5. MAJOR ACTIVITIES

In the previous section, we provided a snapshot of the activities we pursue in the Laboratory for Atmospheres. Let's have a closer look. This section presents a more complete picture of our work in measurements, data sets, data analysis, and modeling. In addition, we'll discuss the Laboratory's support for the National Oceanic Atmospheric Administration's (NOAA) remote sensing requirements. Section 5 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. All instrument systems perform one or both of these functions:

- Providing information leading to a basic understanding of the relationship between atmospheric systems and processes
- Serving as calibration references for satellite instrument validation, or perform both functions

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 let us view such atmospheric processes as precipitation and cloud systems from a high-altitude vantage point but still within the atmosphere. Such platforms serve as a step in the development of spaceborne instruments.

Table II shows the principal instruments that have 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 or balloons, or on the ground. Further information on each instrument appears on the pages following Table II. The four instruments that were completed under the Instrument Incubator Program (IIP) are identified by the IIP acronym.

Table II: 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) QuikTOMS Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE) – Shuttle Earth Polchromatic Imaging Camera (EPIC) – Triana	**IIP**: COmpact Vis IR (COVIR) – Shuttle	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	Large Aperture Scanning Airborne Lidar (LASAL) ER-2 Doppler Radar (EDOP) Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)	Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTEL) **IIP**: Raman Airborne Spectroscopic Lidar (RASL)	Cloud Physics Lidar (CPL) Leonardo Airborne Simulator (LAS) Cloud Radar System (CRS)	
Ground/ Laboratory	Scanning Raman Lidar (SRL) Goddard Lidar Observatory for Winds (GLOW) **IIP**: Lightweight Rain Radiometer	Stratospheric Ozone Lidar Trailer Experiment (STROZ LITE) Tropospheric Ozone Lidar **IIP**: Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA) Aerosol and Temperature Lidar (AT Lidar)	Micro Pulse Lidar (MPL) cloud THickness from Offbeam Returns (THOR) Lidar Scanning Microwave Radiometer (SMiR) Surface Measurements for Atmospheric Radiative Transfer (SMART) The Sun-Sky-Surface photometer (3S)	

Spacecraft-Based Instruments (launch dates are in parentheses)

The ***Total Ozone Mapping Spectrometer (TOMS)*** on Earth Probe (EP) has provided daily mapping and long-term trend determination of total ozone, surface UV radiation, volcanic SO_2, and UV-absorbing aerosols (1996). For further information, contact Richard McPeters (Richard.D.McPeters.1@gsfc.nasa.gov).

The ***QuikTOMS*** Project will provide for continuity of the TOMS database beyond the TOMS-EP mission. A one-year overlap with TOMS-EP is desired for intercomparison of data and calibration (2001). For further information, contact Richard McPeters (Richard.D.McPeters.1@gsfc.nasa.gov).

The ***Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE)*** measured ozone profiles from the stratosphere down to the tropopause with high vertical resolution in 1997. SOLSE is a grating spectrometer that measured ozone in the upper stratosphere, while LORE is a filter radiometer that measured ozone in the lower stratosphere. The instruments are being reconfigured to more accurately simulate the performance expected from the Ozone Mapper and Profiler System (OMPS). A reflight is manifested on STS 107. This will be an important risk mitigation activity for the National Polar Orbiting Environmental Satellite System (NPOESS) ozone instrument (2001). For further information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

Earth Polychromatic Imaging Camera (EPIC) on Triana 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, bi-directional 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). For further information, contact Jay Herman (Jay.R.Herman.1@gsfc.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 multi-sensor 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. For further information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.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.1@gsfc.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.1@gsfc.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.1@gsfc.nasa.gov).

The ***Neutral Gas and Ion Mass Spectrometer (NGIMS)*** on the Comet Nucleus Tour (CONTOUR) mission will provide detailed compositional data on both gas and dust in the near-nucleus environment at precisions comparable to those of Giotto or better (2002). For further information, contact Paul Mahaffy (Paul.R.Mahaffy.1@gsfc.nasa.gov).

Aircraft-Based Instruments

The ***Large Aperture Scanning Airborne Lidar (LASAL)*** measures atmospheric backscatter with an emphasis on boundary-layer height and structure. Capable of (raster) scanning at up to 90 degrees per second, it provides a three-dimensional view of the aerosol structure of the lower troposphere and boundary layer. For further information, contact Stephen Palm (Stephen.P.Palm.1@gsfc.nasa.gov).

