist's conception of CONTOUR in a rendezvous encounter.

2) The Branch continued providing post-launch support for several key planetary missions. These include:

- A Gas Chromatograph Mass Spectrometer on the Cassini Huygens Probe mission to explore the atmosphere of Saturn's moon Titan.
- An Ion and Neutral Mass Spectrometer on the Cassini Orbiter to explore the upper atmosphere of both Saturn and Titan.
- A Neutral Mass Spectrometer on the Japanese Nozomi mission to explore the upper atmosphere of Mars.

3) Branch members continued advanced development for measurements on future missions. These include a probe of the deep atmosphere of Venus to carry out precision measurements of isotopes designed to resolve questions of the origin and processing of this atmosphere; a detailed in situ rendezvous mission with the nucleus of a comet to better understand the complexity of organic molecules that might have been delivered to Earth over the course of its history; a landed experiment on Mars to sample isotopes and molecules from its atmosphere and below its surface that can address studies of past climate and the possibility of past life on this planet.

4) Branch members are participating in a collaborative astrobiology investigation with the Johns Hopkins Applied Research Laboratory to develop a prototype instrument that will aid in the search for the nature of prebiotic chemistry or evidence of past life. The instrument will be centered around a miniaturized time-of-flight mass spectrometer combined with a gas chromatograph that will allow both simple and complex organic molecules to be resolved. Direct ionization of solid samples using laser ablation or energetic ions combined with electron ionization of gases thermally released from the same samples will allow a wide range of highly volatile to highly refractory components to be analyzed. This powerful technique will enable in situ characterization of organics contained in solid phase material sampled on lander missions to comets, asteroids, Jovian moons, or Mars.

5) Branch members developed a mission concept in collaboration with scientists and engineers at GSFC and JPL to carry out measurements for 30 days in the polar region of Mars from a Montgolfiere balloon platform. This mission with the astrobiology focus of a search for pointers to past or present life in the atmosphere, surface, and subsurface was submitted to NASA Headquarters in response to their announcement for this mission.

6) Branch members participated in several national and international workshops which focused on a Comet Nucleus Sample Return mission; a Jupiter deep-entry atmospheric probe mission; and an international workshop on Calibration Techniques for in situ Particle Instruments.

7) Branch members continued the collaborative effort with GSFC's Engineering Directorate in a comprehensive program to achieve a significant reduction in the size and weight of present-day mass spectrometer systems. This includes reduction to the electronics system by utilizing Application Specific Integrated Circuits (ASICS) and other advanced packaging techniques as well as reductions to the mass spectrometer itself by utilizing MEMS techniques.

Instrument Development: Sample Analysis at Mars (SAM)

Paul R. Mahaffy, (Paul.R.Mahaffy@nasa.gov)

A high priority for the next decade of Mars exploration will be the search for signatures of extinct or extant life (Ardvison et al., 2001, Greeley et al., 2000). A key objective of this exploration will be a search for the location and characteristics of the range of organic molecules that may reveal the nature of present or ancient biotic or prebiotic processes on Mars. Since the Martian atmospheric and near surface environment is believed to be highly oxidizing where organic molecules may be rapidly destroyed or chemically transformed into more stable organic species (Benner, 2000) this search is expected to focus on samples obtained from protected regions such as the interior of rocks or from below the surface in low permeability sedimentary layers. Chemical fossils might be found, for example, of processes that were in place earlier in the history of Mars when warmer and wetter conditions (McKay and Davis, 1991) might have favored biological activity. Recent advances in understanding the nature of terrestrial microbial life and its ability to adapt to both warm (hydrothermal) and cold (permafrost) environments (Nienow et al., 1993) suggest that the polar ices of Mars may be an excellent target for the search for evidence of extant life. Wherever organic molecules are found, a comprehensive examination of their character will be necessary to address the important question of what role these molecules might have played in Martian biology or prebiotic chemistry. Fundamental studies of organics, reduced species, and isotopes include:

- A general survey of the number and types of discrete volatile organic molecules.
- A characterization of the refractory macromolecular organic material.
- A characterization of the chemical (association with other reducing phosphorus, sulfur, or nitrogen containing species) and mineralogical context of any organic containing samples.
- An identification of the relative abundance of molecular organic species in a homologous series such as alcohols with increasing number of carbon atoms.
- A sensitive test for the presence of molecules of special relevance to biology such as amino acids.
- A test for the predicted stable intermediate oxidation products (such as carboxylic acids) that might be produced from reactive molecules such as amino acids.
- A determination of the chirality of the molecular species identified.
- A characterization of the isotopic composition of the light elements H, C, O, S, P, and N in organic molecules and other reduced species.
- A characterization of the light isotope composition in minerals and a comparison with the same elements in the atmosphere, that might address studies of atmospheric loss to surface reservoirs and to space and atmosphere exchange with the surface.
- A characterization of the light isotope composition in minerals that might distinguish an abiotic production mechanism from evidence of biomineralization.

With several sources of NASA and CNES support we are developing several of these techniques to address astrobiology/organic studies in a Mars surface lander experiment such as the planned 2009 Mars Science Laboratory (MSL). The instrument suite, Sample Analysis at Mars (SAM), will be designed to carry out a detailed in situ chemical and isotopic analysis of solid phase material sampled from the surface or subsurface of Mars. A special focus of SAM is on the detection and analysis of trace organic species that may reveal the nature of ancient biotic or prebiotic processes on Mars together with a sensitive and detailed study of atmospheric gas. With SAM we initiate a program to extend previous NASA and CNES collaborations in the area of geochemical and exobiological investigations to future exploration of Mars. We specifically target this development for the 2009 Mars Science Laboratory Mission. Members of our international team include several scientists and instrument specialists who developed similar capability for the Cassini/Huygens mission. The SAM development team will bring together a unique set of scientific and analytic capabilities to address outstanding questions in Mars exploration. Development support for this program has been provided from both the NASA and CNES.
The SAM development is an international collaboration with several participating institutions. The technical development will be led by scientists at GSFC, the University of Paris (with support from CNES), the Service d'Aeronomie (SA), and the Johns Hopkins University Applied Physics Laboratory (JHU/APL).

Atmospheric Chemistry and Dynamics Branch, Code 916

Branch Summary

The Atmospheric Chemistry and Dynamics Branch conducts research in the distribution and variability of atmospheric ozone: 1) by making new measurements; 2) by analyzing existing data; and 3) by theoretically modeling the chemistry and transport of trace gases that control the behavior of ozone. An emerging research focus is on the characterization of sources, sinks, and transport of aerosols, carbon dioxide, and ozone in the troposphere. The Branch's accomplishments for 2002 include the following:

1) Branch scientists continued to play key roles in the WMO/UNEP assessment of the stratospheric ozone depletion. This congressionally mandated assessment, held every 3 to 4 years, brings together experts in stratospheric research to assess the current health of the ozone layer and to make informed predictions about its future state. A key input to this assessment is the long-term global record of ozone created by combining ground-based and satellite data developed by the Branch. An emerging focus is to use the 3-D chemistry and transport model developed in the Branch to study the impact of greenhouse warming on the stratosphere.

2) The Branch manages the TOMS project, which along with the SBUV project (a collaborative effort between NASA and NOAA, and supported by the Branch) continues the highly acclaimed ozone time-series. In 2002, advanced algorithms (version 8) to process SBUV and TOMS data were developed under the leadership of Branch scientists. These algorithms are expected to significantly improve the utility of these datasets for atmospheric chemistry research. In addition, Branch scientists continued to improve the quality of several popular datasets produced from TOMS to study global air quality, viz., aerosols, surface UV, and tropospheric ozone.

3) Branch scientists led the development of the 2nd SAGE III Ozone Loss and Validation Experiment campaign (SOLVE II), an aircraft field campaign in the northern polar region designed to improve our understanding of the transport and chemistry of the arctic region and to provide data for the validation of the recently launched SAGE III instrument. Branch scientists provided the stratospheric ozone, temperature, and aerosol Lidar for this campaign.

4) Several Branch scientists are members of the International OMI science team. OMI is a Netherlands-provided instrument, scheduled to fly on the EOS Aura satellite in early 2004. This team participated in developing a 4-volume description of the scientific algorithms that will be used to process OMI data to derive a variety of products relevant in atmospheric chemistry research. This document received good reviews from a panel of experts selected by the EOS Project Office.

5) The Branch manages the SHADOZ (Southern Hemisphere Additional OZonesondes) program. This international program has greatly improved the quality and quantity of ozone vertical profile data in the region of the world that is experiencing rapid environmental change. The Branch scientist who leads this effort, Anne Thompson, was recently awarded a Fellowship of the American Association for the Advancement of Science (AAAS), based partly on her work related to SHADOZ.

6) Branch scientists have developed a state-of-the-art model, called GOCART, to study global distribution and transport of aerosols. This model is proving invaluable in interpreting aerosol data derived from TOMS, SeaWiFS, and MODIS.

The following two articles illustrate some of the science resulting from field campaigns the Branch is heavily involved in.

Zonal Wave-one Structure in Tropical Ozone Observed in SHADOZ (Southern Hemisphere ADditional Ozonesondes) Network Data

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Although the launch of the first total back-scattered ultraviolet (BUV) satellite more than thirty years ago initiated space-era ozone measurements, validation of column and profile ozone is a more recent development, which requires deployment of ground- and balloon-borne instrumentation. Approximately 100 stations worldwide regularly launch an electrochemical concentration cell (ECC) ozonesonde, in which air pumped through cells with potassium iodide solutions produces a current proportional to the amount of ozone; the ozonesonde is flown with a standard radiosonde. Most ozonesonde stations are in northern mid-latitudes. The only tropical station that has operated since the 1970's is at Natal, Brazil, where launches are supported by a partnership between the Goddard/Wallops Upper Air Group and INPE (the Brazilian Space Agency).

To end the lack of tropical ozone profile data, the SHADOZ (Southern Hemisphere ADditional OZonesondes) project was initiated in 1998 by personnel in GSFC's Laboratory for Atmospheres and Laboratory for Hydrospheric Processes, NOAA's Climate Diagnostics and Monitoring Laboratory, and more than a dozen sponsoring nations. Through augmentation of ozonesonde supplies, SHADOZ facilitates weekly launches at a dozen locations (see map in Figure 5-25), collecting and disseminating all data through a centralized archive at the Web site: code916.gsfc.nasa.gov/data_services/shadoz. More than 1600 ozone and PTU (pressure-temperature-humidity) profiles are available at the SHADOZ archive. In addition to enhancing the satellite ozone profile climatology, SHADOZ data are used to study tropical chemistry and dynamics. This has led to a breakthrough in a decade-long scientific argument about the location and origins of a zonal "wave-one" pattern in total ozone that was first detected in TOMS satellite data. The "wave-one" refers to a greater total ozone column amount over the Atlantic and adjacent continents than over the Pacific. Is the "wave-one" due to relatively more Atlantic ozone in the stratosphere or in the troposphere? This question is answered through the vertical resolution of the sonde data and longitudinal coverage of SHADOZ. The zonal structure (Figure 5-26) shows that the "wave-one" results from an ozone excess in the troposphere. Free tropospheric ozone has a lifetime up to a month or more and the general pattern in Figure 5-26 persists throughout the year. Continuing studies with models and correlative data are focusing on the mechanisms causing the wave. Some of the higher ozone features in the lower mid-troposphere are due to photochemical ozone from biomass fires. Convection takes low-ozone (unpolluted) air from boundary layer to upper troposphere over Watukosek (Java), with components of tropical general circulation also contributing to the mean ozone distribution.

Thompson, A.M., et al., The 1998–2000 SHADOZ (Southern Hemisphere ADditional OZonesondes) tropical ozone climatology. 2. Tropospheric variability and the zonal wave-one, *J. Geophys. Res.*, 10.129/2002JD002241, in press, 2002.

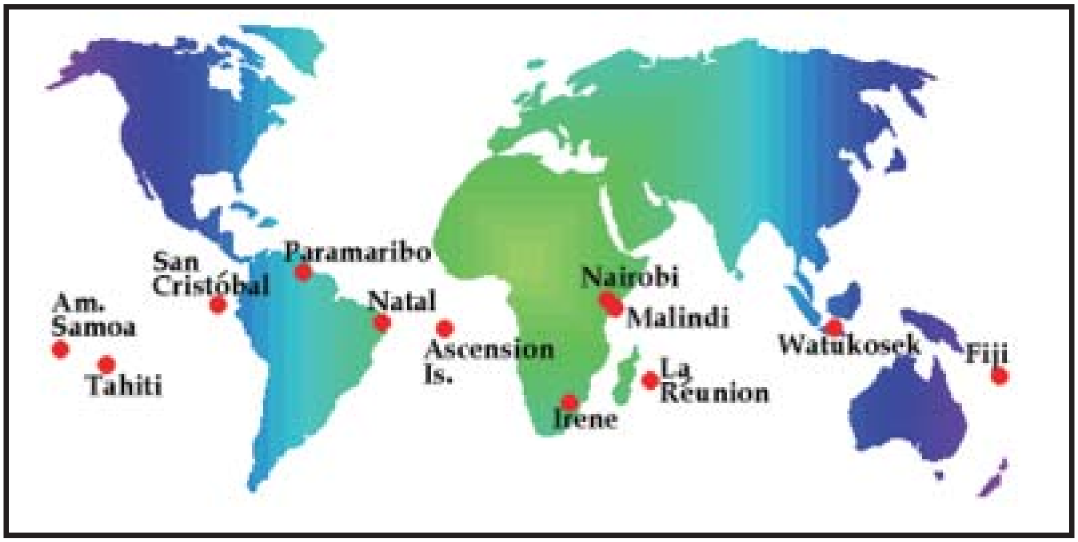

Figure 5-25. SHADOZ sites. The results in Figure 5-23 are based on more than 1100 soundings taken in 1998–2000 at all the stations except Paramaribo and Malindi.

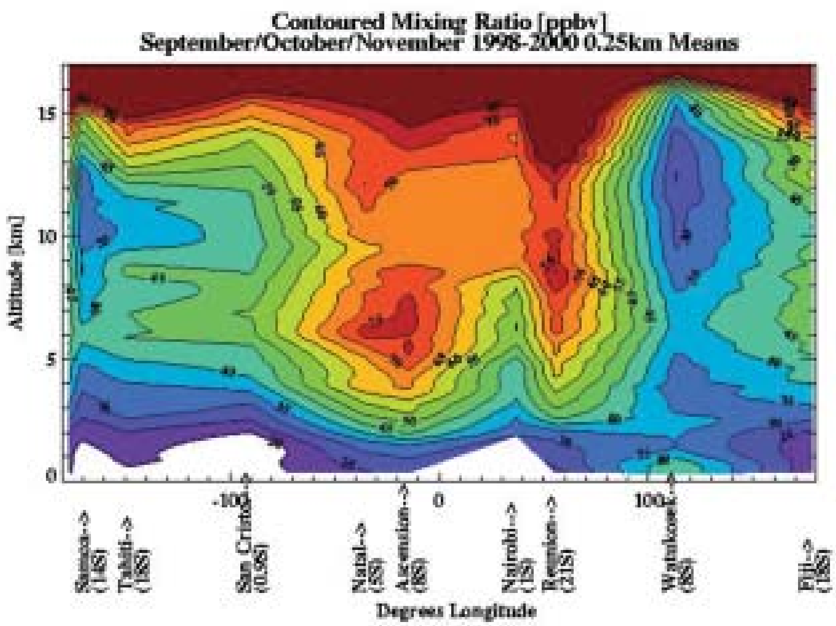

Figure 5-26. The tropospheric "wave-one" pattern in tropospheric ozone results from the structure shown for September-October-November (SON) with mixing ratio contours based on 0.25-km averaged segments.

GSFC Participation in the Second SAGE-III Ozone Loss and Validation Experiment (SOLVE-II).

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The SAGE III Ozone Loss and Validation Experiment (SOLVE II) was a measurement campaign designed to examine the processes controlling ozone levels at mid- to high latitudes. The mission also acquired correlative data needed for the validation of the Stratospheric Aerosol and Gas Experiment (SAGE) III satellite measurements. SAGE-III is a NASA instrument on board a Russian Meteor-3 satellite platform. SAGE-III is primarily used to quantitatively assess high-latitude ozone loss.

The SOLVE II mission was primarily conducted during January 2003. Measurements were made in the Arctic high-latitude region during winter using the NASA DC-8 aircraft, as well as balloon platforms and ground-based instruments. The NASA DC-8 was based in Kiruna, Sweden, slightly north of the Arctic Circle.

GSFC scientists participated in SOLVE II in 3 ways: the Airborne Raman Ozone, Temperature and Aerosol Lidar (AROTAL) instrument, project support, and flight planning. Thomas McGee and John Burris were co-principal investigators on the AROTAL instrument, Paul Newman and Mark Schoeberl served as project scientists for the NASA DC-8, and Leslie Lait performed flight planning for the DC-8.

Integration of instruments onto the DC-8 began in mid-November 2002 and was completed in early December. Four test flights of the entire payload were flown from NASA Dryden Flight Research Center in California, and the DC-8 arrived in Kiruna, Sweden, on January 9, 2003. A total of 11 science flights were conducted in Kiruna, and the DC-8 returned to NASA Dryden on February 6, 2003.

Ozone loss in the polar stratosphere is directly caused by catalytic chlorine and bromine reactions. The high levels of reactive chlorine occur because of reactions of reservoir chlorine species on the surfaces of polar stratospheric clouds (PSCs). PSCs were observed by the NASA DC-8 lidar systems on the flight of January 9, 12, 14, and February 4, 2003, at altitudes between 65,000 and 80,000 feet. In Figure 5-27, we see a PSC cloud that was observed over southern Sweden on January 14, 2003. Three types of PSCs are common in the polar region: type Ia (small crystals), type Ib (small liquid droplets), and type II (large crystals). The type Ia PSCs are probably nitric acid hydrates, the type Ib are probably solutions of nitric acid, water, and sulfuric acid, while the type II PSCs are water ice crystals. The PSC in Figure 5-27 is probably a water ice cloud because of the strong coloration from the ice crystal refraction.

Figure 5-27. Picture of PSC taken from the NASA DC-8 over southern Sweden on January 14, 2003. Photo by Paul A. Newman.

Two chlorine compounds (HCl and $ClONO_2$) that normally do not destroy ozone can collect on the surfaces of PSC particles. On these surfaces, chemical reactions convert the HCl and $ClONO_2$ to Cl_2 and HNO_3. With a small amount of sunlight, the Cl_2 is broken down and begins to catalytically destroy ozone. During the winter of 2002–2003, the polar vortex was cold and had moved southward toward Europe, exposing the air to sunlight. Normally, ozone values in the core of the vortex near 20 km would be approximately 3 parts per million. However, because of the high levels of reactive chlorine, ozone steadily decreased over the course of the month. Figure 5-28 displays ozone values observed on the flight from Kiruna, Sweden, to California on February 6, 2003. The x-axis of the figure shows the time, while the y-axis shows altitude. The polar vortex was situated over Kiruna, such that ozone values at 20 km on the left of the figure are inside the polar vortex. Typically values of ozone inside the vortex in January would be near values of 3000 ppbv (the aqua color). However, during early February, these values are near 1500 ppbv, suggesting very large ozone losses inside the polar vortex.