The ***ER-2 Doppler Radar (EDOP)*** measures vertical profiles of rain and winds within precipitation systems to improve our understanding of mesoscale structure of convective systems. The data are also used to validate spaceborne rain measurement algorithms. For further information, contact Gerald Heymsfield (Gerald.M.Heymsfield.1@gsfc.nasa.gov).

The ***Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)*** measures cloud and aerosol structure and dynamics via laser backscatter in three dimensions. Utilizing a unique conical scanning holographic telescope and a diode pumped solid state infrared laser, this compact high-performance lidar fits into low- to medium-altitude aircraft as well as in a portable ground-based environmental housing for relatively low cost field experiment deployments. HARLIE was successfully operated in two ground-based experiments last year to test and improve the technology and to develop a new data product: atmospheric wind profiles. The wind profiles were derived using time-lag correlation techniques on the structures of cloud and aerosol backscatter. HARLIE was also deployed to the ARM CART site in September–October 2000 where it provided video renderings of the atmospheric dynamic environment on a daily basis for nearly three weeks during the ARM Water Vapor Intensive Operating Period (IOP). The data from this campaign are being analyzed to provide ancillary wind profiles, boundary layer parameters, cloud statistics, and 1-micron backscatter profiles for the entire IOP. HARLIE has flown successfully on the NASA F-27 aircraft on engineering test flights. The next funded application is in an Army experiment in 2002 as a ground-based sensor to map dust plumes from troop activities at a major Army playground, tentatively Fort Bliss in El Paso, TX. This activity is part of EPA mandated studies in collaboration with investigators from Desert Research Institute. The size and weight and other technical aspects of the instrument, such as data products, are described on the HARLIE Web page: http://bll.gsfc.nasa.gov/harlie/. For further information contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

The GSFC ***Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTEL)*** is a two wavelength lidar system (308 nm and 355 nm) that detects two elastically scattered wavelengths and N_2-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 Langley 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. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Raman Airborne Spectroscopic Lidar (RASL)*** is currently being developed under NASA's Instrument Incubator Program (IIP) in collaboration with the Laboratory for Terrestrial Physics (David N. Whiteman, Code 924 is the PI). The instrument will address a large number of high priority atmospheric science measurement requirements, including water vapor, aerosol scattering, extinction, optical depth, depolarization, temperature, cloud liquid water amount and drop size, and cloud top and bottom heights. Through the use of a broadband spectrometer, full spectral tuning across the entire Raman band will also be possible, allowing us to attempt other experimental measurements such as cloud droplet temperature. RASL is on schedule for completion late in CY 2001. For further information contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

The ***Cloud Physics Lidar (CPL)*** measures cloud and aerosol structure from the high-altitude ER-2 aircraft, in combination with multispectral visible, microwave, and infrared imaging radiometers. The instrument operates at 1064, 532, and 355 nm wavelengths with a repetition rate of 5 kHz. The data are used in radiation and remote-sensing studies. For further information, contact Matthew McGill (Matthew.J.McGill.1@gsfc.nasa.gov).

The ***Leonardo Airborne Simulator (LAS)*** is an imaging spectrometer (hyperspectral) with moderate spectral resolutions. LAS will measure reflected solar radiation to retrieve atmospheric properties such as column water vapor amount, aerosol loadings, cloud properties, and surface characteristics. This instrument is currently under development and was successfully deployed in a series of SAFARI related campaigns in 1999-2000. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Cloud Radar System (CRS)*** is a 94 GHz millimeter-wave Doppler radar system for measuring cirrus clouds and precipitation with smaller 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. For further information, contact Gerald Heymsfield (Gerald.M.Heymsfield.1@gsfc.nasa.gov).

Ground-Based and Laboratory Instruments

The Scanning Raman Lidar (SRL) measures light scattered by water vapor, nitrogen, oxygen, and aerosols to determine the water vapor mixing ratio, aerosol backscattering, and aerosol extinction, as well as their structure in the troposphere. Measurements from this mobile system are important for studying radiative transfer, convection, and the hydrological cycle. They are also useful for assessing the water and aerosol measurement capabilities of surface-, aircraft-, and satellite-based instruments.

Using the SRL, a new technique was devised for measuring cloud liquid water, mean droplet radius and droplet number density. A new extension to the theory was developed that allows multiple scattering to be quantified. The technique is based on simultaneously measuring Raman and Mie scattering from cloud liquid droplets using the Raman lidar. The intensity of Raman scattering is known to be proportional to the amount of liquid present in cloud droplets. This fact is used as a constraint on calculated Mie intensity to calculate droplet radius and number density. The general relationship of retrieved average radius and number density is consistent with traditional cloud physics models.