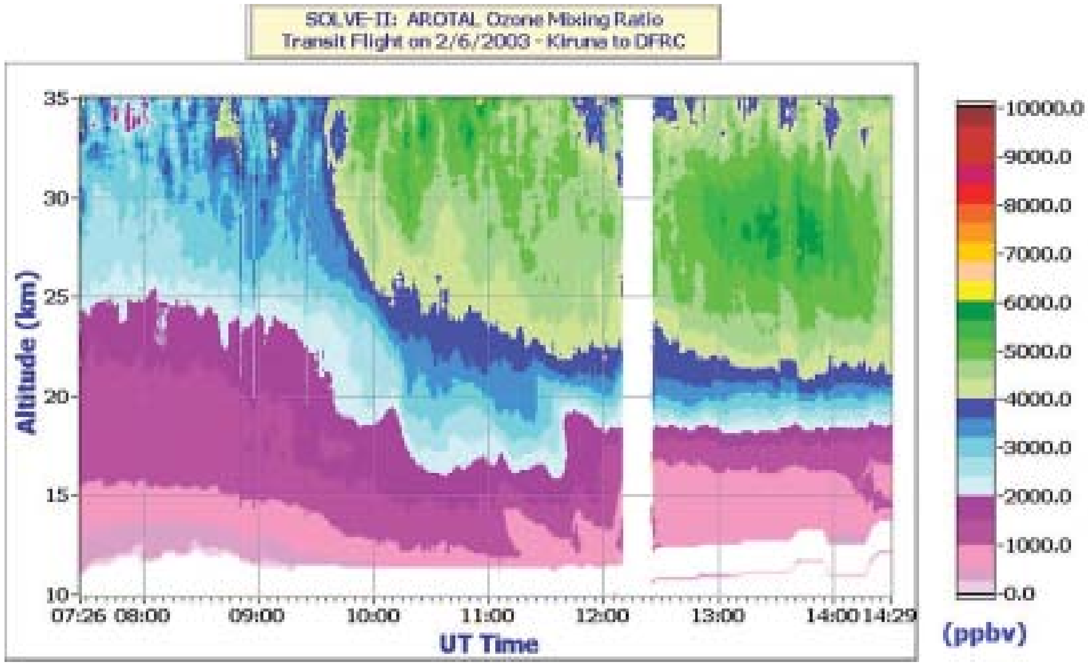

Figure 5-28. Ozone values observed on the flight from Kiruna, Sweden, to California on February 6, 2003, from the GSFC AROTAL instrument.

These initial results are qualitative, and will require further processing and quantitative analysis. These SOLVE II results will be directly used to quantify ozone loss in the vortex. The ozone values and ozone loss will then be compared to the SAGE III ozone values to validate our global observations of ozone.

6. EDUCATION AND PUBLIC OUTREACH

The Laboratory for Atmospheres actively participates in NASA's efforts to serve the education community at all levels and to provide information to the general public. The Laboratory's educational outreach component is consistent with the Agency's objectives to enhance educator knowledge and preparation, supplement curricula, forge new education partnerships, and support all levels of students. Laboratory activities include addressing public policy, establishing and continuing collaborative ventures and cooperative agreements; providing resources for lectures, classes, and seminars at educational institutions; and mentoring or academically advising all levels of students. Through our public outreach component, we seek to make our scientific and technological advances broadly accessible to all members of the public and to increase their understanding of why and how such advances affect their lives. Education and public outreach are an important part of our basic science activities and go hand in hand with our work on projects, field campaigns, instrument development, modeling, data analysis and data set development. This section highlights some of the education and public outreach activities of our Laboratory.

Interaction with Howard University and Other Historically Black Colleges and Universities

A part of NASA's mission has been to initiate broad-based aerospace research capability by establishing research centers at the nation's Historically Black Colleges and Universities (HBCUs). The Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA) was established in 1992 at Howard University (HU) in Washington, D.C., as a part of this initiative. The Laboratory for Atmospheres started a close collaboration with CSTEA in their second 5-year period of NASA funding under a cooperative agreement grant. It has been a goal of the Laboratory and the Earth Sciences Directorate to partner with CSTEA to establish at Howard University a self-supporting facility for the study of terrestrial and extraterrestrial atmospheres, with special emphasis on recruiting and training underrepresented minorities for careers in Earth and space science. Some of the Laboratory's continued research and educational activities with Howard University's CSTEA program during 2002 are highlighted below.

Howard University students in the CSTEA program were invited to give poster presentations on April 22 in the building 28 atrium at Goddard. The visit was sponsored by Magui Cardona, Stokes Fellow in the Minority University Programs office at Goddard. Scientists from codes 900, 600, and 500 were invited to the poster session. The students and Prof. Venable, CSTEA's head, were treated to an E-theater presentation by the Laboratory's Fritz Hasler.

Marshall Shepherd and members of the Howard University Physics Department (Prof. Joseph and Prof. Venable) installed 3 tipping-bucket rain gauges. Two rain gauges were installed at the Howard University Beltsville facility and one gauge on Howard's downtown campus. Marshall Shepherd contributed the gauges (1) to foster his ongoing investigations of urban/rural rainfall anomalies and rainfall variability and (2) to foster continued partnerships with Howard University and the Laboratory for Atmospheres.

The Laboratory works closely with CSTEA faculty to promote the Howard University Program in Atmospheric Sciences (HUPAS). HUPAS is the first M.S.- and Ph.D.-granting program in atmospheric sciences at an HBCU and the first interdisciplinary academic program at Howard University. Scientists from our Laboratory contribute to the HUPAS program as lecturers, advisors to students, and adjunct professors teaching courses. Laboratory for Atmospheres Adjunct Professors Dean Duffy and Richard Stewart wrote parts of the first Ph.D. candidacy exams for HUPAS. The Laboratory's adjunct professors Dean Duffy, Richard Stewart, and Walter Hoegy have attended HUPAS committee meetings to discuss future plans, course offerings, and qualifying exam schedules for the Howard graduate degree program in atmospheric science. After a second round of qualifying exams, 6 Howard students are now on track for earning the Ph.D. in the atmospheric sciences.

The Laboratory continues its enthusiastic support for the Goddard Howard University Fellowship in Atmospheric Sciences (GoHFAS) program. GoHFAS was established in 1999 to broaden and strengthen the research and educational opportunities of underrepresented minorities. The students attend a summer program at Howard University where they engage in research with mentors at HU, GSFC, or NOAA. They receive fellowships at their home institutions during their senior year and are given an opportunity to come to HU during the winter break to continue their research.

Summer Programs

Our Laboratory participates in a number of programs that bring graduate, undergraduate, and high school students to work one-on-one with scientists and engineers in the Laboratory for Atmospheres as well as in other Laboratories and Directorates at Goddard. Our Laboratory also hosts groups for tours of our facilities and lectures to inspire interest in Earth sciences. GoHFAS collaboration with Howard University was mentioned in the previous section. The Summer Institute on Atmospheric and Hydrologic Sciences is the longest running program sponsored by the Earth Sciences Directorate. The Graduate Student Research Program in Earth Sciences, run by GEST, is a successful program that exposes students to the most current research topics in Earth science. Information on this program can be accessed at the Web site (http://www.umbc.edu/gest/) under Student Opportunities. Information on programs sponsored by the Goddard Office of University Programs can be accessed at http://education.gsfc.nasa.gov/. Information on Earth science-related programs may be obtained from http://earthsciences.gsfc.nasa.gov/edu/. These programs are designed to stimulate interest in interdisciplinary Earth science studies by enabling selected students to pursue specially tailored research projects with Goddard scientific mentors. Some examples of student mentoring are given below, followed by examples of summer visiting activities.

Summer Student Mentoring

Judd Welton mentored Torreon Creekmore, a senior from Elizabeth City State University in North Carolina. The student participated in the Goddard Space Flight Center Howard University Fellowship in Atmospheric Science (GoHFAS) program during summer 2002 and winter of 2003. He worked on the construction of the next generation micro-pulse lidar prototype. Mr. Creekmore is expected to return in summer 2003 to continue work on the next phase of the prototype, including data processing.

Kent McCullough mentored a rising junior from the University of Maryland in the area of instrument fabrication.

Richard Lawrence mentored a junior from UMBC in the Summer Institute program on the subject of temporal sampling error analysis of monthly radar rain rate maps.

Tom Bell mentored a UMBC senior on TRMM sampling error estimates.

William Lau mentored a beginning graduate student from SUNY Stony Brook on climate analysis. The student worked on identifying regional rainfall variability for model validation and carried out climate data analysis using Empirical Mode Decomposition. This modeling was applied to rainfall trends in northern and central China.

Kazem Omidvar mentored a junior from Skidmore College, Saratoga, on the subject of Symmetric Charge Transfer Cross Section Calculation for O+-O collisions, and Dr. Omidvar and the student submitted the research results to the Journal of Chemical Physics.

Lorraine Remer mentored a graduate student from CSU on atmospheric science.

Summer Visits

High School—SHARP: On April 16, Andrew Negri took part in a review of over 150 applications for the 2002 summer high school program known as SHARP, and 20 finalists and 15 alternates were selected. The request came from Dillard Menchan, Chief, Equal Opportunity Program Office.

GoHFAS summer students: Six students in the Howard University GoHFAS program visited our Laboratory for a tour of our experiment labs and the visualization lab. Dan Harpold gave a presentation on the activities of the Atmosphere Experiment Branch discussing the wide use of mass spectrometers in planetary exploration and everyday science. Matt McGill, Judd Welton, Tim Berkoff, and Stan Scott guided a tour through the Mesoscale Atmospheric Processes Branch lidar lab. Tom McGee discussed the AROTAL instrument that flew on the DC-8 during SOLVE. Marshall Shepherd gave a visual presentation in the Code 912 Visualization Lab, assisted by Mike Manyin. Finally, Si-Chee Tsay gave an inspiring talk on his SMART instrument in his new traveling lab (trailer). After the visit, two GoHFAS students held discussions with their new mentors. Annette Marerro from Universidad Metropolitana worked with Amita Mehta in Bldg 22, and Torreon Creekmore from ECSU worked with Judd Welton, Tim Berkoff, and Stan Scott in the Code 912 lidar lab.

AMS Student Fellowship Winners visit: On July 18, 10 AMS fellowship winners visited our Laboratory. The students were given a number of science presentations on long-term drought by S. Schubert, Amazonian deforestation by A. Negri, urban weather systems by M. Shepherd, the perfect dust storm by Si-Chee Tsay, all about Aura by A. Douglass, and carbon dioxide by A. Andrews. M. Shepherd and M. Manyin gave a GIS visual presentation. After lunch, the students toured Tom McGee's AROTAL Lidar lab.

Morgan State U., Polytechnic U. of Puerto Rico, and Howard U. student visit: On July 12, about 30 students visited Code 900. The visit was organized by Magui Cardona of the Goddard education office. Walter Hoegy welcomed the students and gave a brief outline of the activities of Code 900. Nancy Maynard gave a "Healthy Planet" presentation, followed by a GIS demo by Fritz Hasler. In the afternoon, Pat Coronado gave a presentation on "Unmanned Vehicles" and finally the students were given a lab tour by Dan Harpold and Tom McGee.

University Education

At the university level, Laboratory scientists have taught undergraduate and graduate courses, given seminars and lectures, and advised degree-seeking students.

Seminars/talks given at educational institutions:

Institution	Subject	Speaker
U. of Alabama, Huntsville	Use of Raman lidar in atmospheric studies	Dave Whiteman
George Mason University	Introduction to AIRS and Cr	Joel Susskind
U.S. Naval Academy	Remote Sensing Research at GSFC	Geary Schwemmer
U. of Nairobi, Kenya; Kenya Meteorological Dept.	Satellite observations for environmental assessment, disaster mitigation, resource surveys	Charles K. Gatebe
Howard University	GPS and Atmospheric Applications	Dev Roy
U. of Illinois, Urbana Champaign	Satellite remote sensing of clouds	Tamas Varnai
Penn State University	Ozone Observations from Space	Richard McPeters
National Central University, Taiwan	Earth Science Enterprise at NASA	William K.-M. Lau
Howard University	Aerosol Absorption measurements from TOMS	Omar Torres
UMCP, Meteorology Dept.	Use of ultraviolet observation to measure aerosol absorption from space	Omar Torres
UMCP, Meteorology Dept.	Progress in Global Rainfall Estimates	George Huffman
Texas A&M; UC-Irvine	Ozone	Anne Thompson
Maryland Space Grant Consortium, Johns Hopkins University	Remote Sensing Observations of the Atmosphere	Marshall Shepherd
University of Virginia	Overview of GPM mission	Marshall Shepherd
University of Virginia	Urban-induced Rainfall Anomalies in Houston	Marshall Shepherd

Other Education/Outreach Seminars:

Educational Group	Location	Subject	Speaker
Professors at small Colleges and Universities	GSFC	Stratospheric Ozone Change	Charles Jackman
Middle School & High School Teachers	GSFC	Stratospheric Ozone Change	Charles Jackman
Graduate Student Summer Program Seminar Series	GSFC	Ocean Surface Fluxes	Mark Helfand
Teachers in the Web Watchers Earth and Space Science program	Goddard Visitors Center	Aerosols and Global Cooling	Yoram Kaufman

Examples of Courses Taught

Chris Barnet taught a class of 5 students in computational physics (PHYS 640), spring 2002, at the University of Maryland Baltimore County (UMBC), where he is an Associate Research Professor. He also gave 3 guest lectures for PHYS 722 and PHYS 622 in spring of 2002.

Thomas Rickenbach taught Geography 311 on weather and climate to a class of 40 students at UMBC/JCET. He is a Research Assistant Professor in the Department of Geography and Environmental Systems.

William Lau taught a class of 10 students in climate modeling at the Hong Kong University of Science and Technology, where he is an Adjunct Professor of Mathematics.

Omar Torres taught a class of 4 students in atmospheric remote sensing in the Physics Department at UMBC where he is a Research Associate Professor.

Alexander Marshak taught a class of 4 students at UMBC in atmospheric radiation.

Dean Duffy taught physical meteorology to 2 students at Howard University. Dr. Duffy is an Adjunct Professor in the Physics Department at Howard.

Yoram Kaufman was a member of the organizing committee and a lecturer of a summer course on aerosols at NCAR, led by Bill Collins. About 30 graduate students (2 from GSFC) participated in the course.

Arthur Hou visited the Atmospheric Science Department of Colorado State University (CSU) where he gave four class lectures on data assimilation and use of satellite rainfall observations to improve climate modeling and analysis. The CSU invitation was accepted in the interest of Goddard outreach to attract able students from a leading atmospheric science department and to form research collaborations under an existing co-op agreement between the two institutions. CSU provided the DAO with the code for CSU's Cloud, Convection, & Radiation Physics model for implementation in the fvDAS, and is working on the adjoint model of the CSU cloud scheme for the DAO and ECMWF.

K-12 Education

Laboratory staff participated in K-12 education in a variety of ways. Laboratory scientists routinely present lectures and demonstrations to K-12 schools and youth groups to help develop an early interest in science. Many Laboratory scientists have also mentored students in grades K-12. Examples of these educational activities are given below.

Chris Barnet participated in the Career Day at Eleanor Roosevelt High School. George Huffman reviewed grade 5–6 Earth science curriculum modules for the Challenger Center for Space Science Education. Anne Douglass gave a talk at a high school in Grass Valley, California, on results from UARS, and the plans for Aura. John Haberman worked with teachers and staff at the Owens Road Elementary School, G. Gardner Shugart Middle School, and Gwynn Park Middle School, all in Prince Georges County, to make operational their classroom and resource computers and computer networks. Dr. Haberman visited individual classrooms and discussed science and space topics of interest to teachers and students.

Academic Year Student Advising

The table highlights some of the advising activities of Laboratory members. Our scientists are on the thesis committees of the Masters and Ph.D. candidates.

School	Student Level	Financial Support	Advisor	Subject
UMBC	Grad	18K	Dave Whiteman	Aerosol extinction
UMBC	Grad	35K	Dave Whiteman	Lidar cirrus cloud measurements
Eleanor Roosevelt HS	Senior	NA	Chris Barnet	CO_2 retrievals
Instituto Nacional de Pesquisas Espaciais (INPE), Brazil	PhD	NA	Chris Barnet	AIRS validation
UMBC	PhD	NA	Chris Barnet	Remote sounding of Ozone
UMBC	PhD	NA	Chris Barnet	Remote sounding of CO
UMCP	Junior	68K	Geary Schwemmer	Instrument control for HARLIE instrument in field experiments
Politecnico di Torino, Turin Italy	Master of Engine ering	NA	Richard Lawrence	Radar rainfall estimation
U. of Witwatersrand, Johannesburg South Africa	2 Master candid ates	3K as GEST short term visitors	Anne Thompson	Atmospheric Sciences
U. of Alaska	PhD	NA	David Starr	Atmospheric Science
Eleanor Roosevelt HS	Senior	NA	John Haberman	Galileo probe instrument performance

Other Educational Outreach Activities

New Techniques and Strategies in Geoscience Education

Shepherd, J.M., 2002. “Science Education Supporting Weather Broadcasters On-air and in the Classroom with NASA ‘Mini-Education Supplements,’” was submitted to the Journal of Geoscience Education, a refereed journal reporting on new techniques and strategies in geoscience education. The paper describes a project funded through GSFC DDF funds, which produced innovative “quick packages focusing on TRMM-related science topics” with standards-based education curricula for use by weathercasters and classrooms. The packages consist of “raw materials for TRMM-related science” in the form of science results, animations, interview footage, suggested narratives, and lessons. This approach was tested by 70–80 pilot weather broadcasters around the nation, including the Weather Channel. The education materials have also been employed in pilot programs by educators and are available at the TRMM and Earth Sciences Directorate Web sites.

Workshop Outreach

GPM Workshop on Applications and Outreach: The first GPM Applications Workshop was held on February 19–20 at the Greenbelt Marriott in Greenbelt, Md. The workshop convened several scientists, professionals, and educators from various fields to discuss the development of an applications strategy for GPM. The meeting was organized by Marshall Shepherd. For more information, see the GPM Monitor at http://gpm.gsfc.nasa.gov.

GLOBE Workshop: Lorraine Remer gave an overview of Earth system science at the GLOBE teacher's workshop on July 9. Using schematics, simple models, and physical demonstrations she explained the Earth's energy balance and the role of aerosols in the energy balance at a level these teachers could copy and bring into the classroom. Lorraine will continue to work with the GLOBE project, using student-measured aerosol optical thickness as validation for the MODIS aerosol products.