A new technique for measuring cloud base altitude using SRL data was also developed. The technique has advantages over conventional elastic backscatter lidar measurements of cloud base during precipitating periods. A combination of the Raman-lidar-derived profiles of water-vapor-mixing ratio and aerosol-scattering ratio, together with the Raman-scattered signals from liquid drops, can minimize or even eliminate some of the problems associated with cloud-boundary detection using elastic lidars. The SRL was deployed to the ARM CART site in Billings, OK, during the ARM Water Vapor IOP in September and October. It was also used later in AFWEX, at the same location. A major objective of the Water Vapor IOP is to resolve discrepancies between various instruments measuring water vapor down to the 2% level. The SRL is a collaborative project with David N. Whiteman, Code 924. For further information, contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

The ***Goddard Lidar Observatory for Winds (GLOW)*** is a mobile Doppler lidar system that measures vertical profiles of wind from the surface to the stratosphere using the double-edge technique. The instrument operates at two wavelengths to measure 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 and lower troposphere and the 355 nm channel provides wind profiles to altitudes as high as 35 km. For further information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The small ***Lightweight Rain Radiometer*** is a Laboratory development under the Instrument Incubator Program (IIP). The radiometer will employ a thinned-array synthetic antenna at 10.7 GHz for future measurements from space. The instrument will provide global high-temporal-resolution precipitation measurements from a constellation of small satellites. For further information, contact Charles E. Cote (Charles.E.Cote.1@gsfc.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). For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Tropospheric Ozone Lidar*** will measure tropospheric ozone at wavelengths that have a large ozone-absorption cross-section. The system will provide validation data for research and development programs aimed at monitoring tropospheric ozone from space. The system is in development to be completed in early 2001. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA)*** instrument is in development under the Instrument Incubator Program (IIP). The primary objective is high-resolution measurement 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.1@gsfc.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. For further information, contact Thomas J. McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Micro Pulse Lidar (MPL)*** makes quantitative measurements of clouds and aerosols. MPL is a unique “eye-safe” lidar system that operates continuously (24 hours a day) in an autonomous fashion. Twenty instruments are currently deployed. In 2000, the MPL program was initiated for continuous lidar monitoring at globally distributed sites. For further information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The cloud ***THickness from Offbeam Returns (THOR) Lidar*** will determine the physical and optical thickness of dense cloud layers from the cloud Green's function, which is the halo of diffuse light up to 0.5 km from the entry point of a lidar beam incident on the cloud layer. Lidar returns at these wide angles are stronger for thicker clouds and are relatively insensitive to cloud microphysics. For further information, contact Robert Cahalan (Robert.F.Cahalan.1@gsfc.nasa.gov).

The ***Scanning Microwave Radiometer (SMiR)*** will measure the column amounts of water vapor and cloud liquid water using discrete microwave frequencies. This instrument was successfully deployed in a series of SAFARI related campaigns in 1999-2000. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Surface 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 many broadband radiometers, shadow-band radiometers, sun photometers, solar spectrometers, 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. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Sun-Sky-Surface photometer (3S)*** fabrication was funded through GSFC/DDF, with the collaboration of 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@gsfc.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 2000, Laboratory personnel supported many such activities as scientific investigators, or as mission participants, in the planning and coordination phases. Field campaigns supported in this way include the following:

The ***Atmospheric Radiation Measurement Program (ARM)*** is a Department of Energy program in which NASA participates. ARM focuses on obtaining field measurements and developing models to better understand the processes that control solar and thermal infrared radiative transfer in the atmosphere, especially in clouds and at the Earth's surface. The goal is to improve the tools used to study global climate change; i.e., General Circulation Models (GCM). Laboratory personnel participate in various aspects of this program, especially the intensive observation periods (IOPs) such as the WISC-T2000 ER-2 EOS Terra validation mission that was coordinated with the Spring 2000 Cloud IOP (CLS), and the Fall 2000 Water Vapor IOP (SRL, HARLIE). For further information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The ***GroundWinds Validation Campaign*** was carried out to validate the performance of ground-based Doppler lidar techniques and to demonstrate the technology used by the University of New Hampshire GroundWinds Doppler Lidar. The experiment was held at the GroundWinds facility in North Conway, NH, and included several active Doppler systems, all simultaneously measuring wind profiles. Regular rawinsonde balloon observations provided further corroborative data. The Goddard Lidar Observatory for Winds (GLOW) provided molecular motion observations in the upper troposphere for comparison with the UNH GroundWinds lidar. In addition to GLOW, NOAA provided a radar profiler and a coherent Doppler lidar measuring aerosol motion in the boundary layer and lower troposphere. The combination of all these data, taken under a variety of atmospheric conditions, will aid in the evaluation of the readiness of Doppler lidar technology to meet NOAA and NASA requirements for space-based wind profiles observations. For further information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The ***Network for the Detection of Stratospheric Change (NDSC)*** is an international program to determine changes in the physical and chemical state of the stratosphere, to obtain data to test and improve multidimensional stratospheric chemical and dynamical models, and to provide independent calibration of satellite instruments. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