Workshop on Infectious Disease Outbreaks: Marshall Shepherd and George Huffman (along with several other code 900 scientists) attended a workshop at the USUMS campus in Bethesda along with ESSIC and U.S. Unified Military Services personnel to understand and forge potential partnerships on using remote sensing, modeling, and analysis to diagnose and predict infectious disease outbreaks. The goal of the workshop was to position the group to respond to an upcoming NIH NRA on bio-defense. Huffman and Shepherd represented NASA's interest from a precipitation, TRMM, and GPM perspective. Talk given at the workshop: Adler, R.F., G.J. Huffman, D.T. Bolvin, E.J. Nelkin, and J.M. Shepherd, 2002: Quasi-Global, Multi-Sensor Precipitation Estimates from GPCP, TRMM, GPM. Planning Retreat on Biosecurity Proposal to NIH, 1 August 2002, Bethesda, Maryland.

Science Organization Outreach

AMS: At the invitation of the District of Columbia chapter of the American Meteorological Society, Robert Atlas agreed to serve on a panel of experts to discuss Careers in Atmospheric Science at the D.C. chapter's follow-up meeting. The meeting, held March 20th, at Washington-Lee High School, Arlington, Virgina, was an opportunity for us in the atmospheric science community to enhance the awareness of parents and teenagers of the wide variety of potential jobs in atmospheric science and related areas.
Anne Thompson was a Career Speaker at the AMS Student Conference.

Project Outreach

Alma College and CPL: Under the direction of Matt McGill, the Cloud Physics Lidar (CPL) outreach activity continued in 2002. As in previous years, faculty and students from Alma College (a small 4-year college in Michigan) participated with the CPL personnel during the CRYSTAL-FACE field campaign. During CRYSTAL-FACE, one faculty member and one student from Alma College traveled to Key West and participated in data collection and analysis. During the school year, the student(s) and faculty work to infuse NASA remote-sensing data into the physics curriculum at Alma College, and the student(s) participates in directed study activities, using CPL data. This outreach activity is directly funded by CPL, under the direction of the P.I., Dr. Matthew McGill.

Charles Jackman: Training for Future Satellite Operators: The TOMS, UARS, and ERBS missions are currently being operated in conjunction with the Space Operations Institute of Capitol College. Besides providing useful atmospheric measurements, these three satellites are allowing undergraduate college students an incredible educational opportunity to receive training in satellite operations. Eight students are involved in this program with two students assigned to TOMS, three to UARS, and three to ERBS. The students work with professional engineers and are learning all aspects of satellite operations. This activity was started October 1, 2002, and it is hoped that it will continue through September 30, 2005.

Education and Outreach Colloquia

David Herring of the Climate and Radiation Branch hosts the monthly series of education and outreach colloquia, which has the goal of coordinating and improving the education and outreach activities of the Directorate.

Collaborations with University Faculty

David Starr helped Professor Sandra Cruz-Pol, University Puerto Rico–Mayaguez, develop a successful FAR proposal for a student project (provided feedback on proposal and additional NASA contacts).

Cooperative Agreements with Universities

Geary Schwemmer supports 3–4 undergraduate students at Utah State University on a cooperative agreement funded at $22K/year.

Public Outreach

Informing the public of how their tax dollar investments are working for them within the Laboratory is a critical subset of the Center and Agency public outreach mission. Laboratory scientists, working with other Laboratories at Goddard and outside institutions, continue to pass their knowledge and interest in Earth and space science to the general public via public information and education programs. Our scientists and engineers have been interviewed by the news media, have appeared in press conferences, have generated Web sites, CDs, and educational material oriented toward the general public, and have participated in public forums.

FTP Sites

Warren Wiscombe maintains an anonymous ftp site that is widely used for software by graduate students and colleagues.

Web-Based Outreach

Richard McPeters works on maintaining the TOMS Web site, which offers ozone data from TOMS on a near real-time basis-12 hour refresh. This site is heavily used by both external researchers and students, especially during ozone hole season.

Radio & TV Outreach

On March 26, 2002, “Earth and Sky” broadcast an interview with Yoram Kaufman on measurements of aerosol absorption of sunlight using AERONET and Landsat based on a paper with Tanre, Karnieli, Remer and Dubovik.

On May 1, Marshall Shepherd, David Adamac, and Claire Parkinson participated in a live morning TV press campaign in support of the upcoming Aqua launch. The scientists conducted live interviews via satellite with various TV stations around the country and fielded questions on the water cycle, weather, and climate and how new systems like Aqua will advance science understanding.

Laboratory for Atmospheres Support of NASA HQ Outreach

On April 23, at the request of NASA HQ, Marshall Shepherd spoke to a group of students in Annapolis to support NASA’s involvement with the Volvo Ocean Race. Several Code 900 speakers have spoken on Earth science, atmospheric science, and ocean science in support of this effort.

The Smithsonian's National Museum of Natural History opened its exhibit on Global Links. This exhibit features El Niño and its impact on the environment and mankind. The exhibit was largely supported by NASA and is the first in a series. The next exhibit, opening in 2004, will feature atmospheric chemistry and the Aura mission.

Marshall Shepherd served on a career panel on August 12 that addressed the 2002 GSFC Cooperative Students on future career opportunities at NASA and GSFC.

GPM Project Office has commissioned a group consisting of Marit Jentoff-Nilsen, Mike Manyin, and Fritz Hasler to develop an animation for the GPM constellation. This animation will be used by Dr. Asrar as well as the GPM Project office.

Walter Hoegy on October 24 presented a talk outlining the science activities to the Goddard Principal Investigator Conference. This was an all-day conference for about 20 investigators from minority universities who have received NASA grants.

Marshall Shepherd and Horace Mitchell on December 10 gave an overview of Earth science results and visualizations to Dr. Adena Loston, the new NASA Associate Administrator for Education. The overview and demonstration were presented at the Scientific Visualization Studio in bldg. 28. Along with Dr. Loston, the delegation included members of her HQ staff, Director Al Diaz, Janet Ruff, and PAO staff.

Popular Press

Marshall Shepherd has been asked to contribute an article to the popular magazine, Weatherwise, highlighting the use of NASA satellites for weather monitoring and prediction. The article will appear in an issue in 2003.

Outreach Effect from Refereed Publications

Media Attention to TRMM Paper on Urban Heat Island Rainfall by Shepherd et al., 2002, paper in the Journal of Applied Meteorology received high-level media attention. There were about 40 total stories airing in 29 U.S. markets from the TRMM Urban Heat Island Rainfall story.

Judging and participation at science fairs, etc.

Ryan Caveney judged Senior Division Physics at the 46th Annual Montgomery Area Science Fair, Montgomery County Community College, Rockville, Maryland, March 17, 2002.

Warren Wiscombe judged Blake High School Science Fair, spring 2002.

Richard Lawrence served as a judge for the outstanding student paper award, AGU.

Lena Iredell judged the Elementary School Science Fair, Annapolis, Maryland, and the Middle School Science Fair, Upper Marlboro, Maryland.

John Haberman judged a number of elementary and middle school science fairs in Prince Georges County; he also judged at the countywide "Kids for Science" Science Fair where only the "top 1%" of the projects from the schools are eligible.

TRMM Outreach/Education

TRMM continues its comprehensive Education/Outreach program, in which Laboratory personnel promote TRMM science and technology to the public under the leadership of the TRMM Project Scientist Robert Adler (910) and TRMM Education and Outreach Scientist Jeffrey Halverson (912/JCET). TRMM has included the development of broadcast visuals and educational curricula focusing on the Tropical Rainfall Measuring Mission. These packages are available on the TRMM Web site (http://trmm.gsfc.nasa.gov/) and have been reviewed as a part of the ESE Education product review. They are currently under revision. TRMM scientists regularly appear on major media outlets (Earth and Sky Radio, CBS, NBC, ABC, and CNN) in support of the mission. In addition, Laboratory personnel have spoken at and conducted several outreach workshops in support of TRMM. Marshall Shepherd released a new Web site highlighting current mesoscale and TRMM-related research on rainfall modification by urban areas. The Web site address is http://rsd.gsfc.nasa.gov/912/urban. This Web site was completely designed and implemented by one of the Mesoscale Atmospheric Processes Branch's summer high school interns as a part of the Branch and Laboratory's outreach initiatives. Articles authored by Jeff Halverson and Marshall Shepherd, featuring the TRMM satellite and other NASA remote sensors, recently appeared in the national publication, Weatherwise. Images of hurricanes and floods as imaged by TRMM occasionally have appeared as Image of the Day on NASA's Earth Observatory.

GOES Web Server

This Web server continues to provide GOES images online, including full-resolution images of all sectors of the United States for the most recent two days. There are extensive scrapbooks of digital movies and pictures of important weather events observed by the GOES-8 through GOES-12 satellites since the first launch in 1994. The Remote Sensed Data (RSD) server (http:rsd.gsfc.nasa.gov) has been judged by NASA HQ to be one of the 20 most popular NASA Web sites during the year 2000. The science administrator of RSD supplies GOES-derived high-quality graphics and severe storm animations to the Visualization Analysis Laboratory (VAL), to GSFC Public Affairs Office (PAO), and directly to the public via the Internet. During active hurricanes, the GOES section of the RSD Web server is accessible to the general public.

EOS Terra Outreach Synopsis

The EOS Terra outreach effort under the direction of Yoram Kaufman (Code 913), Jon Ranson (Code 920), and David Herring (Code 913) is a coordinated effort to foster greater cooperation and synergy among the various outreach groups within the EOS community. This effort is intimately integrated with the larger, ongoing Earth Observatory (http://earthobservatory.nasa.gov/) and Visible Earth (http://visibleearth.nasa.gov/) projects. A sampling of these activities, described below, represents contributions from the diverse EOS community.

The Terra Project Science Office (Code 900) produced a Terra mission overview brochure as well as a general public brochure and poster. The brochures, poster, and many more images, animations, and information about Terra are available on the Terra Web site (http://terra.nasa.gov), which is also maintained by the Terra Project. Beginning in the spring of 2003, under the direction of the Terra Project Scientist (Ranson), a new video will be produced demonstrating Terra's new measurement capabilities and its ongoing contributions to Earth system science.

David Herring leads a core group of content developers for the Earth Observatory. This Web environment provides a NASA Web-based interactive magazine written in a popularized style where the general public can access timely satellite imagery and information about the Earth. It showcases new data visualizations and new science results from EOS and ESE missions. All resources produced for the Earth Observatory are freely available for use by the EOS community, the general public, museums, educators, students, public media, regional stakeholders, environmental awareness groups, etc. While leadership for this site resides in Code 913, significant contributions to its development come from Codes 900, 902, 912, 921, 922, 923, 935, 971, as well as the Jet Propulsion Laboratory, Johnson Space Center, Langley Research Center, the DAAC Alliance, and other organizations outside of NASA.

Folded into the Earth Observatory operation is maintenance and development of NASA's Visible Earth (http://visibleearth.nasa.gov/)—a digital repository of Earth images, animations, and data visualizations stored at a range of resolutions. This site is design to scale up so as to provide the public with a one-stop portal for access to the superset of all publicly available NASA Earth imagery. The responsible civil servant for Visible Earth is Michael King, Code 900. Dr. King is the primary sponsor for this entire suite of activities.

As a new part of this task, David Herring was asked to advise the Earth Sciences Director, Dr. Franco Einaudi, on how to form a new strategic plan for education and outreach for all of Code 900. Herring has formed an Education and Outreach Committee as well as working subcommittees to begin developing the recommendations for this plan. This activity has been underway for roughly 1 year.

EOS Aura Education and Public Outreach Synopsis

The Laboratory for Atmospheres has responsibility for conducting the Education and Public Outreach program for the EOS Aura mission. Aura's Education and Public Outreach program has four objectives. The first objective is to educate students about the role of atmospheric chemistry in geophysics and the biosphere. The second objective is to enlighten the public about atmospheric chemistry and its relevance to the environment and their lives. The third objective is to inform geophysics investigators of Aura science, and thus enable interdisciplinary research. The final objective is to inform industry and environmental agencies of the ways Aura data will benefit the economy and contribute to answering critical policy questions regarding ozone depletion, climate change, and air quality.

To accomplish these objectives, the Laboratory has partnered with several institutions, which have established infrastructures that reach large audiences through formal and informal education. The GLOBE program and the American Chemical Society (ACS) will carry out formal EOS Aura education outreach effort. Grants are now in place with the American Chemical Society (ACS), the Smithsonian's National Museum of Natural History (NMNH), and the GLOBE Program, via Drexel University for the various educational and public outreach activities relating to atmospheric chemistry and the Aura mission. The grants have resulted in educational material that will reach tens of thousands of teachers and their students and millions of members of the general public. Creation and dissemination of additional education products will continue through launch.

GLOBE is a worldwide network of students, teachers, and scientists working together to study and understand the global environment. Students and teachers from over 10,000 schools in 100 countries are working with the science community to learn more about the environment by making observations at or near their schools and reporting their data through the Internet. The Aura/GLOBE connection includes partnering with the P.I.s of the GLOBE Aerosol and GLOBE Surface Ozone investigations. Through Aura, the Laboratory has funded the development of a GLOBE Special Measurement using a handheld UVA meter that is similar in design to the GLOBE Sun photometer. During the summer of 2002, Aura hosted a teacher workshop for middle- and high school educators on the GLOBE/Aura Atmosphere Monitoring project. The workshop featured presentations from Lab scientists including P.K. Bhartia, Nickolay Krotkov, Lorraine Remer, and Charles Ichoku. Since the Aura mission involves partners from Europe, their education and public outreach programs will also support the GLOBE international components. KNMI (OMI PI institution) has entered into an agreement with GLOBE Netherlands and Drexel University to support GLOBE aerosol and UVA measurements.

The American Chemical Society (ACS) publishes ChemMatters, a magazine for high school students, that is distributed to over 30,000 high school teachers in classrooms throughout the country. During the past two years, ACS, in partnership with the Laboratory, has published two special issues of ChemMatters that focused on EOS Aura. These magazines were not only distributed to regular subscribers; they were also mailed to every high school chemistry teacher in the country. The September 2002 issue highlighted the “People of Aura” with articles profiling the scientists and engineers who are part of the Aura project. Anne Douglass (Aura Deputy Project Scientist) was the subject of one of the articles. Both the September 2001 and the 2002 issues were designated “Outstanding Products” in the semi-annual Earth Science Enterprise Education Products Review (http://www.strategies.org/2002ESEReview/Rec1997_2002.html). In an effort to promote the mission and the ChemMatters special issues, Aura EPO with ACS staff gave presentations at three regional NSTA (National Science Teachers Association) meetings in the fall.

Our outreach to the general public includes an exhibit at the Smithsonian Institution National Museum of Natural History (NMNH) and contributing feature and reference stories to the NASA Earth Observatory Web site. NMNH has millions of visitors per year. We are supporting an exhibit that is part of the “Forces of Change” Global Links Gallery. The exhibit is built around an Earth system science theme and tells ‘stories’ around components of the Earth’ system. Work on the Aura-related “More than Meets the Eye” story of the chemistry of the atmosphere is in development and will open in June 2004. It will include modules on the Aura science questions and will also link to Aura data and GLOBE surface ozone, aerosol and UVA data. The museum will also develop a tool kit that will allow components of the exhibit to be portable and, thereby, available to other museums in the United States and abroad.

The Earth Observatory is one of NASA’s premiere outreach Web sites. To date, Aura EPO staff have contributed six articles for the site that focus on atmospheric chemistry and Aura science. Four of the articles are on the site (published), one is submitted, and one is being revised.

- Ultraviolet Radiation: How It Affects Life on Earth, published
- Highways of a Global Traveler, published
- The Ozone We Breathe, published
- Chemistry in the Sunlight, published
- Watching Ozone Weather, submitted to editor
- Tango in the Atmosphere: Ozone and Climate Change, in revision

For further information, see the Aura Web site at http://eos-aura.gsfc.nasa.gov/outreach.

NASA/NOAA: Earth Science Electronic Theater 2002

The NASA/NOAA Earth Science Electronic Theater (E-Theater) uses HDTV display at up to IMAX size to deliver powerful visualizations promoting Earth science. Scientists from the various Earth science disciplines work directly with the Visualization Analysis Laboratory (VAL) team to develop scientifically accurate visualizations. E-Theater visualizations are rendered at High Definition TV (HDTV) quality, the highest resolution that can be easily distributed. The visualizations are also available in lower resolutions such as standard definition TV and as QuickTime movies. Multiple resolution versions of each E-Theater visualization are being added to the E-Theater Web page (http://Etheater.gsfc.nasa.gov/index.html/) and the Visible Earth Web page (http://visibleearth.gsfc.nasa.gov) along with an explanation of the scientific significance and the origin of the data. The Electronic Theater has been presented at universities, high schools, grade schools, museums, and Government laboratories as well as to scientists and the general public. E-theater presentations were made on a daily basis at the Children’s Museum of Utah during the 2002 Winter Olympics in Salt Lake City. NASA visualizations also appeared during the Olympic Ceremonies and on Network and international television during the Games. The E-theater has recently been on a one-month tour of South Africa and has visited Montreal and Harvard University.

Visualization Technology & Display Development

The VAL, as well as other Goddard and NASA visualization groups, continues to produce visualizations using Earth science data from NASA, NOAA, and our international partners. These visualizations continue to be shown around the world using new display technologies. The VAL is a leader in the production of HDTV movies using low-cost editing systems. The VAL has pioneered and continues to develop low-cost systems to display HDTV movies using MPEG2 servers and the latest video projector and plasma screen display technology.

The VAL has developed methods for visualizing and interpreting immense remote-sensing data sets and 3-dimensional numerical models. We call the data from many new Earth-sensing satellites HyperImage data sets, because they have such high resolution in the spectral, temporal, and spatial domains. The traditional numerical spreadsheet paradigm has been extended to develop a scientific visualization approach for interactively processing HyperImage data sets and 3-D models. The advantages of extending the powerful spreadsheet style of computation to multiple sets of images and organizing image processing were demonstrated using the Distributed Image SpreadSheet (DISS). The DISS has been used as a high performance testbed application for the Next Generation Internet (NGI).

Museum Support

The Visualization Analysis Laboratory, VAL, actively works with large and small museums in creating new, innovative Earth science displays. Some of these museums include the National Museum of Natural History, the National Air and Space Museum, the American Museum of Natural History in New York City, the Virginia Science Center, The Children's Museum of Utah, and the Houston Museum of Natural History.

One successful museum activity is the permanent "Earth Today" exhibit of near real-time Earth science data displays at the Smithsonian National Air and Space Museum—the most visited museum in the world. These near real-time data presently include global cloud cover, global water vapor, sea surface temperature, sea surface temperature anomalies, biosphere, and earthquakes. VAL personnel are developing an upgraded extensible version of this exhibit that will allow its adoption by other museums.

7. ACKNOWLEDGMENTS

We thank all the Laboratory members whose work motivates this report and generates its substance. We especially thank the Branch Heads and Branch Secretaries for helping to gather and write some of the text.

We thank David Starr for the cover material from the CRYSTAL-FACE campaign, and Winnie Humberson who designed and produced the layout.