Stratospheric Aerosol and Gas Experiment (SAGE) III Ozone Loss and Validation Experiment (SOLVE) is a measurement campaign designed to examine the processes controlling ozone levels at mid- to-high latitudes. During the winter of 1999-2000, this NASA-sponsored experiment was jointly conducted with the European Commission-sponsored Third European Stratospheric Experiment on Ozone (THESEO 2000). Direct observations using the NASA ER-2 and DC-8 aircraft have confirmed that polar stratospheric clouds (PSCs) are key components of the ozone loss process. Further, we now understand how these cloud particles modify the stratosphere as they slowly fall. Such information will be applied in both diagnostic and assessment models for more accurate predictions of changes of stratospheric ozone. For further information, contact Paul A. Newman (Paul.A.Newman.1@gsfc.nasa.gov).

The ***Southern Africa Fire-Atmosphere Research Initiative (SAFARI)*** focused on biomass burning in the Savannah region of southern Africa. SAFARI is a critical part of EOS Terra (MODIS, MOPITT, MISR, CERES, and ASTER) science and validation mission in collaboration with international research communities. Opportunities to study Namibian marine stratus clouds at the end of SAFARI-2000 were also taken. This marked one of the most aggressive and successful coupled ground-based, *in situ*, and remote sensing campaigns ever in Africa. Our key objectives were to understand the linkages between land-atmosphere processes and to understand the relationship of biogenic, pyrogenic, or anthropogenic emissions and the consequences of their deposition to the biogeophysical and biogeochemical systems of southern Africa.

This campaign involved two aircraft and an array of instruments. Both the NASA ER-2 aircraft and the University of Washington CV-580 participated in SAFARI. Primary instruments of interest for the ER-2 are the MAS, MOPITT-A, AirMISR, SSFR, LAS, S-HIS (these simulating Terra instruments), and CPL (a lidar for profiling the atmosphere). The ER-2 coordinated with *in situ* aerosol, radiation, and chemistry measurements on the CV-580 and overflew numerous AERONET locations in Namibia, Botswana, South Africa, Zambia, and Zimbabwe and over the SAVE/SMART site in Skukuza, South Africa. The Cloud Physics Lidar (CPL) on the NASA ER-2 performed well in its first field mission during the SAFARI experiment. The CPL replaced the former CLS and the advances permitted enhanced science capabilities and facilitated more rapid data processing. The initial flights showed heavy aerosol loading capped by strong inversions. Ground-based MPL instruments were installed and worked well in Mongu, Zambia and Skukuza, South Africa.

These ground sites were part of the SAFARI campaign. They provided monitoring of the elevated structure of smoke and haze. The sites also served as ground truth sources for the NASA ER-2 aircraft remote sensing. The Skukuza site will likely become a permanent site for the MPL network project, which is to involve over a dozen globally distributed sites for aerosol and cloud-structure measurements as needed for climate and satellite verification studies.

For more information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov). For more information about SMART, contact Matthew McGill (Matthew.J.McGill.1@gsfc.nasa.gov). For more information about CPL, contact Elsworth Welton (Elsworth.J.Welton.1@gsfc.nasa.gov).

The ***Puerto Rico Dust Experiment (PRiDE, June 2000)*** was designed to measure the properties of Saharan dust transported across the Atlantic Ocean to the Caribbean and is a NASA collaborative endeavor with the Office of Naval Research and the University of Miami. In the summer months, moderate quantities of desert dust are observed in the Caribbean. Puerto Rico is the first significant landfall for the dust travelling across the ocean from Africa. The experiment took place June–July 2000. During PRiDE, simultaneous aerosol optical thickness, precipitable water vapor, and downwelling irradiance measurements were made from the SMART and a low-flying aircraft at the time of the Terra/MODIS overpass. Analyses of PRiDE measurements will lead us to a better understanding of dust optical, microphysical, and chemical properties, especially the significant parameters of dust single scattering albedo and nonsphericity. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The International Global Atmospheric Chemistry program has organized a series of ***Aerosol Characterization Experiments (ACE-Asia)*** to acquire data sets needed for assessing aerosol effects in major regions of the globe. ACE-Asia is designed to study the compelling variability in spatial and temporal scales of both pollution-derived and naturally occurring aerosols. These aerosols often exist in high concentrations over eastern Asia and along the rim of the western Pacific. Phase-I of ACE-Asia will be conducted from March –May 2001 in the vicinity of the Gobi desert, the east coast of China, the Yellow Sea, and Japan, along the pathway of Kosa (severe events that blanket east Asia with yellow desert dust, peaking in spring). For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Boundary Layer Dynamics Lidar*** group organized a joint field experiment to study the interaction between gravity waves and active marine boundary layer convection induced by cold air outbreaks off the Atlantic Coast during late fall and winter months, when the air-sea temperature differences are greatest. These episodes often lead to the development of cloud streets, long parallel linear features in the clouds in the first few days following the cold frontal passage. The mechanism for the formation of these features has been a matter of some debate with boundary-layer meteorologists. Are they caused by alternating helical roles within the boundary layer? Or are they merely organizing themselves under the crests of gravity waves induced by shear at the top of the marine boundary layer? Are the structures present in the pre-cloud environment? Is significant momentum transfer taking place as a result of any gravity wave activity under these conditions? Assembling atmospheric remote-sensing instrument experimenters and boundary layer theoreticians from several universities in the U. S. and Europe, we hope to answer these and other questions with airborne measurements in a field experiment dubbed Convective Wave Experiment (COWEX). For further information, contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

Data Sets

In the previous discussion, we examined the array of instruments we use to gather weather and climate data. Once we have obtained the raw data from these instruments, we arrange the information into data sets useful for studying various atmospheric phenomena.

Televised Infrared Operational Satellite (TIROS) Operational Vertical Sounder Pathfinder

The Pathfinder Projects are joint NOAA/NASA efforts to produce multi-year 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 1979-2000 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 15 and 16 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 21-year TOVS Pathfinder Path A data set. We are developing improved methodologies to analyze ATOVS data to produce a future climate data set and also to use in conjunction with the DAO data assimilation system to improve analyses and numerical weather prediction skill. 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@gsfc.nasa.gov).

Tropospheric Ozone Data

Gridded data sets on tropospheric column ozone (TCO) and stratospheric column ozone (SCO) in the tropics for 1979-present are now available from NASA Goddard Space Flight Center via either direct ftp, World Wide Web, or electronic mail. Until recently, the primary method to derive TCO and SCO from satellite data was by combining TOMS and SAGE ozone measurements. At NASA Goddard, 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]. Further details regarding methodology and new adjustments made for aerosol contamination are discussed in Ziemke et al. [Bull. Amer. Meteorol. Soc., 81,580-583, 2000]. These data have recently been used in several published studies within Code 916 to characterize tropospheric ozone variabilities from monthly to decadal time scales. The CCD, TCO, and SCO data may be obtained via World Wide Web (http://hyperion.gsfc.nasa.gov/Data_services/Data.html). For more information, contact Sushil Chandra (Sushil.Chandra.1@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 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 non-absorbing 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 index provides excellent information about sources, transport, and seasonal variation of a variety of aerosol types. Work is currently in progress to release the data relating the index to aerosol optical thickness and single-scatter albedo. For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.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 has been 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 12.5-year data set (from July 1987 through December 1999) 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.1@gsfc.nasa.gov).

Global Precipitation Data Set

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, NC), at the Goddard Distributed Active Archive Center (DAAC), and at the Global Precipitation Climatology Centre (located at the Deutscher Wetterdienst in Offenbach, Germany). 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 observation. 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 3-hr resolution rainfall analysis combining TRMM and other satellite data is being developed and is currently being tested. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

SHADOZ (Southern Hemisphere ADditional OZonesondes) Data Set

The first-archived data set dedicated to tropical and sub-tropical ozonesonde profiles is coordinated in Code 916 within the Laboratory. Initiated three years ago in a unique effort to fill in gaps in the tropical ozone profile record, SHADOZ (Southern Hemisphere ADditional OZonesondes) meets community needs for development of ozone-retrieval satellite algorithms, validation of new ozone products, global chemical-transport model evaluation and for basic understanding of ozone in the tropics [Thompson et al., 2000]. With weekly ozonesonde launches at ten tropical stations, and occasional tropical field campaigns, SHADOZ has supplied high-quality ozone and temperature profiles to ~35 km and relative humidity to 12 km, since 1998. In less than 3 years, over 900 profiles have been added to the world's ozone data record. Thompson, A M., J. C. Witte, F. J. Schmidlin, S. J. Oltmans, R. D. McPeters, "SHADOZ (Southern Hemisphere ADditional OZonesondes): An Ozonesonde Network for Satellite Validation, Climatology and Modeling, " Extended Abstract Volume, 32nd Quadrennial Ozone Symposium, Sapporo, Japan, NASDA, Tokyo, 3-8 July 2000. For more information, contact Anne Thompson, (Anne.M.Thompson.1@gsfc.nasa.gov).