Laura Rumburg turned her keen proofreader's eyes on our copy. In addition to the normal proofreading function, Laura diligently researched, edited, and checked factual items, figures, and tables, and spent a considerable effort in collecting input.

We also thank Lynne Keffer for her contribution to this publication. Lynne accomplished the report's final formatting and editing.

Charles Cote chose the cover design, helped to gather material, insured the accuracy of our instrument and project descriptions, and edited much of the material. Walter Hoegy was responsible for the overall production of the report, designed the scheme for collecting input, set deadlines, and collected and edited the material.

APPENDIX 1. 2002 SHORT-TERM VISITORS

DATA ASSIMILATION OFFICE

Konstantinos Vogiatzis
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Baton Rouge, Louisiana
January 3

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Asheville, North Carolina
January 8

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National Climate Data Center
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January 8

Mozheng Wei
UCAR/NCEP
Boulder, Colorado
January 9

Anthony Hollingsworth
ECMWF
Reading, United Kingdom
January 10

Alan K. Powers
Computer Sciences Corp.
NASA Ames Research Center
Moffett Field, California
January 23

George Stenchikov
Rutgers University of New Jersey
Newark, New Jersey
January 30

Mitch Goldberg
NOAA, NESDIS
Camp Springs, Maryland
January 31

Byron Boville
National Center for Atmospheric Research
Boulder, Colorado
February 4

Nilton O. Reno
Lunar & Planetary Laboratory
University of Arizona
Tucson, Arizona
February 12

Peter H. Smith
Lunar & Planetary Laboratory
University of Arizona
Tucson, Arizona
February 12

Myong-In Lee
Seoul National University
Seoul, Korea
February 14

Simon Chang
Office of Naval Research NRL
Washington, D. C.
February 20

Matthew McNamara
Halcyon System, Inc.
San Francisco, California
February 22

A. Khokhlov
Naval Research Laboratory
Washington, D. C.
February 27

G. Patnaik
Naval Research Laboratory
Washington, D. C.
February 27

Alan Betts
Atmospheric Research
Pittsford, Vermont
March 11

Paul Francis van Delst
NOAA/NCWEP/EMC
Camp Springs, Maryland
March 19

Milija Zupanski
Colorado State University
Fort Collins, Colorado
March 19

Tomi Vukicevic
Colorado State University
Fort Collins, Colorado
March 20

Oliver Hans-Jurgen Reitebuch
German Aerospace Center DLR
Wessling, Bavaria, Germany
March 21

Henry Jin
NASA Ames Research Center
Moffett Field, California
April 3

Christiane Jablonowski
University of Michigan
Ann Arbor, Michigan
April 5

Joyce Penner
University of Michigan
Ann Arbor, Michigan
April 5

Jeffery R. Key
NOAA/NESDIS
Camp Springs, Maryland
April 12

David A. Santek
University of Wisconsin
Madison, Wisconsin
April 12

Christopher S. Velden
University of Wisconsin
Madison, Wisconsin
April 12

Ralf Giering
Fastopt
Hamburg, Germany
April 17

Thomas Kaminski
Fastopt
Hamburg, Germany
April 17

Dave Broutman
Naval Research Laboratory
Washington, D. C.
April 19

Tijana Janjic
Institut fuer Physik
Universitaet Hohenheim
Bremen, Germany
May 13

Manuel de la Torre Jurez
NRC/RRA (JPL)
Pasadena, California
May 30–31

Richard Swinbank
The MET office, Middle Atmosphere group,
Bracknell, United Kingdom
June 12–14

Dave Emmitt
Simpson Weather Associates, Inc.
Charlottesville, Virginia
June 26

Tijana Janjic
Institut fuer Physik
Universitaet Hohenheim
Bremen, Germany
August 19–20

Joel Tenenbaum
State University of New York
Purchase, New York
September 20

Dirceu Herdies
National Institute for Space Research
Sao Paulo, Brazil
October 23

Robert Miller
Oregon State University
Corvallis, Oregon
October 24

Weiyu Yang
SAIC NCEP
Beltsville, Maryland
October 30–31

Mike Fiorino
PCMDI
Livermore, California
October 31

Joel Norris
Assistant Prof. of Climate and Atmospheric Sciences
University of California
San Diego, California
November 5

Samson Cheung
Halcyon Systems
San Francisco, California
November 15–20

Ralf Giering and Thomas Kaminski
Co owners of Fastopt
Hamburg, Germany
November 18–21

Hui Liu
Florida State University
Tallahassee, Florida
December 2

Lidia Cucurull
University Corporation for Atmospheric Research
Boulder, Colorado
December 3

William Kuo
NCAR/UCAR
Boulder, Colorado
December 3–4

Stephen J. Lord
NOAA/NCEP
Camp Springs, Maryland
December 3–4

John C. Derber
NOAA/NCEP
Camp Springs, Maryland
December 3–4

Fuzhong, Weng
NOAA/NESDIS
Camp Springs, Maryland
December 3–4

James G. Yoe
NOAA/NESDIS
Camp Springs, Maryland
December 3–4

Gyorgi Gyarmati
University of Maryland
College Park, Maryland
December 16

Aleksey Zimin
University of Maryland
College Park, Maryland
December 16

Istvan Szunyogh
University of Maryland
College Park, Maryland
December 16–18

MESOSCALE ATMOSPHERIC PROCESSES BRANCH

Christopher Perez
Austin College
Sherman, Texas
January 7–26

Jeremy Dobler
University of Arizona
Tucson, Arizona
March 13–15

Oliver Reitebuch
Deutsches zentrum für Luft-und Raumfaurt
March 20–21

Paolo Di Girolamo
University of Basilicata
Potenza, Italy
April–June

Dr. Arnoud Apituley
National Institute of Public Health and the Environment
The Netherlands
April 17

Dr. Sonia Garcia
United States Naval Academy,
Annapolis, Maryland
May 14–August 15

Victor Marrero
University of Puerto Rico
San Juan, Puerto Rico
May 28–August 16

Dr. Emmanouil Anagnostou
University of Connecticut
Storrs, Connecticut
May 29

Torreon Creekmore
Elizabeth City State University
Elizabeth City, North Carolina
June 1–August 15

Manuel Lonfat
University of Miami
Coral Gables, Florida
June 10–August 16

Paula Hennon
Ohio State University
Columbus, Ohio
June 10-August 16

Rebecca Eager
Valparaiso University
Valparaiso, Indiana
June 17–August 9

Bradley Hammerschmidt
Kansas State University
Manhattan, Kansas
June 17–August 9

Joseph Hoch
Pennsylvania State University
University Park, Pennsylvania
June 17–August 9

Amy Maddox
University of Missouri
Columbia, Missouri
June 17–August 9

Dave Robbins
UMBC
Baltimore, Maryland
June 17–August 9

Dr. David Baker
Austin College
Sherman, Texas
June 24–July 31

Professor Steve Burian
University of Arkansas, Civil Engineering Department
Fayetteville, Arkansas
July–August

Dr. Igor Veselovskii
Physics Instrumentation Center, Triotsk Russia
July–November

Prof. Marie Christine Quesuel de Flainville
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July 12

Jen-Ping Chen
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July 29–August 9

Dr. Randall Updike
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August 14–15

Dr. James Lesh
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August 29

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September 13–15

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United Kingdom
September 17

Jen-Ping Chen
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September 23–24

Osman K. Dursun
Istanbul Technical University
Istanbul, Turkey
October 7–December 20

Regina Ryan
University of Delaware
Newark, Delaware
November 21

Michelle Stevenson
University of Delaware
Newark, Delaware
November 21

CLIMATE AND RADIATION BRANCH

Jung Moon Yoo
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January 1–June 29

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January 7

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January 9

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January 9

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January 9

June-Yi Lee
Seoul National University
Seoul, South Korea
January 17

Pinhas Alpert
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January 28–July 29

Hafuidi Johnson
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January 31

Arnon Karnieli
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Jacob Blaustein Institute for Desert Research
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February 1

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Sao Paulo, Brazil
February 15

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February 20

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February 28

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March 19

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April 3

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April 18

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Wenying Su
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Mark Janoff
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Swarthmore, Pennsylvania
June 3

Donald Sam
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June 3

Segayle Walford
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June 5

Kate Jr-Shiuan Yang
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June 10

Lou-Chuang Lee
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Taiwan
June 12

Yaw-Nan Chen
Taipei Cultural Representative Office
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June 12

Shao Jih
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Kieran Boyle
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June 20

Kyu-Tae Lee
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June 20–December 20

Wenying Su
NASA/Langley Research Center
Hampton, Virginia
July 8

Stefan Kinne
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July 19

Martin Wooster
King's College of London
London, England
July 19

Yuri Knyazikhin
Boston University
Boston, Massachusetts
July 22

Karla Longo de Freitas
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Sao Paulo, Brazil
July 29

Wen-Yih Sun
Purdue University
W. Lafayette, Indiana
August 3

Professor Harshvardhan
Purdue University
W. Lafayette, Indiana
August 5

Neng-Huei Lin
National Central University
Chung-li, Taiwan
August 26

Richard Hansell
University of California, Los Angeles
Los Angeles, California
August 26

Qingxian Gao
Chinese Research Academy
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September 1

Edmilson Dias de Freitas
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Sao Paulo, Brazil
September 3

Surabi Menon
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September 18

Graham Feingold
NOAA/ETL
Boulder, Colorado
September 30

James A. Coakley, Jr
College of Oceanic & Atmospheric Sciences
Oregon State University
Corvallis, Oregon
October 1

Reto Stockli
ETH Zurich
Zurich, Switzerland
October 4

Antonio Queface
Eduardo Mondlane University
Maputo, Mozambique
October 11

Kuo-Nan Liou
University of California, Los Angeles
Los Angeles, California
October 15

In-Sik Kang
Seoul National University
Seoul, South Korea
October 24

Hongbin Yu
Georgia Institute of Technology
Atlanta, Georgia
November 17

Dorothy Koch
Yale University/NASA-GISS
New Haven, Connecticut
November 21

Ken Knapp
NOAA/NESDIS/ORA
Camp Springs, Maryland
November 21

Michael Box
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December 5

Bernard Pinty
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EC Joint Research Centre (JRC)
Ispra, Italy
December 5

Michele Verstraete
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EC Joint Research Centre (JRC)
Ispra, Italy
December 5

ATMOSPHERIC EXPERIMENT BRANCH

John Guzowski
Bristol-Meyers Squibb
New Brunswick, New Jersey
April 5–6

Daniel Austin
California Institute of Technology
Pasadena, California
May 28–30

Laura Buchner
Concordia College
Moorhead, Minnesota
June–August

Kathryn O’Connor
Miami University
Oxford, Ohio
June–August

ATMOSPHERIC CHEMISTRY AND DYNAMICS BRANCH

Wouter Peters
University of Utrecht
Utrecht, The Netherlands
January 17

Ellen Brinksma
KNMI, Royal Netherlands Meteorological Institute
DeBilt, The Netherlands
January 28–31

Irene Xueref
Harvard University
Cambridge, Massachusetts
February 4–6

Folkert Boersma
KNMI
Delft, The Netherlands
February 4–8

Pierternel Levelt
KNMI
DeBilt, The Netherlands
February 4-8

Bert Oord
KNMI
Delft, The Netherlands
February 4–8

Pieter Stammes
KNMI
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February 4–8

Kelly Chance
Smithsonian Astrophysical Observatory
Cambridge, Massachusetts
Various times

Olga Munoz
Institute de Astrofisica de Andalucia
Granada, Spain
March 14–15

Hester Volten
FOM Institute AMOFL
The Netherlands
March 14–15

Hongbin Yu
Georgia Institute of Technology
Atlanta, Georgia
March 20–21

Neil Bradshaw
University of Wales
Aberystwyth, United Kingdom
April 2–4

Robert Spurr
Smithsonian Astrophysical Observatory
Cambridge, Massachusetts
Various times

Rosanne Diab
University of Natal
Durban, South Africa
May 6

Bill Barnard
EPA (retired)
Washington, D. C.
June 14

Ira Sundram
NASA Goddard Institute for Space Studies (GISS)
New York, New York
July 11–12

Mike Newchurch
University of Alabama
Huntsville, Alabama
August 5–8

Robert Evans
NOAA
Boulder, Colorado
August 26–30

Eladio Knipping
University of California at Irvine
Irvine, California
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M. Tali Freiman
University of Witwatersrand
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October 2

Pepijn Veefkind
KNMI
Delft, the Netherlands
October 11

John P. Burrows
University of Bremen
Bremen, Germany
Various times

Peter Bundi
University of Witwatersrand
Johannesburg, South Africa
October 24

Fok-Yan Thomas Leung
California Institute of Technology
Pasadena, California
November 8

David Noone
California Institute of Technology
Pasadena, California
November 21

David Baker
National Center for Atmospheric Research (NCAR)
Boulder, Colorado
November 26

APPENDIX 2. 2002 COMPOSITION OF THE VISITING COMMITTEES FOR THE LABORATORY

LABORATORY VISITING COMMITTEE (OCTOBER 1993)

Alan K. Betts, Chairperson
Atmospheric Research Corporation, Pittsford, Vermont

Michael Ghil
Department of Atmospheric Science
University of California at Los Angeles, California

Donald R. Johnson
Space Science and Engineering Center
University of Wisconsin, Madison, Wisconsin

Timothy L. Killeen
Space Physics Research Laboratory
University of Michigan, Ann Arbor, Michigan

Jose M. Rodriguez
AER, Inc., Cambridge, Massachusetts

Edward Westwater
CIRES, Boulder, Colorado

DATA ASSIMILATION OFFICE ADVISORY PANEL (OCTOBER 1992, OCTOBER 1993, JANUARY 1995, JUNE 1996, MAY 1998)

Roger Daley, Chairperson
Naval Research Laboratory, Monterey, California
(served Advisory Panel 1992, 1993, 1995, 1996, 1998)

Jeffrey Anderson
GFDL/NOAA
Princeton University, Princeton, New Jersey
(served Advisory Panel 1995, 1996, 1998)

Andrew F. Bennett
College of Oceanography
Oregon State University, Corvallis, Oregon
(served Advisory Panel 1995, 1996, 1998)

Guy Brasseur*
National Center for Atmospheric Research, Boulder, Colorado (served Advisory Panel 1992, 1993, 1995)

Phillippe Courtier
Laboratoire d'Ocêanographie Dynamique et de Climatologie (LODYC), Paris, France
(served Advisory Panel 1995, 1996, 1998)

Robert E. Dickinson
Department of Atmospheric Science
University of Arizona, Tucson, Arizona
(served Advisory Panel 1995, 1996, 1998)

Anthony Hollingsworth*
European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, England
(served Advisory Panel 1992, 1993)

Daniel J. Jacob
Division of Engineering and Applied Science
Harvard University, Cambridge, Massachusetts
(served Advisory Panel 1995, 1996, 1998)

Donald R. Johnson
Space Science and Engineering Center
University of Wisconsin, Madison, Wisconsin
(served Advisory Panel 1992, 1993, 1995, 1996, 1998)

Kikuro Miyakoda*
GFDL/NOAA
Department of Commerce
Princeton University, Princeton, New Jersey
(served Advisory Panel 1992, 1993, 1995)

James J. O'Brien
Professor of Meteorology and Oceanography
Florida State University, Tallahassee, Florida
(served Advisory Panel 1992, 1993, 1995, 1996, 1998)

Alan O'Neill
The Center for Global Atmospheric Modelling
Department of Meteorology
University of Reading, Reading, England
(served Advisory Panel 1992, 1993, 1995, 1996, 1998)

DATA ASSIMILATION OFFICE COMPUTER ADVISORY PANEL (MARCH 1996, AUGUST 1997)

William E. Farrell, Chairperson
SAIC, San Diego, California

Tony Busalacchi
Laboratory for Hydrospheric Processes, Code 970
NASA Goddard Space Flight Center, Greenbelt, Md.

Bill Dannevik
L262, Environmental Programs
Lawrence Livermore National Laboratory,
Livermore, California

Alan Davis
Center for Ocean-Atmosphere Prediction Studies
Florida State University, Tallahassee, Florida

Geerd-R. Hoffmann, Head
Computer Division
European Centre for Medium-Range Weather
Forecasts (ECMWF), Reading, England

Menas Kafatos
University Professor of Interdisciplinary Science
Director, Institute for Computational
Sciences and Informatics
George Mason University, Fairfax, Virginia

Reagan W. Moore
Enabling Technologies Group
San Diego Supercomputer Center, San Diego, Calif.

John Sloan*
NCAR/SCD, Boulder, Colorado

Thomas Sterling*
Lawrence Livermore National Laboratory,
Livermore, California

MESOSCALE ATMOSPHERIC PROCESSES BRANCH, EXTERNAL REVIEW COMMITTEE REPORT, NASA GSFC, NOVEMBER 9, 1999

Dr. Robert Gall, Chair
Mesoscale Microscale Meteorology Division
National Center for Atmospheric Research
Boulder, Colorado

Dr. Michael Hardesty
Environmental Technology Laboratory
National Oceanic and Atmospheric Administration
Boulder, Colorado

Dr. Frank Marks
Hurricane Research Division
National Oceanic and Atmospheric Administration
Miami, Florida

Dr. Eric Smith
Department of Meteorology
Florida State University
Tallahassee, Florida

EDGE TECHNIQUE REVIEW COMMITTEE, NASA GSFC AUGUST 6-7, 1997

R. Michael Hardesty (Chair)
NOAA ERL, Boulder, Colorado

Edwin Eloranta
University of Wisconsin, Madison, Wisconsin

Chester Gardner
University of Illinois, Urbana, Illinois

Robert Menzies
NASA Jet Propulsion Laboratory, Pasadena, Calif.

* No longer on the committee

ATMOSPHERIC CHEMISTRY AND DYNAMICS BRANCH REVIEW, NASA GSFC, APRIL 16-18, 1997

Dr. William L. Chameides
School of Earth and Atmospheric Sciences
Georgia Institute of Technology, Atlanta, Georgia

Douglas D. Davis
School of Geophysical Science
Georgia Institute of Technology, Atlanta, Georgia

Matthew H. Hitchman
Dept. of Atmospheric and Oceanic Sciences
University of Wisconsin, Madison, Wisconsin

David J. Hoffman
Climate Monitoring and Diagnostics Laboratory
NOAA, Boulder, Colorado

Susan Solomon
Environmental Research Laboratory
National Oceanic and Atmospheric Administration,
Boulder, Colorado

Joe W. Waters
Microwave Atmospheric Science Group
NASA Jet Propulsion Laboratory, Pasadena, Calif.