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

The fluxes of momentum (or wind stress), latent heat (due to evaporation), and sensible heat, called turbulent fluxes, at the global ocean surface are essential to weather, climate, and ocean problems. These fluxes are required for driving ocean models and validating coupled ocean-atmosphere global models, as well as performing climate studies. The Special Sensor Microwave/Imagers (SSM/I) aboard three Defense Meteorological Satellite Program (DMSP) satellites have provided near-global coverage with improved coverage, spatial resolution, and accuracy over prior passive microwave instruments. Laboratory scientists have developed methodology to produce the Version 1 data set of Goddard Satellite-Based Surface Turbulent Fluxes (GSSTF) from the SSM/I radiances and other data. It provides daily- and monthly-mean turbulent fluxes and some relevant parameters over global oceans for the period July 1987-December 1994 and the 1988-1994 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 lowest 500-m bottom-layer precipitable water. Its resolution is 2.0^{o} x 2.5^{o} lat-long. The data set is archived at the Goddard Distributed Active Archive Center (DAAC) and participates in the SEAFLUX Ocean Surface Turbulent Flux Project for comparison with other flux data sets. For more information, contact Shu-Hsien Chou (Shu-Hsien.Chou.1@gsfc.nasa.gov).

Data Analysis

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.1@gsfc.nasa.gov).

Total Column Ozone and Vertical Profile

Laboratory for Atmospheres scientists have been involved in measuring ozone since the late 1960s when a satellite instrument, the Backscatter Ultraviolet (BUV) Spectrometer, was launched on NASA's Nimbus4 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.1@gsfc.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 multi-year data set of surface UV flux generated from TOMS data and high-quality ground-based measurements, we are increasingly able to quantify the respective roles of ozone, aerosols, and clouds in controlling the surface UV flux over the globe. While the agreement between satellite and ground-based measurements of surface UB flux is becoming good, the satellite data covers regions not normally accessible by the ground-based instruments (e.g., oceans, deserts, etc.). For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

Data Assimilation

The DAO in the Laboratory 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 must be given to insuring 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.1@gsfc.nasa.gov).

Observing System Simulation Experiments

Since the advent of meteorological satellites in the 1960s, considerable research effort has been directed toward designing space-borne 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. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Seasonal-to-Interannual Variability and Prediction

Climate research seeks 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 seasonal-to-interannual variability. The key areas of research include the El Niño Southern Oscillation (ENSO), monsoon variability, interseasonal oscillation, and water vapor and cloud feedback processes. Several advanced analytical techniques are used, including wavelets, multivariate empirical orthogonal functions, singular value decomposition, and nonlinear system analysis.

The Laboratory is also involved in NASA’s Seasonal-to-Interannual Prediction Project (NSIPP). This collaboration between NASA and outside scientists is developing a system to predict El Niño events 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 the host of new high-resolution satellite data. This capability will allow us to better characterize the local and remote physical processes that control regional climates and limit predictability.

Promoting the use of satellite data is a top priority. Important satellite-derived data sets include TOPEX/Poseidon and Jason-1 ocean topography, the Earth Radiation Budget Experiment (ERBE), the International Satellite Cloud Climatology (ISCCP), Advanced Very High Resolution Radiometer (AVHRR), SSM/I, QuikSCAT, MSU, and TOVS Pathfinder data. Data from TRMM and EOS Terra and EOS Aqua platforms will be used extensively, as they become available. For more information, contact William Lau (William.K.Lau.1@gsfc.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 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 tropical 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.1@gsfc.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 world wide 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 will be established with accuracies that meet mission requirements. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

Predicting Errors in Satellite Rainfall Measurements

To use TRMM maps of monthly rainfall, we need some measure of the accuracy of the satellite average. We have developed a statistical model of rain behavior that predicts that the random error in satellite rainfall averages—not including systematic biases that might be present—should depend in a straightforward way on the local average rain amounts and simple measures of rain variability. We have seen behavior consistent with the prediction in a number of studies based on simulations using rain gauges and radar data. The model prediction has recently been confirmed using rain observations from the Defense Meteorological Satellite Program satellites. Based on the model, we are developing a simple method of estimating the error levels in satellite rainfall so that satellite rain products can be accompanied by documented estimates of intrinsic error in the averages provided. [T.L. Bell, P.K. Kundu, and C.D. Kummerow, to appear in *J. Appl. Meteorology*.] For more information, contact Thomas L. Bell (Thomas.L.Bell.1@gsfc.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. For more information, contact Yoram Kaufman (Yoram.J.Kaufman.1@gsfc.nasa.gov).

Laboratory scientists are actively involved in analyzing data recently obtained from national and international campaigns. These campaigns include the Puerto Rico Dust Experiment (PRiDE) and the Southern Africa Fire-Atmosphere Research Initiative, (SAFARI) 2000. For more information, contact Lorraine Remer (Lorraine.A.Remer.1@gsfc.nasa.gov).

Hydrologic Processes and Radiation Studies

Laboratory scientists 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. The observational data include the ERBE radiation budgets, ISCCP clouds data, Geostationary Meteorological Satellite (GMS; Japan) radiances, National Center for Environmental Prediction (NCEP) sea surface temperature, and Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) observations. The models include the Goddard Earth Observing System (GEOS) GCM, the Goddard Cloud Ensemble model (GCE), and an ocean mixed layer model.

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. We also investigate the relative importance of large-scale dynamics and local thermodynamics on clouds and radiation budgets and modulating sea surface temperature. In addition, we assess 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.1@gsfc.nasa.gov).

Earth Observing System Interdisciplinary Investigations

The overall goal of NASA’s EOS Program is to determine the extent, causes, and regional consequences of global climate change. This major scientific challenge will be addressed by more than 20 instruments flown on a series of spacecraft over a period of at least 15 years. In addition to the scientific investigations to be carried out by the instrument scientists, the EOS program also supports various interdisciplinary science investigations. Interdisciplinary investigations, such as the two described below, are designed to improve understanding of the Earth as a system by developing and refining integrated models that will use observations from EOS instruments.

Stratospheric Chemistry and Dynamics

The goal of Laboratory investigations of stratospheric chemistry and dynamics is to separate natural from human-made changes in the Earth’s atmosphere, to determine their effects on ozone, and to assess radiative and dynamical feedbacks. We do this by analyzing stratospheric chemical and dynamical observations from current satellites and from aircraft campaigns. Studies include examining the processes that produce the Antarctic ozone hole and understanding similar processes that are occurring in the northern polar regions. The investigation combines Upper Atmosphere Research Satellite (UARS) data, trajectory modeling, and TOMS observations. This work will continue as new instruments are deployed on aircraft and satellites by the United States and by other nations. For more information, contact Mark Schoeberl (Mark.R.Schoeberl.1@gsfc.nasa.gov).

Regional Land-Atmosphere Climate Simulation System (RELACS)

An end-to-end RELACS system is being developed in the Laboratory. RELACS consists of four components: A nested mesoscale model (MM5), a coupled land surface model, a regional four-dimensional data assimilation (4DDA) component, and a general circulation component. The investigation will provide downscaling of large-scale climate forcings derived from GCM and from 4DDA.

The core component of RELACS is a MM5 derived from the National Center for Atmospheric Research (NCAR)/Pennsylvania State University.

The MM5 is a non-hydrostatic meso-alpha- (200-2000km) and meso-beta- (20-200 km) scale primitive equation model. MM5 is an excellent tool for studying the multi-scale dynamics associated with precipitation processes and their impact on regional hydrological cycles. Improved physics include microphysical processes, radiation, land-soil-vegetation, and ocean mixed-layer processes. These variables have been incorporated to produce realistic simulations of tropical-midlatitude precipitation systems and their relationship to the large-scale environment. Components of the physical package have been tested for various mesoscale convective systems, including monsoon depressions, supercloud clusters, and meso-scale convective complexes. In an effort to develop RELACS, the MM5 has been coupled with the Land Surface Model (LSM), the Parameterization for Land Atmosphere Cloud Exchange (PLACE) model. The MM5-LSM will be nested within the GEOS GCM over continental scale regions in Southeast Asia and in the continental United States.

This approach represents a new Laboratory effort geared toward regional water cycle and climate studies, with emphasis on regional climate and water resource assessment under the Earth Science strategic plan and the science priorities of the US Global Change Research Program (USGCRP). For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Modeling

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 NSIPP, which was established in 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. For more information, contact Max Suarez (Max.J.Suarez.1@gsfc.nasa.gov).