APPENDIX 3. 2002 VISITING SCIENTISTS AND ASSOCIATES OF JOINT CENTERS

DISTINGUISHED VISITING SCIENTIST
David Atlas

ESSIC
Christian Alcala
David Considine
Andrew E. Dessler
Michael Fox-Rabinovitz
Vikram Mehta
Kenneth Pickering
Maria Tzortziou

GEORGE MASON UNIVERSITY
Dave Augustine
Bart Kelley
David Marks
Jason Pippitt
David Silberstein

GEORGIA TECH.
Mian Chin
Paul Ginoux

GEST CENTER
Julio Bacmeister
Tim Berkoff
Eric Bucsela
Yehui Chang
Baode Chen
Jiun-Dar Chern
Wookap Choi
James Coakley
Peter Colarco
Ron Errico
Rosana Nieto Ferreira
Santiago Gasso
Charles Gatebe
Paul Ginoux
Mircea Grecu
Guojun Gu
Mohan Gupta
Harshvardhan
Hiroo Hayashi
Dirceu Luis Herdies
Christina Hsu
Dan Johnson
Nickolay Krotkov
Prasun Kundu
Kwo-Sen Kuo
Redgie Lancaster
David Lary
Lihua Li
Shuhua Li
Xiaowen Li
Ruei-Fong Lin
Xin Lin
Dan Lubin
Ashwin Mahesh
Kenneth Minschwaner
Peter Norris
Steven Pawson
Zhaoxia Pu
Oreste Reale
Jerome Riedi
Lars Peter Riishojgaard
Joan Rosenfield
Chung-Lin Shie
Dan Stillman
Susan Strahan
Lin Tian
Igor Veselovskii
Guiling Wang
Hailan Wang
J.J. Wang
Zhien Wang
Clark J. Weaver
Judd Welton
Liguang Wu
Fanglin Yang
Song Yang
Kevin Yeh
Xiping Zeng
Jiayu Zhou
Jerald Ziemke

JCET

Eyal Amitai
Christopher Barnet
Scott Curtis
Belay Demoz
Keith Evans
Jeffrey Halverson
Alexander Marshak
J. Vanderlei Martins
Amita Mehta
William Olson
Lazaros Oraiopoulos
Steven Platnick
Paul Poli
Jens Reichardt
Susanne Reichardt
Thomas Rickenbach
Alexander Sinyuk
Lynn Sparling
Andrew Tangborn
Ali Tokay
Omar Torres
Tamas Varnai
Yansen Wang
Guoyong Wen

JOHNS HOPKINS UNIVERSITY

Jun Ma

LAOR

Joe Otterman

NRC

Matthew Boehm
Ilan Koren
Moyses Nussenzveig
Mark Olsen
Sam Shen
Mark Wenig

NSF

Sankar-Rao Mopidevi

UNIVERSITY OF ARIZONA

Robert Loughman
Liming Xu

URF

Timothy Gubbels
Jess Lewis
Willis Wilson

APPENDIX 4. 2002 SEMINARS

SEMINARS HELD AT GSFC:

DATA ASSIMILATION OFFICE

Robert Eskridge and James Luers, National Climatic Data Center, hosted by Chris Redder, 910.3, “Radiation bias correction of radiosonde temperature observations,” January 8.

Mozheng Wei, UCAR/NCEP Environmental Modeling Center, hosted by Lars Peter Riishojgaard, 910.3, “The development and utility of NCEP’s ensemble weather forecast system,” January 9.

Anthony Hollingsworth, ECMWF, hosted by Richard Rood, 910.3, “Monitoring and predicting the global environment,” January 10.

Susan Strahan, GEST/DAO, “The influence of planetary wave transport on Arctic ozone as observed by POAM,” January 18.

Andy Tangborn, GEST/DAO, “Assimilation of stratospheric winds,” January 25.

Byron Boville, National Center for Atmospheric Research, hosted by S.J. Lin, 910.3, “Atmospheric chemistry transport modeling and fvWACCM results from NCAR,”
February 4.

Nilton O. Renno and Peter H. Smith, Lunar and Planetary Laboratory, Univ. of Arizona, hosted by Arlindo Da Silva, 910.3, “Mars Atmospheric Processes,” February 12.

Myong-In Lee, Seoul National University, “Moist processes in idealized large-scale models,” February 14.

Ivanka Stajner, DAO/SAIC, “Ozone assimilation at the DAO,” February 15.

Simon Chang, Office of Naval Research, NRL, “The data assimilation and predictability program at the Office of Naval Research,” February 22.

Richard Rood, GSFC code 930, hosted by Steven Pawson, 910.3, “Constituent data assimilation: challenges and limitations,” February 22.

A. Khokhlov and G. Patnaik, Laboratory for Computational Physics and Fluid Dynamics, Naval Research Laboratory, hosted by Leonid Zaslavsky, 910.3, “Adaptive COAMPS project,” February 27.

David Lary, DAO, GEST visiting fellow, hosted by Steven Pawson, 910.3, “Chemical data assimilation,” March 1.

Alan Betts, Atmospheric Research, Pittsford, VT, hosted by Michael Bosilovich, 910.3, “Modeling the water cycle, clouds and precipitation,” March 11.

Milija Zupanski, Colorado State University, Cooperative Institute for research in atmosphere, hosted by Stephen Cohn, Code 910.3, “Development of a weak-constraint 4dvar data assimilation system at CIRA/CSU and future work,” March 19.

Tomi Vukicevic, Cooperative Institute for Research in the Atmosphere, Colorado State University, “An overview of data assimilation research at the Cooperative Institute for Research in the Atmosphere (CIRA): Toward satellite radiance assimilation under all weather condition,” March 20.

Steven Pawson, GEST/DAO, hosted by 910.3, “How well can we model the climate of the middle atmosphere? The SPARC GRIPS project,” April 5.

Ralf Giering and Thomas Kaminski, Fastopt, hosted by Ricardo Todling, 910.3, “Status of the tangent linear and adjoint models of the FV-GCM,” April 17.

Dave Broutman, NRL, Washington DC, hosted by Steven Pawson, 910.3, “Rays, caustics, and gravity waves,” April 19.

Manuel de la Torre Jurez, Jet Propulsion Laboratory, hosted by Joanna Joiner, “Climate monitoring using GPS radio-occultations,” May 31.

Ron Errico, NCAR, hosted by Ron Gelaro, 910.3, “Optimal (SV) perturbations produced for moisture-measuring,” June 26.

Boyin Huang, MIT, “Sensitives of deep-ocean heat content in the MIT adjoint ocean,” July 9.

Ricardo Todling and Yanqiu Zhu, DAO/SAIC, hosted by 910.3, “Studies with the DAO retrospective Data assimilation system,” July 10.

Lars Peter Riishojgaard, DAO/UMBC/GEST, hosted by 910, “Data assimilation at Goddard: the role and the challenges,” September 12.

Ichiro Fukumori, JPL, hosted by Ricardo Todling, Code 910.3, “A routine global ocean data assimilation system of the consortium for Estimating the Circulation and Climate of the Ocean (ECCO),” September 19.

Dick Dee, SAIC, hosted by 910.3, “An adaptive scheme for estimating error variances during data assimilation,” October 21.

Robert Miller, Oregon State University, hosted by Ricardo Todling, Code 910.3, “Ensemble generation for models of multi-modal systems,” October 29.

Mike Fiorino, PCMDI, hosted by Dick Dee, Code 910.3, “Spooky results from the ERA-40 reanalysis project,” October 31.

Joel Norris, Scripps Institute of Oceanography, Univ. of California, San Diego, “Evaluation of GCM cloudiness as a function of meteorological process,” November 5.

Steven Pawson, GEST/UMBC at GSFC, “Challenges in the Data Assimilation for studies of the middle atmosphere,” November 27.

Hui Liu, Florida State University, hosted by Joanna Joiner, “Assimilation of GPS radio occultation data,” December 2.

Ivanka Stajner, DAO/SAIC, “Ozone assimilation at NASA/Goddard Data Assimilation Office,” December 18.

MESOSCALE ATMOSPHERIC PROCESSES BRANCH

David Jorgensen, NOAA/NSSL/Mesoscale Research Division- Boulder,“ The Kinematic Structure of two intense narrow cold frontal rainbands observed by Airborne Doppler Radar” January 22.

T. N. Krishnamurti, Florida State University, “A Multi Model Approach to the Cumulus Parameterization Issue,” April 10.

Matthew Boehm, “Tropical Convection’s Roles in Tropical Tropopause Cirrus,” May 16.

Scott Curtis, “Understanding the Cause and Effects of El NiÒo with Satellite Estimates of Precipitation,” June.

Christopher C. Hennon, Ohio State University, “Predicting tropical cyclogenesis: Current Approaches and future possibilities,” September 19.

Wei-Chyung Wang, Atmospheric Sciences Research Center, State University of New York, “The role of cloud-radiation interaction in East Asia summer monsoon,” September 23.

J. Marshall Shepherd, “Overview of NASA’s Precipitation Program, White House Science Advisor Marburger and Guests,” October 11.

J. Marshall Shepherd, “Urban Rainfall Anomalies in Houston,” October 15.

Wei-Kuo Tao, Aerocenter, NASA/Goddard Space Flight Center, “Goddard Cumulus Ensemble Model: Microphysics and its application for cloud-aerosol Interaction,” Greenbelt, Maryland, October 15.

Wei-Kuo Tao, GSFC aerosol science “The Goddard Cumulus Ensemble Model: Microphysics and its application for cloud-aerosol-chemistry interaction,” Greenbelt, Maryland, November 21.

Detlef Muller, Institute for Tropospheric Research, Leipzig, Germany, “Characterization of European and Indo-Asian Pollution with 6-Wavelength Lidar,” December 3.

J. Marshall Shepherd, “Overview of Mesoscale Atmospheric Processes Branch Applications Activities,” Richard Miller/NASA Stennis, December 13.

J. Marshall Shepherd, “Etheatre Seminar to ISRO and IMD Delegation,” December 16.

CLIMATE AND RADIATION BRANCH

Leo J. Donner, NOAA, Princeton, NJ, “The Impact of Mesoscale Processes Driven by Deep Convection on the General Circulation,” January 9.

Si-Chee Tsay, NASA/GSFC, Aerocenter Seminar, “ Dust Characterization at ACE-Asia Source Region: A Satellite/Surface Perspective,” January 9.

Jean-Francois Leon, Laboratoire d”Optique, “Passive and Active Remote Sensing of Aerosols: Results from the Indian Ocean Experiment and New Concepts from the Aqua-Train,” January 23.

Yoram J. Kaufman, NASA/GSFC and J. Vanderlei Martins, JCET/UMBC, " A Concept for Satellite Observations of Aerosol Absorption over the Oceans," January 23.

Jim Butler, NASA/GSFC, "Radiometric Calibration of EOS Satellite and Vicarious Calibration Instruments from 400 to 250nm: Results and Lessons Learned," February 6.

Paul Ginoux, UMBC, Aerocenter Seminar, "Characteristics of Dust Sources Derived from TOMS Aerosol Index," February 6.

Daniel Rosenfeld, The Hebrew University of Jerusalem, Israel, "Why do Clouds over Ocean Become Maritime?" February 19.

Lazaros Oreopoulos, JCET/UMBC, "Shortwave Cloud Absorption Estimates from the ARESE II Experiment," February 20.

Oleg Dubovik, UMBC, Aerocenter Seminar, " Non-Spherical Aerosol Retrieval Method Employing Light Scattering by Spheroids: Applications to AERONET data," February 20.

Julio Bacmeister, GEST/UMBC, "Clouds, Convection, and Boundary Layer Physics in the NSIPP AGCM," March 6.

Omar Torres, University of Maryland, Aerocenter Seminar, "Aerosol Single Scattering Albedo from TOMS: Comparison to AERONET Observations," March 6.

Albert Arking, Johns Hopkins University, "The Partitioning of Solar Energy Between Atmosphere and Surface," March 20.

Grace Wahba, University of Wisconsin, "Reproducing Kernel Space Methods for Hard and Soft Classification, with Potential Application to the No-Cloud/Cloud-Type Classification of Radiance Profiles," April 3.

Eric Vermote, University of Maryland, Aerocenter Seminar, "The 1km MODIS Aerosol Product for Atmospheric Correction," April 10.

Ilan Koren, Tel Aviv University, Israel, "Seeing Clouds," April 15.

Ngar-Cheung (Gabriel) Lau, NOAA, "The Atmospheric Bridge Linking ENSO Events to Variability of the World Oceans," April 15.

Mikhail Alexandrov, GISS, Aerocenter Seminar, "Remote Sensing of Aerosol and Trace gases by Means of MFRSR Networks," April 24.

Gabriele C. Hegerl, Duke University, "Detection of Anthropogenic Climate Change," May 1.

L. Larrabee Strow, University of Maryland Baltimore Campus, "Radiative Transfer for the Atmospheric Infrared Sounder (AIRS) on EOS-AQUA," May 15.

Charles Ichoku, Science Systems and Applications, Inc., "MODIS Aerosol Products and Climate Research," June 5.

Varnai, Tamas JCET/UMBC, “3D Radiative Effects in MODIS Cloud Observations,” June 19.

Rosana Nieto Ferreira, GEST/UMBC, “Zonal Index Cycle in the Southern Hemisphere,” July 12.

Ichoku, Charles, Science Systems and Applications, Inc., Special Seminar, “Quality Control Strategies in Aerosol Remote Sensing by MODIS,” July 17.

Martin J. Wooster, King’s College London, “Fire Radiative Energy for Biomass Burning Emissions Inventories: Pilot Studies using Ground and Satellite Based Infrared Spectral Radiances,” July 19.

William K. M. Lau, NASA/GSFC, “My Vision of the Laboratory for Atmospheres,” August 30.

Holben, Brent, NASA/GSFC, Aerocenter Seminar, “AERONET-What’s Cookin?” September 17.

Menon, Surabi, NASA/Goddard Institute for Space Studies and Columbia University, “Evaluating the Direct and Indirect Aerosol Effect on Climate,” September 18.

Steven Platnick, UMBC/JCET, Special Seminar, “An Overview of the Operational MODIS Cloud Products,” September 24.

Harshvardhan, Earth and Atmospheric Sciences, Purdue University, “Retrieval of Microphysical and Thermodynamic Properties from Non-Uniform Cloud Field,” September 25.

Graham, Feingold, NOAA Environmental Technology Laboratory, Boulder, Colorado, “First Measurements of the Aerosol Indirect Effect Using Ground-Based Remote Sensors,” October 1.

Kuo-Nan Liou, Department of Atmospheric Sciences, University of California, “Remote Sensing of 3D Inhomogeneous Cirrus Clouds Using Bidirectional Reflection and Polarization Measurements: Implications for Climate Research,” October 16.

Ken Knapp, CIRA-NOAA/NESDIS, Aerocenter Seminar, “The GOES Aerosol/Smoke Product (GASP),” October 29.

James Coakley, College of Oceanic & Atmospheric Sciences, Oregon State University, “Cloud Properties for Partly Cloudy Fields of View,” November 6.

P.K. Bhartia, NASA/GSFC, Aerocenter Seminar, “Effect of Aerosols on Ultraviolet Radiation – What we Know, What we do not Know, and Why it is Important to Know,” November 13.

Christophe Pietras, SIMBIOS Group, Aerocenter Seminar, “SeaWiFS and MODIS Aerosol Optical Thickness Matchups Using Sun Photometers,” November 26.

Edmilson De Freitas, University de Sao Paulo, and J. Vanderlei Martins, UMBC/JCET, “Influence in the Direct Radiative Forcing of Aerosols by Surface Properties using MODIS,” November 30.

Bernard Pinty and Michel Verstraete, Institute for Environment and Sustainability, Ispra, Italy, Special Aerocenter Seminar, “Use of MISR and SeaWiFS Angular/spectral Information to Monitor Vegetation Vitality, Vegetation Structure and Surface Liquefaction,” December 4.

Ming-Dah Chou, NASA/GSFC, “Clouds, Radiation Budgets and Climate in the Tropical Western Pacific,” December 18.

Thomas F. Eck (923), Brent N. Holben (923), Rong-Rong Li (913), Robert C. Levy (913), Joel S. Schafer (923), Omar Torres (916), Pawan K. Bhartia (916), Aliaksandr Sinyuk (916), Oleg Doubovik (923), and Nordine Souaidia (National Institute of Standards and Technology, Gaithersburg, Maryland), Aerocenter Seminar, “Poster Session using AERONET Observations,” December 19.

ATMOSPHERIC CHEMISTRY AND DYNAMICS BRANCH

Atmospheric Chemistry and Dynamics Branch, Paul Ginoux, NASA GSFC/GEST, “Characteristics of dust sources derived from TOMS Aerosol Index,” February 6.

Climate and Radiation Branch, Omar Torres, “Aerosol Single Scattering Albedo from TOMS: Comparison to AERONET observations,” March 6.

Atmospheric Chemistry and Dynamics Branch, Hongbin Yu, Georgia Institute of Technology, “Impacts of Aerosols on the Land-Atmosphere Interactions,” March 20.

Atmospheric Chemistry and Dynamics Branch, Neil Bradshaw, Department of Physics, University of Wales, Aberystwyth, “A dynamical theory of ozone layering in the stratosphere,” April 2.

Atmospheric Chemistry and Dynamics Branch, P. K. Bhartia, NASA GSFC, “UV Remote Sensing - concentrating on its application to ozone monitoring,” June 27.

Atmospheric Chemistry and Dynamics Branch, Donald Anderson, NASA GSFC, “The NASA CRYSTAL-FACE Mission and the GSFC Laboratory for Atmospheres,” August 13.

Atmospheric Chemistry and Dynamics Branch, Eladio Knipping, University of California at Irvine, “Modeling C12 Formation from Sea-Salt Particles: Mechanism & Effects on Urban Coastal Ozone,” September 4.

Atmospheric Chemistry and Dynamics Branch, Fok-Yan Thomas Leung, California Institute of Technology, “Elucidation of the sources of stratospheric sulfate aerosols by isotopic methods,” November 8.

Climate and Radiation Branch, P. K. Bhartia, NASA GSFC, “Effects of aerosols on ultraviolet radiation - what we know, what we do not know, and why it is important to know,” November 13.

Atmospheric Chemistry and Dynamics Branch, David Noone, California Institute of Technology, “Investigating the Influence of Arctic Sea Ice on Stratospheric Circulation and Ozone with GCMs,” November 21.

Atmospheric Chemistry and Dynamics Branch, David Baker, National Center for Atmospheric Research (NCAR), “Recent Work on Atmospheric CO_2 Data Assimilation at NCAR using the GSFC PCTM Model,” November 26.

SEMINARS HELD OFF-CENTER BY LABORATORY MEMBERS:

SOUNDER RESEARCH TEAM

Joel Susskind, “Introduction to AIRS and CrIS,” host: Menas Kafatos, George Mason University, Fairfax, Virginia, October 17.

MESOSCALE ATMOSPHERIC PROCESSES BRANCH

Wei-Kuo Tao, “Goddard Cumulus Model and Precipitation Processes,” Indian Meteorological Society, New Delhi, India, February 12.

David Whiteman, “Atmospheric Research Using Raman Lidar,” University of Alabama, Huntsville, Alabama, February 20.

George J. Huffman, “Progress in Global Rainfall Estimates,” Dept. of Meteorology Seminar, University of Maryland, College Park, Maryland, March 7.

J. Marshall Shepherd , “Overview of NASA Earth Science Activities: Atmospheric Sciences Component,” National Park Service, March 11.

Wei-Kuo Tao, “Microphysics, Radiation and Surface Processes in the Goddard Cumulus Ensemble (GCE) Model,” Japan Meteorological Research Institute, Tsukuba, Ibaraki, Japan. March 18.

Geary Schwemmer, “Laser Atmospheric Remote Sensing at NASA Goddard Space Flight Center,” U.S. Naval Academy, Applied Math Department, Annapolis, Maryland, March 19.

James R. Campbell, “A Ground-Based Global Lidar Network for Cloud and Aerosol Research,” National Taiwan University, Department of Meteorology, Taipei, Taiwan, March 19.

Wei-Kuo Tao, “Goddard Cumulus Ensemble Model and its applications on precipitation processes,” Tokyo University, Tokyo, Japan, March 20.

J. Marshall Shepherd, “Rainfall Anomalies in Houston,” Pennsylvania State University, Meteorology Department, University Park, Pa., March 21.

J. Marshall Shepherd, “An Overview of the GPM Mission,” Pennsylvania State University, Meteorology Department, University Park, Pa., March 21.

Xiaowen Li, “Simulating the Evaporation in Stratiform Rain,” University of Chicago, Chicago, Illinois, March 26.

Xiping Zeng, “Ensemble Simulation of Tropical Convection,” New Mexico Tech, Physics Department, Socorro, N.M, April 19.

Wei-Kuo Tao, “Mesoscale Convective Systems in SCSMEX: Simulated by a regional climate model and a cloud resolving model,” National Taiwan University, Taipei, Taiwan, June 7.

Wei-Kuo Tao, “Precipitation processes and Cloud Resolving Models,” Taiwan Central Weather Bureau, Taipei, Taiwan, June 8.

Wei-Kuo Tao, “Mesoscale Convective Systems in SCSMEX: Simulated by a cloud resolving model,” Colorado State University, Fort Collins, Colorado, June 27.

George J. Huffman and Barbara L. Summey, “Earth Science Data As Never Before Seen: Cutting-Edge Visualizations in Code 912,” SSAI Brown-Bag Seminar, SSAI, Lanham, Maryland, July 30.

Song Yang, “Updates on TRMM/GPM and Latent Heating Products,” National Satellite Meteorological Center, Beijing, China, August 22.

Song Yang, “The Global Precipitation Measurement (GPM),” Institute of Atmospheric Physics, Beijing, China, August 23.

Wei-Kuo Tao, “Cloud model and weather modification,” National Academy of Sciences, Washington, D.C., August 28.

J. Marshall Shepherd, “Rainfall Anomalies in Houston,” Morgan State University, Engineering and Computation Sciences Department, Baltimore, Maryland, September 17.

Wei-Kuo Tao, “Microphysics, Radiation and Surface Processes in the Goddard Cumulus Ensemble (GCE) Model,” NASA Ames, Moffett Field, California, September 17.

Wei-Kuo Tao, “Microphysics, Radiation and Surface Processes in the Goddard Cumulus Ensemble (GCE) Model,” Naval Research Laboratory, Monterey, California, September 19.

Wei-Kuo Tao, “Regional-and Cloud-Scale Modeling at NASA Goddard Space Flight Center,” Bay area air quality management district, San Francisco, California, September 20.

Wei-Kuo Tao, “Convective Systems over the South China Sea: Cloud-Resolving Model Simulation,” University of Maryland, Department of Meteorology, College Park, Maryland, October 10.

J. Marshall Shepherd, “Rainfall Anomalies in Houston,” University of Virginia, Department of Environmental Sciences, Charlottesville, Virginia, October 24.

J. Marshall Shepherd, “An Overview of the GPM Mission,” University of Virginia, Department of Environmental Sciences, Charlottesville, Virginia, October 25.

Song Yang, “Global Precipitation Measurement (GPM)—overview,” Nanjing Institute of Meteorology, Nanjing China, October 27.

Wei-Kuo Tao, “Microphysics, Radiation and Surface Processes in the Goddard Cumulus Ensemble (GCE) Model,” Japan Frontal Research System for Global Change, Yokohama, Japan, October 28.

Song Yang, “Precipitation from Satellite Passive Microwave Measurements,” Nanjing Institute of Meteorology, Nanjing, China, October 29.

Song Yang, Shanghai Typhoon Institute, Shanghai, China, “TRMM—impact on hurricane research,” November 7.

Wei-Kuo Tao, “Comparison of surface energy budget and precipitation efficiency between convective systems developed during ARM, SCSMEX, TOGA COARE, GATE, WMO-01 and KWAJEX,” ARM Cloud Parameterization and Modeling Meeting, Reston, Virginia, November 8.

Wei-Kuo Tao, “CRM: Status and plans in TRMM,” ARM Cloud Parameterization and Modeling Meeting, Reston, Virginia, November 8.

Biswadev Roy, “Global Positioning System and Some Atmospheric Applications,” Howard University, Department of Physics & Astronomy, Washington, D.C., November 13.

Eyal Amitai, “NASA Precipitation Measurement Missions,” Politecnico di Torino, Turin, Italy, November 15.

Eyal Amitai, “Improved Radar-Gauge Adjusted Rain Fields Based on the TRMM Validation Program,” Politecnico di Torino, Turin, Italy, November 15.

George J. Huffman, “Remote Sensing of Precipitation,” SSAI Brown-Bag Seminar, SSAI, Lanham, Maryland, December 12.

CLIMATE AND RADIATION BRANCH

Steven Platnick, “Multispectral Cloud Retrievals and the MODIS Algorithm,” Institute for Terrestrial and Planetary Atmospheres, State University of New York, Stony Brook, NY, February 27.

Alexander Marshak (NASA/GSFC), “A Correct of Large Droplets in Radiative Transfer and its Effects on Cloud Absorption,” State University of New York, Stony Brook, NY, March 20.

Charles Gatebe, “Perspective of Earth from Space,” University of Nairobi, College of Architecture and Engineering, Nairobi, Kenya, July 24.

Charles Gatebe, “Understanding our Planet from Space,” University of Nairobi, College of Biological and Physical Sciences, Nairobi, Kenya, July 26.

Charles Gatebe, “Use of MODIS Satellite Data from Improving Weather Forecasting in Africa,” Kenya Meteorological Department Headquarters, Nairobi, Kenya, August 1.

Charles Gatebe, “Use of Satellite Data for Environmental Research Venue: Kenya Chemical Society International Workshop at Egerton University,” Nakuru, Kenya, August 19.

Steven Platnick, “MODIS Retrieval of Cloud Optical and Microphysical Properties and Cloud Mask,” Remote Sensing of the Earth’s Environment from Terra, International Summer School on atmospheric and Oceanic Sciences 2002, L’Aquila, Italy, August 25-30.

Lorraine A. Remer, “Global Aerosols: The view from MODIS,” University of Maryland, Department of Meteorology, College Park, Maryland, September 13.

James A. Coakley, Jr. (GEST), “Man-Made Haze, Clouds, and Climate Change,” UMBC, Baltimore, Maryland, October 15.

ATMOSPHERIC CHEMISTRY AND DYNAMICS BRANCH

Charles Jackman, “Atmospheric Effects due to the July 2000 Solar Proton Event,” hosted by Dale Allen, University of Maryland, College Park, Maryland, February 6.

Anne M. Thompson, “SHADOZ (Southern Hemisphere ADditional Ozonesondes) - What Have We Learned About Tropical Tropospheric Ozone from the First Three Years’ (1998-2000) Data?” hosted by G. North, Texas A&M, Dept. of Atmospheric Science, College Station, Texas, February 28.

Richard P. Cebula, “Understanding Stratospheric Ozone,” hosted by SSAI, Lanham, Maryland, April 11.

Mian Chin, “Local Emission to Global Climate Forcing: Understand Tropospheric Aerosols,” hosted by Scott Martin, Harvard University, Cambridge, Mass., May 10.

Anne Thompson, “What Have We Learned about Tropical Tropospheric Ozone from the First Three Years’ of SHADOZ Data?” hosted by E. S. Saltzman, Earth System Science Department, University of California at Irvine, Irvine, California, May 16.

Mian Chin, “Aerosols from Surface to Sky to Space,” hosted by Dale Allen, University of Maryland, College Park, Maryland, June 5.

Pawan K. Bhartia, “Remote Sensing of the Earth in Ultraviolet,” hosted by Richard P. Cebula, SSAI, Lanham, Maryland, June 27.

Anne M. Thompson, “Satellite and Sounding Views of Tropospheric Ozone,” hosted by Oliver Zafiriou, Woods Hole Oceanographic Institution, July 23.

Charles G. Wellemeyer, Lead Programmer/Analyst, SSAI, “Version 8 TOMS Total Ozone Retrieval Algorithm,” hosted by Richard P. Cebula, SSAI, Lanham, Maryland, October 10.

Mian Chin, “Synergy of Model and Measurements to Study Atmospheric Aerosols,” hosted by Rodney Weber, Georgia Institute of Technology, Atlanta, Georgia, October 18.

Omar Torres, “Aerosol absorption measurements from TOMS,” hosted by Howard University, Physics Department, Washington, D.C., October 23.

Richard P. Cebula, “A Whirlwind Tour of the Earth’s Ozone Layer,” hosted by Mike Darzi, SSAI, Lanham, Maryland, October 29.

Omar Torres, “The use of ultraviolet observations to measure aerosol absorption from space,” hosted by University of Maryland, Meteorology Dept., College Park, Maryland, October 31.

Andrew Dessler, “Elucidation of the sources of stratospheric sulfate aerosols by isotopic methods,” hosted by Fok-Yan Thomas Leung, California Institute of Technology, Pasadena, California, November 8.

Anne M. Thompson, “Insights into Tropical Tropospheric Ozone from Satellite and Sonde Data,” hosted by Maarten Krol, University of Utrecht, The Netherlands, December 16.

APPENDIX 5. 2002 CONFERENCES, SCIENCE POLICY MEETINGS, SCIENCE TEAM MEETINGS, SOCIETY MEETINGS, AND WORKSHOPS

CONFERENCES

Earth Science Technology Conference–2002, Pasadena, California, June 11–13, S.R. Kawa.

First TRMM International Conference, Honolulu, Hawaii, July 22–26.

Global Energy & Water Cycle Experiment (GEWEX) Asian Monsoon Experiment-Tropics (GAME-T) Conference, Bangkok, Thailand, October 28.

GOES-R Users Conference, Boulder, Colorado, October 1–3.

IGAC and SPIE Conferences, Crete, Greece, September 18–25.

International Conference on East-Asian Climate (EAC), Harbin, China, August 7.

International Conference on Mesoscale Convective System and Heavy Rainfall/Snowfall in East Asia, Tokyo, Japan, October 29–November 3.

International Geoscience & Remote Sensing Symposium (IGARSS'02), Toronto, Canada, June 25.

MUSCLE 12, Lidar Multiple Scattering Experiments Conference, Bavaria, Germany, September 10–12.

SPIE Remote Sensing Conference, Hangzhou, China, October 23–27, J.R. Herman.

VOLTAIRE "Validation of Multisensors Precipitation Fields and Numerical Modeling in Mediterranean Test Sites" Politecnico di Torino, Turin, Italy, November 14–15.

WCRP International Conference on quantitative Precipitation Forecast, Reading, United Kingdom, September 2–6.

SCIENCE POLICY MEETINGS

9th Meeting of the Science Steering Committee of the U.S. Climate Variability & Predictability (CLIVAR) Program, Boulder, Colorado, July 16.

Complements to Kyoto: Technologies for Controlling CO2 Emissions, National Academy of Sciences, Washington, D.C., April 23–24, Chris Barnet.

Earth Science Vision Retreat, Petersburg, Virginia, August 19.

GSFC Earth Science Overview to White House Science Advisor John Marburger, NASA GSFC, October 11.

NASA Coastal Zone Program Formulation Meeting, NASA Wallops Flight Facility, November 17–18.

NATO Advanced Study Institute, Data Assimilation for the Earth System, Maratea, Italy, May 19–June 1.

Science Advisory Committee Meeting, Short-term Prediction Research and Transition Center (SpoRT), Huntsville, Alabama, November 13–14.

U.S. Climate Change Science Program: Planning Workshop for Scientists and Stakeholders, Washington, D.C., December 3–5, M. Gupta.

U.S. Climate Change Science Program Meeting, Washington D.C., December 3–5.

WCRP/UNEP Ozone Assessment Meeting, Les Diablerets, Switzerland, June 24–28.

SCIENCE TEAM MEETINGS

12th International TOVS Study Conference, Lome, Australia, February 27–March 5.

AIRS Meeting and Aqua Launch, Solvang, California, May 1–4, Joel Susskind, John Blaisdell.

AIRS Science Team Meeting, Suitland, Maryland, February 12–14, Joel Susskind.

AIRS Team Meeting, Silver Spring, Maryland, September 18–20, Lena Iredell, Chris Barnet, Lou Kouvaris, Fricky Keita, John Blaisdell.

ARM Science Team Meeting, St. Petersburg, Florida, April 8–12.

Asian-Brown-Cloud Science Team Meeting, San Diego, California, October 24.

Aura Science Team Meeting Woudshoten, the Netherlands, April 9–11 A. Douglass (Organizer), P.K. Bhartia, E. Hilsenrath.

CAMEX Science Team Meeting, National Space Science and Technology Center, University of Alabama-Huntsville, Huntsville, Alabama, November 20–22.

Cassini INMS Science Team Meeting, University of Michigan, February 27–28, W.T. Kasprzak, Science Team Member.

Cloud Aerosol-Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Science Team Meeting, Hampton, Virginia, May 23.

CloudSat Science Team Meeting, Monterey, California, April 29–May 1.

CRYSTAL Science Team, Greenbelt, Maryland, January 30–February 1.

DAO-TES meeting, NASA GSFC, June 16.

EOS AMSR-E Science Team Meeting, Santa Rosa, California, August 8–9.

First CHAMP Science Meeting, Potsdam, Germany, January 22–25.

GLAS Calibration /Validation and Science Team Meeting, Greenbelt, Maryland, November 11–12.

GLAS Science Team Meeting, Austin, Texas, February 21–22.

GLAS Science Team Meeting, Boulder, Colorado, September 26–27.

GLAS Science Team Meeting, Lanham, Maryland, May 2–3.

Japanese SPARC meeting, Fukuoka, Japan, November 12–16.

Living with a Star Targeted Research and Technology Science Definition Team Meeting, University of Maryland, University College, Adelphi, Maryland, September 30–October 2, C.H. Jackman.

POAM Science Meeting Berkeley Springs, West Virginia, October 29–30, S.R. Kawa.

Second GPM International Partnership Meeting, Tokyo, Japan, May 2002.

Sixth OMI Science Team Meeting Sodankyla, Finland, June 3-7 P.K. Bhartia, E. Hilsenrath, A. Krueger, R. McPeters, G. Jaross, J. Joiner, M. Linda, T. Johnson, A. Vasilkov, E. Celarier, O. Torres, J. Ziemke, R. Cebula.
Small Business Innovative Research (SBIR) Project Team Meeting, Honolulu Hawaii, January 17.

Solar Radiation & Climate Experiment (SORCE) Science Team Meeting, Steamboat Springs, Colo., July 16–19.

TIMED Science Team Meeting Johns Hopkins Applied Physics Laboratory Laurel, Maryland, February 19–20 H.G. Mayr, C.H. Jackman.

TIMED Science Team Meeting Johns Hopkins Applied Physics Laboratory Laurel, Maryland, September 5–6 H.G. Mayr, C.H. Jackman.

TRACE-P Science Team Meeting Norfolk, Virginia, June 24–26 Mian Chin.

Tropical Rainfall Measuring Mission (TRMM) International Science Team Meeting, Honolulu, Hawaii, July 22–26.

USWRP Science Symposium, Boulder, Colorado, April 22–24.

WMO Ozone Assessment: Chapter 3 writing team meeting, Boulder, Colorado, April 16–18.

SOCIETY MEETINGS

27th EGS Assembly, Nice, France, April 21–26.

34th COSPAR Scientific Assembly, 2nd World Space Congress, Houston, Texas, October 10–19.

Committee on Space Research (COSPAR) Meeting, Houston, Texas, October 14.

82nd AMS annual meeting, Orlando, Florida, January 13–18.

AGU Fall meeting, San Francisco, California, December 6–10.

AGU Spring meeting, Washington D.C., May 28–31.

American Association for the Advancement of Science (AAAS) & Science Innovation Exposition, Boston, Massachusetts, February 17.

American Association of Advancement of Science AAAS Meeting "Big Climate Impact of Tiny Particles" Symposium, Boston, Mass., February 14–19.

American Meteorological Society (AMS) 25th Conference on Hurricanes and Tropical Meteorology, San Diego, California, April 29–May 3.

AMS 11th Conference on Cloud Physics and Atmospheric Radiation, Ogden, Utah, June 3–7.

AMS 12th Conference on the Middle Atmosphere San Antonio, Texas, November 4–8, A. Douglass, S. Strahan, R. Kawa.

Canadian Applied and Industrial Mathematics Society, Calgary, Canada, June 8–10.

European Geophysical Society Meeting, Nice, France, April 21–26.

Western Pacific Geophysics Meeting, Wellington, New Zealand, July 8–12, R.S. Stolarski.

World Space Congress 2002 IAF COSPAR Houston, Texas, October 10–19, P.K. Bhartia, E. Hilsenrath, C.H. Jackman, A.M. Thompson, M. Deland.

WORKSHOPS

16th Working Group on Data Management of the GPCP, Tokyo, Japan, May 13–16.

1st GPM Applications Workshop, Greenbelt, Maryland, February.

1st GPM Cloud-Microwave radiative modeling workshop, Hawaii, July 20.

AEROSAT Mission Planning Meeting, New York, New York, March 22.

AEROSAT Planning Workshop Lanham, Maryland, October 3–4, S.R. Kawa, J. Mao, O. Torres.

Aerosol Workshop, Beijing, China, May 6.

Air Pollution as a Climate Forcing, University of Hawaii, Honolulu, April 29–May 3, Mian Chin.

Apare Workshop & 6th Intl. Aerosol Conference, Taipei, Taiwan, September 6–13.

ARM Cloud Parameterization and Modeling Meeting, Reston, Virginia, November 6–8.

ARM Instantaneous Radiative Fluxes Semi-Annual Workshop, October 7.

Aura Science Validation Workshop Boulder, Colorado, September 17–20, A. Douglass (Organizer), E. Hilsenrath, A. Fleig, T. Johnson, K. Stefanidies.

Aura Validation for the Troposphere Greenbelt, Maryland, January 28–29, A.R. Douglass (Organizer).

AURA Validation Working Group Meeting Pasadena, California, March 19–20, A.R. Douglass (Organizer), P.K. Bhartia, E. Hilsenrath, P.A. Newman.

Calibration Techniques for In-Situ Particle Instruments, International Space Science Institute, Bern, Switzerland, September 30–October 4, W.T. Kasprzak, Participant.

CAMEX-4 workshop, Huntsville, Alabama, November 20–22.

CAMEX-4 workshop, New Orleans, Louisiana, March 12–15.

Carbon Lidar Workshop Goddard Space Flight Center, August 27–28, S.R. Kawa, A. Andrews, J. Burris.

CCSR Workshop on Next-Generation Climate Model, Awaji Island, Japan, March 4–8.

Cirrus Regional Study of Tropical Anvils and Cirrus Layers (CRYSTAL)-Florida Area Cirrus Experiment (FACE) Meeting, Key West & Miami, Florida, June 28 and July 25.

CLAMS Workshop; Progress and Directions for the CLAMS Experiment Data Analysis, MODIS Aerosol Team, presenters, Aerospace Building, Greenbelt, Maryland, February 27–28.

Climate Diagnostics and Prediction Workshop, Fairfax, Virginia, October 21–25.

Climate Variability and Predictability (CLIVAR) International Working Group, Beijing, China, August 12.

Coastal Research Workshop NASA's Wallops Flight Facility Wallops Island, Virginia, October 17–18, M. Gupta.

Coordinated Data Analysis Workshop for Solar Energetic Particles: Solar and Geospace Connections SSAI, Lanham, Maryland, July 22–26, M. Deland, C.H. Jackman.

Coordinated Enhanced Observing Period (CEOP) Workshop, Nanuet, New York, September 9.

CRYSTAL Preparatory Workshop, Pennsylvania State University State College, Pennsylvania, May 13–15.

CRYSTAL-FACE Workshop, Lanham, Maryland, January 28–February 1.

Data Assimilation for the Carbon Cycle University of Maryland, College Park, October 21–22 S.R. Kawa, A. Andrews, S. Pawson.

Data Assimilation Office Users Workshop, University of Maryland, College Park, May 16, S.R. Kawa, A.R. Douglass.

Earth System Modeling Framework Meeting, Boulder, Colorado, September 23.

Earth System Sciences Workshop, Chung-Li, Taiwan, June 3–4.

ECMWF/GEWEX Workshop on Humidity Analysis, ECMWF, Reading, England, July 8–11, Dick Dee, Chairman of Working Group on Analysis Methods.

EOS Investigator Working Group Meeting, Ellicott City, Maryland, November 18–20.

ESTO Technology Strategy Meeting, Glenn Research Center, Ohio, April 22.

First GEWEX Atmospheric Boundary Layer Study Workshop, Reading, United Kingdom, March 25–27.

First International Workshop on Occultations for Probing Atmosphere and Climate (OPAC-1), Graz, Austria, September 16–20.

GAME-T Workshop and Hydrometeorological Studies in Thailand and Southeast Asia, Chiang Rai, Thailand, October 29–31.

Global Energy & Water Cycle Experiment (GEWEX) Cloud System Study (GCSS)-ARM Workshop on Representation of Cloud Systems in Large-Scale Models, Kananaskis, Alberta, Canada, May 19.

Global Energy & Water Cycle Experiment (GEWEX) Radiation Panel Meeting, Zurich, Switzerland, July 30.

Global Modeling Initiative Greenbelt, Maryland, November 21–22, S.R. Kawa, A.R. Douglass, E. Fleming, S. Strahan.

Global Modeling Initiative Lanham, Maryland, May 13–15, S.R. Kawa, A.R. Douglass, E. Fleming, M. Chin, S. Strahan, M. Gupta.

GOFC/GOLD Workshop, University of Maryland, College Park, Maryland, July 17–19, Mian Chin.

GOME Science Advisory Group Meeting Frascati, Italy, April 11–12, J. Gleason and E. Hilsenrath.

GPM Algorithm Workshop, Greenbelt, Maryland, March 12–13.

GPM Applications Workshop, Greenbelt, Maryland, February 19.

GPM Ground Validation Workshop, Seattle, Washington, February 6–8.

GPM International Planning Workshop, Tokyo, Japan, May 20–22.

GPM modeling workshop, July 20–21, Honolulu, Hawaii.

GRIPS Workshop, Tsukuba, Japan (Steven Pawson and K. Kodera were organizers), March 12–15.

H2O Project (IHOP), UMBC, September 30–October 1.

Harsh-Environment Mass Spectrometry, Pasadena, California, March 25–28.

HDF-EOS Workshop VI, San Francisco, California, December 4–5.

Hurricane WRF workshop, Alexandria, Virginia, May 29–30.

Hyperspectral Workshop, Singapore, March 21.

IHOP Convective Initiation Workshop, UMBC, Catonsville, Maryland, September 30.

Indo-US Workshop on Weather and Climate Modeling-Sponsored by Indo-US S&T Forum, February 7–10.

Intercomparison of 3-D Radiation Codes (I3RC) Workshop, Tucson, Arizona, June 1.

International Aerosol Conference/Workshop, Taiwan, Taipei, September 9.

International Precipitation Working Group, Madrid, Spain, September 23–27.

IPCC Workshop on Changes in Extreme Weather and Climate Events, Beijing, China, June 11–13.

ISLSCP II Data Intercomparison Workshop, Lanham, Maryland, March 12–14.

Living With a Star Science Workshop, Johns Hopkins Applied Physics Lab, Laurel, Maryland, November 14–15, C.H. Jackman.

Long-Term Climate Workgroup Meeting, New York, New York, March 13.

Maine Teachers Earth and Space Sciences Workshop, NASA GSFC, August.

MM5/WRF users workshop, Boulder, Colorado, June 24–26.

Model-Data Integration and Network Design for Biogeochemical Research Advanced Study Institute Boulder, Colorado, May 20–31, A.E. Andrews.

MODIS Land Surface Workshop, Boston University, Boston, Massachusetts, October 21–22.

NAME 3rd Science Working Group Meeting, George Mason University, Fairfax, Virginia, October 25.

NASA Educators Workshops, NASA GSFC, July.

NASA ESE Computational Technology Requirements Workshops, Washington, D.C., April 30–May 1.

National Aerosol Workshop, La Jolla, California, January 8.

National Carbon Data Assimilation Workshop, University of Maryland, College Park, Maryland, October 21 (Steven Pawson, co-organizer).

New Optical Remote Sensing Techniques for Air Quality Compliance and Air Toxics Detection Workshop, USEPA, Research Triangle Park, North Carolina, July 29–31.

NewDISS Workshop, University of Maryland, College Park, Maryland, February 6, Louis Kouvaris.

ONR-35 Aerosol Characterization Program Kick-Off Meeting, NRL Conference Room, B. 57, Room 117, April 19.

Prediction of Hurricane Intensity and Precipitation, San Diego, California, May 3–5.

Prospects for Improved Forecasts of Weather and Short-term Climate Variability on Subseasonal (2 week to 2 month) time scales, at the Newton White Mansion, April 16–18, lead organizer, Siegfried Schubert.

Puerto Rico Dust Experiment (PRIDE) Workshop, Miami, Florida, February 11.

Radiosonde Workshop Hampton University, Hampton, Virginia, May 21–23, A.M. Thompson.

Remote Sensing and Modeling Workshop Beijing, China, August 21–24, Mian Chin.

Southern African Regional Science Initiative (SAFARI) Workshop, Charlottesville, Virginia, October 7.

Space Based Lidar Winds Workshop, North Glen, New Hampshire, July 16–18.

SPARC Data Assimilation Workshop, University of Maryland Baltimore County, Baltimore, Maryland, June 10–12, P.K. Bhartia.

SPICE Tutorial Workshop, ESTEC, Noordwijk, Netherlands, September 16–18, W.T. Kasprzak, J. Demick, Participants.

The 4th Workshop on Next Generation GCMs, Boulder, Colorado, March 12–14.

The 5th Regional Climate Simulation Workshop, Chung-Li, Taiwan, June 5–6.

The Hurricane-Flood-Landslide Continuum, NOAA/USGS, Boulder, Colorado, May 9–10.

Third International Workshop on Multiangular Measurements and Models (IWMMM-3) Workshop, Steamboat Springs, Colorado, June 10–12.

TRMM Cloud Modeling-TRMM Validation, Hawaii, July 21.

Twenty-seventh Annual Climate Diagnostics and Prediction Workshop, Fairfax, Virginia, October 2002.

Whole Atmosphere Community Climate Model Workshop Longmont, Colorado, June 20–21, C.H. Jackman, A.R. Douglass, E. Fleming.

Working Group on Space-based Lidar Winds, Key West, Florida, January 23–25.

Working Group on Space-based Lidar Winds, North Conway, New Hampshire, July 15–18.

Workshop of Partial Differential Equations on the Sphere, Toronto, Canada, August 12–15.

Workshop on Arctic Ozone Loss Potsdam, Germany, March 4–6, S.R. Kawa, P.A. Newman.

Workshop on Dust Storms and Their Effects on Human Health, Raleigh, North Carolina, November 25–26, Christina Hsu.

Workshop on Interactions of Urban Pollution with the Regional and Global Environment NASA's GSFC Visitor's Center, May 7–9, A.M. Thompson (Organizer), J.F. Gleason (Organizer), P.A. Newman (Organizer), N. Krotkov, M. Chin, M. Gupta.

Workshop on Remote Sensing and Health Issues Uniformed Health Services University, Bethesda, August 1, A. Thompson, J. Herman.

Workshop on Representation on Cloud Systems in Large-Scale Models, (Joint GCSS-ARM Workshop), Kananaskis, Alberta, Canada, May 20–24.

Workshop on validation data sets for modeling mineral aerosols in global climate cycles, Jena, Germany, May 2–4, O. Torres.

APPENDIX 6. 2002 NASA TECHNICAL REPORTS AND OTHER PUBLICATIONS

NASA TECHNICAL REPORTS

Cahalan, R.F., Solar Radiation and Climate Experiment Brochure, NASA Publication/NP-2002-9-482-GSFC.

Cahalan, R.F., Solar Radiation and Climate Experiment Fact Sheet, NASA Publication/FS-2002-052-GSFC.

Cahalan, R.F., Solar Radiation and Climate Experiment Writer's Guide, NASA Publication/ NP2002-9-082-GSFC.

Gervin, J.C., P.S. Caruso, L.A. DeMaio, C.R. McClain, F.G. Hall, G.J. Collatz, S.R. Kawa, W.W. Gregg, A. Andrews, S. Pawson, and J. Hansen, Cost Analysis for a Recommended NASA Carbon Cycle Initiative, NASA Technical Memorandum, NASA/TM-2002-210007.

Heaps, W.S., and S.R. Kawa, Fabry-Perot Interferometer for Column CO_2, NASA Earth Science Technology Conference Proceedings.

Krotkov, N., J.R. Herman, P.K. Bhartia, C. Seftor, A. Arola, J. Kaurola, P. Taalas, I. Geogdzhaev, and A. Vasilkov, OMI surface UV irradiance algorithm, Vol. 3: NASA EOS Project Office, Earth Sciences Directorate, P. Stammes, Editor.

Krueger, A., N. Krotkov, S. Datta, O. Dubovik, D. Flittner, OMI SO_2 algorithm in OMI ATBD, Vol. 4, OMI Trace Gases Algorithms, NASA EOS Project Office, K. Chance, Editor.

McClain, C.R., F.G. Hall, G. J. Collatz, S.R. Kawa, W.W. Gregg, J.C. Gervin, J.B. Abshire, A.E. Andrews, C.D. Barnett, M.J. Behrenfeld, P.S. Caruso, A.M. Chekalyuk, L.D. Demaio, A.S. Denning, J.E. Hansen, F.E. Hoge, R.G. Knox, J.G. Masek, K.D. Mitchell, J.R. Moisan, T.A. Moisan, S. Pawson, M.M. Rienecker, S.R. Signorini, and C.J. Tucker, Science and Observation Recommendations for Future NASA Carbon Cycle Research, NASA/ TM-2002-210009.

Shepherd, J.M., A. Mehta, E. Smith, J. Adams, 2002: Summary of First GPM Partners Planning Workshop, NASA/CP-2002-211602-GPM Report 7.

Shepherd, J.M., E. Smith, J. Adams, 2002: Bridging from TRMM to GPM to 3-Hourly Precipitation Estimates. NASA/TM-2002-211602-GPM Report 7.

Torres, O., R. Decae, and P. Veefkind, OMI Aerosol Retrieval Algorithm, OMI Algorithms Theoretical Basis Document, Volume III, Clouds, Aerosols, and Surface UV Irradiance, NASA-KNMI, P. Stammes, Editor.

OTHER PUBLICATIONS

Amitai E., D.B. Wolff, D.A. Marks, and D.S. Silberstein, 2002: Radar rainfall estimation: Lessons learned from the NASA/TRMM validation program. Second European Conference on Radar Meteorology (ERAD), November 18-22, Delft, Netherlands. ERAD Publication Series, 1, 255-260 (Copernicus GmbH peer reviewed publication, ISBN 3-936586-04-7).

Chin, M., Black carbon aerosols: A burning question, Air Pollution as a Climate Forcing Workshop Report, 2002.

Chin, M. and P. Newman, From Regional Emission to Global Atmospheric Loading: Intercontinental Transport of Aerosols in the Context of ACE-Asia, Air Pollution as a Climate Forcing Workshop Report, 2002.

Huffman, G.J., 2002: Selections in the NASA/EOS Earth Observatory Web site's Ask A Scientist dept. http://earthobservatory.nasa.gov/Library/AskScientist/index.html. Why do the sunrise/sunset times change together at the Winter Solstice?

Palm, S., W. Hart, D. Hlavka, E. Welton, A. Mahesh, and J. Spinhirne, 2002: Geoscience Laser Altimeter System (GLAS) Atmospheric Data Products Algorithm Theoretical Basis Document, Version 4.2, October 2002.

Roy, B., 2002: Fact sheet Title: Support on improvement of ITU-R Rain attenuation Model using NASA Tropical Rainfall Measuring Mission (TRMM) and associated radio meteorological data (USA Fact Sheet WP3J-USA-4) Geneva, Switzerland. International Telecommunication Union (ITU)-R Fact Sheet Document Number WP3J-USA-4 recommended by ITU Working Group WP-3J in document number WP 3J/49 during the ITU-R Working Group Meetings held in Geneva, Switzerland, May 20–June 4, 2002.

Roy, B. and J. Halverson, 2002: TRMM Field Campaign Soundings Quality Control, http://trmm.gsfc.nasa.gov/trmm soundings.

Schwemmer, G., D. Miller, T. Wilkerson, D. Guerra, and R. Rallison, 2002: NASA lidar uses HOEs for lightweight scanning. *Laser Focus World*, **38**, No. 6, pp. 141-147.

Turner, D.D., D. N. Whiteman, 2002: Web Remote Raman Spectroscopy: Profiling Water Vapor and Aerosols in the Troposphere Using Raman Lidars. Handbook of Vibrational Spectroscopy, J.M. Chalmers and P.R. Griffiths (Eds), John Wiley & Sons, Ltd, 4, 2857-2878. January 2002.

APPENDIX 7. 2002 REFEREED PUBLICATIONS

LABORATORY FOR ATMOSPHERES

Atlas, D., 2002: Radar calibration–Some simple approaches. *BAMS*, **83** (9), 1313-1316.

Atlas, D., C.W. Ulbrich and F.D. Marks, 2002: Potential for estimating cloud liquid water path over sea ice from airborne passive microwave measurements–Reply. *JGR-Atmos*., **107** (D1-D2), 4006.

Ulbrich, C.W. and D. Atlas, 2002: On the separation of tropical convective and stratiform rains. *JAM*, **41** (2), 188-195.

SOUNDER RESEARCH TEAM

Wielicki, B.A., T. Wong, R.P. Allan, A. Slingo, J.T. Kiehl, B.J. Soden, C.T. Gordon, A.J. Miller, S-K. Yang, D.A. Randall, F. Robertson, J. Susskind and H. Jacobowitz, 2002: Evidence for large decadal variability in the tropical mean radiative energy budget. *Science*, **295**, 841-844.

Wielicki, B.A., A. Del Genio, T. Wong, J. Chen, B.E. Carlson, R.P. Allen, F. Robertson, H. Jacobowitz, A. Slingo, D.A. Randall, J.T. Kiehl, B.J. Soden, C.T. Gordon, AJ. Miller, S.-K. Yang and J. Susskind, 2002: Response to “Changes in tropical clouds and radiation.” *Science*, **296**, 2095a.

DATA ASSIMILATION OFFICE

Atlas, R.A. Hou, and Oreste Reale, Hurricane & Flood Prediction for Community Disaster Preparedness, Earth Observation Magazine, Special NASA Earth Science Enterprise Issue. August 2002, 38-40.

Austin, J., D. Shindell, S.R. Beagley, C. Brühl, M. Dameris, E. Manzini, T. Nagashima, P. Newman, S. Pawson, G. Pitari, E. Rozanov, C. Schnadt, and T.G. Shepherd, Uncertainties and Assessments of Chemistry-Climate Models of the Stratosphere. *Atmos. Chem. Phys. Discuss. 2*, 1035-1096.

Bosilovich, M.G., On the Vertical Distribution of Local and Remote Sources of Water for Precipitation. *Meteorol. Armos. Phys*., **80**, 31-41.

Bosilovich, M.G., On the use and validation of mosaic heterogeneity in atmospheric numerical models. *Geophys. Res. Lett*., **29**, 10.1029/2001GL013925.

Bosilovich, M.G. and R. Lawford, Report on the coordinated enhanced observing period (CEOP) international workshop. *Bull. Amer. Met. Soc*., **83**, 1495-1499.

Bosilovich, M., S. Schubert, Water vapor tracers as diagnostics of the regional hydrologic cycle. *J. Hydrometeor.* **3**, 149-165.

Dickinson, R.E., S.E. Zebiak, J.L. Anderson, M.L. Blackmon, C. De Luca, T.F. Hogan, M. Iredell, M. Ji, R.B. Rood, M.J. Suarez, and K.E. Taylor, 2002: How Can we Advance our Weather and Climate Models as a Community? *Bull. Of the Amer. Meteor. Soc*., **83**, 431-434.

Erfani, A., A. Methot, R. Goodson, S. Belair, K.-S. Yeh, J. Cote and R. Moffet, Synoptic and mesoscale study of a severe convective outbreak with the non-hydrostatic Global Environmental Multiscale (GEM) model. *Meteorology and Atmospheric Physics* (published online November 21, 2002.)

Gelaro, R., C.A. Reynolds and R.M. Errico, Transient and asymptotic perturbation growth in a simple model. *Q. J. R. Meterol. Soc*., **128**, 205-227.

Gelaro, R., T.E. Rosmond and R. Daley, Singular vector calculations with an analysis error variance metric. *Mon. Wea. Rev*., **130**, 1166-1186.

Hayashi, H., M. Shiotani, and J.C. Gille, Horizontal wind disturbances induced by inertial instability in the equatorial middle atmosphere as seen in rocketsonde observations. *J. Geophys. Res*., **107**, 10.1029/2001JD000922

Kang, I.-S., K. Jin, K.-M. Lau, J. Shukla, V. Krishnamurthy, S.D. Schubert, D.E. Waliser, W.F. Stern, V. Satyan, A. Kitoh, G.A. Meehl, M. Kanamitsu, V. Ya. Galin, J.-K. Kim, A. Sumi, G. Wu, and Y. Liu, Intercomparison of Atmospheric GCM Simulated Anomalies Associated with the 1997/98 El Niño. *J. Climate*, **15**, 2791-2805.

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APPENDIX 8. 2002 AWARDS/HONORS/MEMBERSHIPS/ EDITORSHIPS

SOUNDER RESEARCH TEAM

Lena Iredell:

DAO/SRT Outstanding Performance Award, January 7.
Member of American Meteorological Society (AMS).

DATA ASSIMILATION OFFICE

Stephen Cohn:

Editor of Monthly Weather Review.

Siegfried Schubert:

Editor of the Journal of Climate.
Adjunct Associate Professorship within the Earth System Science Interdisciplinary Center (ESSIC) at the University of Maryland.
Member of AGU and AMS.

Man-Li C. Wu:

GSFC Performance Award, May 5.

Doug Collins, John Rosenfelder, Ann Melton, Manina Almeida, and Sarah Jackson:

DAO/SRT Group Achievement Award.

MESOSCALE ATMOSPHERIC PROCESSES BRANCH

Scott Braun:

NASA Group Achievement Award, “Fourth Convection and Moisture Experiment (CAMEX4) Science Team,” June 2002.

Scott Curtis:

Laboratory for Atmospheres Best Senior Author Publication Award, 2002.

Jeffrey Halverson:

NASA Group Achievement Award, “Fourth Convection and Moisture Experiment (CAMEX4) Science Team,” June 2002.

Gerald Heymsfield:

NASA Group Achievement Award, “Fourth Convection and Moisture Experiment (CAMEX4) Science Team,” June 2002.

George J. Huffman:

NASA GSFC Laboratory for Atmospheres Contractor Award for Outstanding Performance in Science, 2002.

Andrew Negri:

Outstanding Research Paper (Peer) Award, Laboratory for Atmosphere, 2002.

Biswadev Roy:

NASA Group Achievement Award, “Fourth Convection and Moisture Experiment (CAMEX4) Science Team,” June 2002.

Geary Schwemmer:

Chairman, AMS Committee on Laser Atmospheric Studies, 2002.
Laser Focus World Commendation for Excellence in Technical Communications, 2002.

J. Marshall Shepherd:

Nominated for Presidential Early Career Award, 2002.
Recipient of NASA New Investigator Program Award, 2002.
Serves on Howard University NOAA Center for Atmospheric Sciences Advisory Committee, 2002.
Served on AMS Committee on Satellite Meteorology, 2002.
Served on Code 910 Peer Award Selection Committee, 2002.

David O'C. Starr:

Secretary, International Commission on Clouds and Precipitation

Wei-Kuo Tao:

Guest Editor, AMS Meteorological Monographs-Cloud Systems, Hurricanes and TRMM, 2002.
Editor, AMS Journal of Atmospheric Sciences, 2002.
Chair, AGU Committee on Precipitation and Cloud, 2002.

Lin Tian:

NASA Group Achievement Award, "Fourth Convection and Moisture Experiment (CAMEX4) Science Team," June 2002.

David Whiteman:

Allen Prize, Optical Society of America, 2002.

CLIMATE AND RADIATION BRANCH

Robert Cahalan:

2002 Excellence in Technical Communications Award (Laser Focus World).

Winston Chao:

2002 Special Act Award (Scientific Research) from GSFC.

Prabhakara Cuddapah:

2002 Special Act Award (Scientific Research) from GSFC.

Yoram Kaufman:

2002 Goddard Senior Fellow.

Yogesh Sud:

2002 Earth Science Achievement Award from GSFC.

Si-Chee Tsay:

2002 Technical Engineering Award from GSFC.
2002 NASA Exceptional Scientific Achievement Award.

Julio Bacmeister (GEST):

2002 Climate and Radiation Best Paper Award.

Baode Chen (GEST):

2002 Climate and Radiation Scientific Achievement Award.

David Herring (Earth Observatory Group) (SSAI):

2002 People's Voice Award for Science (Webby Award from the International Academy of Digital Arts and Sciences).

ATMOSPHERIC CHEMISTRY AND DYNAMICS BRANCH

Arlyn E. Andrews:
Performance Award, NASA GSFC.

Anne M. Thompson:
Fellow, American Association for the Advancement of Science (AAAS).

Anne R. Douglass:
Special Act Award, NASA GSFC.

UARS Team:
UARS Project Science Office in Code 916, William T. Pecora Award.

Paul A. Newman:
Arthur S. Flemming Award, Jaycees.

APPENDIX 9. 2002 Acronyms

3S	Sun-Sky-Surface photometer
ACE-Asia	Aerosol Characterization Experiment-Asia
ACMAP	Atmospheric Chemistry Modeling and Analysis Program
ACS	American Chemical Society
ADEOS	Advanced Earth Observation Satellite
AERONET	Aerosol Robotic Network
AETD	Applied Engineering and Technology Directorate
AGCM	Atmospheric Global Circulation Model
AI	Aerosol Index
AIRS	Atmospheric Infrared Sounder
AL	Aerosol Lidar
AMS	American Meteorological Society
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
ARM	Atmospheric Radiation Measurement
ARM CART	ARM Cloud and Radiation Test Bed
AROTAL	Airborne Raman Ozone, Temperature, and Aerosol Lidar
ARREX	Aerosol Recirculation and Rainfall Experiment
AT Lidar	Aerosol and Temperature Lidar
ATMS	Advanced Technology Microwave Sounder
ATOVS	Advanced TOVS
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
BASE-ASIA	Biomass-burning Aerosols in South East-Asia: Smoke Impact Assessment
BUV	backscatter ultraviolet
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAMEX	Convection And Moisture EXperiment
CCAST	Cooperative Center for Atmospheric Science and Technology
CCD	Convective Cloud Differential
CDC	Centers for Disease Control and Prevention
CEAS	Center for Earth-Atmosphere Studies
CEDAR	Coupling, Energetics and Dynamics of Atmospheric Regions
CERES	Clouds and the Earth's Radiant Energy System
CFCs	Chlorofluorocarbons
CHINA-TEA	Climate & Health Impacts in North/east Asia-Tropospheric Experiment on Aerosols
CHyMERA	Compact Hyperspectral Mapper for Environmental Remote Sensing Applications
CIFAR	Cooperative Institute for Atmospheric Research
CIMSS	Cooperative Institute of Meteorological Satellite Studies
CLAMS	Chesapeake Lighthouse and Aircraft Measurements for Satellites
CLIVAR	Climate Variability and Predictability Programme
CNES	Center Nationale d'Etude Spatiales
Co-I	Co-Investigator
COMMIT	Chemical, Optical, and Microphysical Measurements of In-situ Troposphere
CONTOUR	Comet Nucleus Tour
COVIR	Compact Visible and Infrared Radiometer
CPL	Cloud Physics Lidar
CrIS	Crosstrack Infrared Sounder

CRS	Cloud Radar System
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers-Florida Area Cirrus Experiment
CSIRO	Commonwealth Scientific Industrial Research Organization
CSTEA	Center for the Study of Terrestrial and Extraterrestrial Atmospheres
CTM	Chemical Transport Model
DAAC	Distributed Active Archive Center
DAO	Data Assimilation Office
DAS	Data Assimilation System
DDF	Director’s Discretionary Fund
DDR	Detailed Design Review
DIAL	DIfferential Absorption Lidar
DISS	Distributed Image Spreadsheet
DMSP	Defense Meteorological Satellite Program
DSCOVR	Deep Space Climate Observatory Project (formerly Triana)
DWP	Doppler Wind Lidar
ECS	EOSDIS Core System
ECSO	Executive Committee for Science Outreach
EDOP	ER-2 Doppler Radar
EDR	Environmental Data Record
EMC	NCEP’s Environmental Modeling Center
ENSO	El Niño Southern Oscillation
ENVISAT	Environmental Satellite
EO3	Earth Observing 3 mission called GIFTS
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EPA	Environmental Protection Agency
EPIC	Earth Polychromatic Imaging Camera
EP-TOMS	Earth Probe TOMS
ERBE	Earth Radiation Budget Experiment
ERBE TOA	Earth Radiation Budget Experiment Top-Of-Atmosphere
ERBS	Earth Radiation Budget Satellite
ESA	European Space Agency
ESE	Earth Science Enterprise
ESPI	ENSO Precipitation Index
ESSIC	Earth System Science Interdisciplinary Center
ESSP	Earth System Science Pathfinder
ESTO	Earth Science Technology Office
ESTO/ACT	Earth Science Technology Office/Advanced Component Technologies
E-Theater	Electronic Theater
FFPA	filter/focal plane array
FvDAS	Finite volume data assimilation system
GADS	Global Aircraft Data Set
GATE	GARP Atlantic Tropical Experiment
GCE	Goddard Cumulus Ensemble model
GCM	General Circulation Model
GCMS	Gas Chromatograph Mass Spectrometer
GEOS	Goddard Earth Observing System
GEST Center	Goddard Earth Sciences and Technology Center
GEWEX	Global Energy and Water Cycle Experiment

GIFTS	Geosynchronous Imaging Fourier Transform Spectrometer
GIS	Geographical Information Systems
GISS	Goddard Institute for Space Studies
GLAS	Geoscience Laser Altimeter System
GLOBE	Global Learning and Observations to Benefit the Environment
GLOW	Goddard Lidar Observatory for Winds
GMS	Geostationary Meteorological Satellite
GOCART	Global Ozone Chemistry Aerosol Radiation Transport
GOES	Geostationary Operational Environmental Satellite
GoHFAS	Goddard Howard University Fellowship in Atmospheric Sciences
GOME	Global Ozone Monitoring Experiment
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Measurement
GPS	Global Positioning Satellite
GSFC	Goddard Space Flight Center
GSRP	Graduate Student Researchers Program
GSWP	Global Soil Wetness Project
GTE	Global Tropospheric Experiment
GTWS	Global Tropospheric Wind Sounder
GV	Ground Validation
GVP	Ground Validation Program
HARGLO-2	Intercomparison of Wind Profile Systems experiment involving the HARLIE and GLOW instruments
HARLIE	Holographic Airborne Rotating Lidar Instrument Experiment
HBCUs	Historically Black Colleges and Universities
HDTV	High Definition TV
HIRDLS	High Resolution Dynamics Limb Sounder
HIRS	High Resolution Infrared Sounder
HOTS	Holographic Optical Telescope and Scanner
HSB	Humidity Sounder Brazil
HU	Howard University
HUPAS	Howard University Program in Atmospheric Sciences
I3RC	Intercomparison of 3D Radiation Codes
IAMAS	International Association of Meteorology and Atmospheric Sciences
ICESat	Ice, Cloud, and Land Elevation Satellite
IGS	Internal Government Studies
IHOP	International H_20 Project
IIP	Instrument Incubator Program
INDOEX	Indian Ocean Experiment
INMS	Ion and Neutral Mass Spectrometer
INPE	Instituto Nacional de Pesquisas Espaciais (Institute for Space Research)
INSAT	India’s Geosynchronous Satellite
IORD	Integrated Operational Requirements Document
IPCC	International Panel on Climatic Change
IPO	Integrated Program Office
IR	infrared
ISAS	Institute of Space and Aeronautical Science
ISCCP	International Satellite Cloud Climatology Project
ISIR	Infrared Spectral Imaging Radiometer

ITCZ	Intertropical Convergence Zone
JARG	Joint Agency Requirements Group
JCET	Joint Center for Earth Systems Technology
JCOSS	Joint Center for Observation System Science
JCSDA	Joint Center for Satellite Data Assimilation
JHU/APL	Johns Hopkins University Applied Physics Laboratory
JIESIC	Joint Interdisciplinary Earth Science Information Center (with George Mason University)
JPL	Jet Propulsion Laboratory
KNMI	Royal Netherlands Meteorological Institute
L2-SVIP	Lagrange-2 Solar Viewing Interferometer Prototype
LaRC	Langley Research Center
LAS	Leonardo Airborne Simulator
LASAL	Large Aperture Scanning Airborne Lidar
LORE	Limb Ozone Retrieval Experiment
LRR	Lightweight Rainfall Radiometer
MBA	microbolometer array
MBL	Marine Boundary Layer
MEIDEX	Mediterranean Israeli Dust Experiment
MEMS	Micro Electro Mechanical Systems
Metop	future European POES satellites
MISR	Multi-Angle Imaging Spectroradiometer
MIT	Massachusetts Institute of Technology
MLS	Microwave Limb Sounder
MM5	Mesoscale Model 5
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITT	Measurements of Pollution in the Troposphere
MPI	Message Passing Interface
MPL	Micro Pulse Lidar
MPLNET	Micro Pulse Lidar Network
MSU	Microwave Sounding Unit
MTR	Management Technical Review
NAS	NASA Advanced Supercomputing Division
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency
NCAR	National Center for Atmospheric Research
NCCS	NASA Center for Computational Sciences
NCEP	National Center for Environmental Prediction
NDSC	Network for the Detection of Stratospheric Change
NESDIS	National Environmental Satellite Data and Information Service
NGI	Next Generation Internet
NGIMS	Neutral Gas and Ion Mass Spectrometer
NIEHS	National Institute of Environmental Health Sciences
NIIEM	Russian Scientific Research Institute of Electromechanics
NIST	National Institutes of Standards and Technology
NMNH	National Museum of Natural History
NMS	Neutral Mass Spectrometer
NOAA	National Oceanic Atmospheric Administration
NOAA CMDL	NOAA Climate Monitoring and Diagnostics Laboratory
NPOESS	National Polar Orbiting Environmental Satellite System

NPOL	NASA Polarimetric Radar
NPP	NPOESS Preparatory Project
NRC	National Research Council
NRL	Naval Research Laboratory
NSCAT	NASA Scatterometer
NSF	National Science Foundation
NSIPP	NASA Seasonal-to-Interannual Prediction Project
NTSC	National Television Standards Committee
NWP	Numerical Weather Prediction
NWS	National Weather Service
OAT	Operation Algorithm Team
ODIN	a Swedish small satellite project for astronomical and atmospheric research
OGO	Orbiting Geophysical Observatory
OLR	Outgoing Longwave Radiation
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapper and Profiler System
OSE	Observing System Experiment
OSIRIS	ODIN Spectrometer and IR Imager System
OSSE	Observing System Simulation Experiment
PACJET	Pacific Landfalling Jets Experiment
PBL	Planetary Boundary Layer
PI	Principal Investigator
PICASSO-CENA	Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations-Climatologie Etendue des Nuages et des Aerosols
PLACE	Parameterization for Land Atmosphere Cloud Exchange
POAM	Polar Ozone and Aerosol Measurement
POES	Polar Orbiting Environmental Satellite
PR	Precipitation Radar
PRESTORM	Oklahoma-Kansas Preliminary Regional Experiment for STORM-Central
PRiDE	Puerto Rico Dust Experiment
PSAS	Physical-space Statistical Analysis System
PSC	Polar stratospheric clouds
QEM	Quality Education for Minorities
QuikSCAT	(NASA's) Quick Scatterometer satellite
RASL	Raman Airborne Spectroscopic Lidar
RCDF	Radiometric Calibration and Development Facility
RDAS	Retrospective data assimilation system
RTOP	Research and Technology Objectives and Plans
RTOVS	Revised TIROS-N Operational Vertical Sounder
SACZ	South Atlantic Convergence Zone
SAFARI	Southern Africa Fire-Atmosphere Research Initiative
SAGE	Stratospheric Aerosol and Gas Experiment
SBIR	Small Business Innovative Research
SBUV	Solar Backscatter Ultraviolet
SBUV/2	Solar Backscatter Ultraviolet/version 2
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SCO	stratospheric column ozone
SCSMEX	South China Sea Monsoon Experiment
SeaWiFS	Sea-viewing Wide Field-of-View Sensor

SERDP	Strategic Environmental Research and Development Program
SHADOZ	Southern Hemisphere ADditional OZonesondes
SHARP	Summer High School Apprenticeship Research Program
SIMBIOS	Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies
SLAM	Small Lidar Advanced Measurement
SLP	Sea Level Pressure
SMART	Surface-sensing Measurements for Atmospheric Radiative Transfer
SMiR	Scanning Microwave Radiometer
SO	Southern Oscillation
SOARS	Significant Opportunities in Atmospheric Research and Science
SOAT	Sounder Operation Algorithm Teams
SOLAS	Surface Ocean Lower Atmosphere Studies
SOLSE/LORE	Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment
SOLVE	SAGE III Ozone Loss and Validation Experiment
SORCE	SOlar Radiation and Climate Experiment
SPANDAR	Space Range Radar, Wallops Island, Virginia
SPCZ	South Pacific Convergence Zone
SPIE	Society of Photo-Optical Instrumentation Engineers
SPRL	Space Physics Research Laboratory
SRL	Scanning Raman Lidar
SRT	Sounder Research Team
SSBUV	Shuttle Solar Backscatter Ultraviolet
SSE	Space Science Enterprise
SSM/I	Special Sensor Microwave Imager
SST	sea surface temperature
SSU	Spectral Sensor Unit
STAAC	Systems, Technology, and Advanced Concepts Directorate
STROZ LITE	Stratospheric Ozone Lidar Trailer Experiment
STS	Space Transportation System
TCO	tropospheric column ozone
TES	Tropospheric Emission Spectrometer
THOR	cloud THickness from Offbeam Returns
THORPEX	THe Observing-system Research and Predictability Experiment
TIM	Technical Interchange Meeting
TIMED	Thermosphere Ionosphere Mesosphere Energetics and Dynamics
TMI	TRMM Microwave Imager
TOGA-COARE	Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Topography Experiment
TOVS	TIROS Operational Vertical Sounder
TPW	total precipitable water
TRACE-P	TRAnsport and Chemical Evolution over the Pacific
TRMM	Tropical Rainfall Measuring Mission
TRMM KWAJEX	TRMM Kwajalein Experiment
TRMM LBA	TRMM Large Scale Biosphere-Atmosphere Experiment in Amazonia
TRR	Test Readiness Review
TSVO	TRMM Satellite Validation Office
UARS	Upper Atmosphere Research Satellite
UAV	Unmanned Aerial Vehicle

UCAR	University Corporation for Atmospheric Research
UCLA	University of California - Los Angeles
UHI	Urban Heat Island
UMBC	University of Maryland Baltimore County
UMCP	University of Maryland College Park
UNEP	United Nations Environment Programme
URF	University Research Foundation
USRA	Universities Space Research Association
USWRP	U.S. Weather Research Program
UV	ultraviolet
UV-B	ultraviolet-B radiation
VAL	Visualization Analysis Laboratory
VSEP	Visiting Student Enrichment Program
WCRP	World Climate Research Programme
WHO	World Health Organization
WMO	World Meteorological Organization
WMO/UNEP	WMO/United Nations Environment Programme
WVTs	Water vapor tracers