Global Modeling and Data Assimilation

Development of the Data Assimilation System

The DAO currently uses the GEOS-3 DAS to support the EOS Terra Mission. The GEOS-3 DAS is a major upgrade of the GEOS-1 DAS used for the first NASA reanalysis. The GEOS-3 DAS provides data products at a higher horizontal resolution (1° longitude by 1° latitude) and employs a new Physical-space Statistical Analysis System (PSAS). Other improvements include an interactive Mosaic-based land surface model, a state-of-the-art moist turbulence scheme, an on-line estimation and correction procedure for systematic forecast errors, and assimilation of space-borne observations of marine surface winds and total precipitable water. In the next upgrade scheduled before the EOS Aqua launch, the GEOS-3 DAS will be capable of assimilating interactively retrieved TOVS and advanced sounder data and precipitation data from TRMM and SSM/I instruments.

For the EOS-Aqua and beyond, the DAO is developing a next-generation numerical model for climate prediction and data assimilation in collaboration with NCAR. In addition, DAO is developing advanced data assimilation techniques using a combination of Kalman filtering and four-dimensional variational approaches. These techniques will allow us to make better use of synoptic observations. DAO is also developing flow-dependent covariance models to maximize the benefit of high spatial resolution of the observations and of the model. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Development of the Next-Generation Global Model

The DAO is collaborating with the NCAR to develop a unified global general circulation model for climate, numerical weather prediction, data assimilation, and chemical constituent transport applications. The prototype configuration consists of a finite-volume, flux-form semi-Lagrangian dynamic core developed at the DAO, and physical parameterizations and land surface schemes available through NCAR. The DAO dynamic core, which is a candidate for incorporation into the NCAR Community Climate Model version 4 (CCM4), is highly accurate in conservation properties; it also eliminates several known deficiencies of the spectral representation of the dynamic core. For more information, contact Shian-Jiann Lin (Shian-Jiann.Lin.1@gsfc.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 midlatitude deep convective systems, surface (ocean and land; i.e., vegetation and soil) effects on atmospheric convection, cloud-chemistry interactions, and stratospheric-tropospheric interaction. Other important applications include assessment of the potential benefits of assimilating satellite-derived water vapor, winds and precipitation fields on tropical and extra-tropical regional-scale (i.e., hurricanes and cyclones) weather simulations, and climate applications. The latter involve long-term integration of the models and allow 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 and mid-latitude weather systems.

Data collected during several major field programs, TOGA COARE (1992-1993), SCSMEX (1998), TRMM LBA (1999), and TRMM KWAJEX (1999), was used to validate the GCE model. The MM5 was improved in order to study regional climate variation.

The models also are 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. Four-dimensional latent heating structures (5° by 5°, monthly) were retrieved from December 1997 to August 2000. For more information, contact Wei-Kuo Tao (Wei-Kuo.Tao.1@gsfc.nasa.gov).

Physical Parameterization in Atmospheric GCM

The development of physical sub-models of the climate system is an integral part of climate modeling activity. Laboratory scientists are actively involved in developing and improving physical parameterizations of the major radiative transfer and moisture processes in the atmosphere. Both of these areas are extremely important for eliminating model biases and leading 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 material. This scheme incorporates attributes from physically based cloud life cycles, including the effects of downdraft, cloud microphysics within convective towers and anvils, cloud-radiation interactions, and cloud inhomogeneity correction. We are evaluating coupled radiation and the prognostic water schemes with *in situ* observations from the ARM and TOGA-COARE IOPs as well as satellite data. For land-surface processes, a new snow physics package is being evaluated with GWEX GSWP data sets. It is currently in the GEOS GCMs. Moreover, the soil moisture prediction is extended down to 5m, which often goes through the groundwater table. All these improvements are found to better represent the hydrologic cycle in a climate simulation. For more information, contact Yogesh Sud (Yogesh.C.Sud.1@gsfc.nasa.gov).

Trace Gas Modeling

We have 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. The three-dimensional models 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. 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 interannual. 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.

The modeling effort has evolved in four directions: (1) *Lagrangian models* are used to calculate the chemical evolution of an air parcel along trajectory. The Lagrangian modeling effort is primarily used to interpret aircraft and satellite chemical observations. (2) *Two-dimensional (2D) non-interactive 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 (3D) models* 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.

We use 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 2D and 3D models, are critical to the reliability of these models. For more information, contact Anne Douglass (Anne.R.Douglass.1@gsfc.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 fly 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.

Geostationary Operational Environmental Satellites

NASA GSFC project engineering and scientific personnel support NOAA for the GOES operational satellites. GOES supplies images and soundings to study atmospheric processes, such as moisture, winds, clouds, and surface conditions. In particular, GOES observations are used by climate analysts to monitor the diurnal variability of clouds and rainfall and to track the movement of water vapor in the upper troposphere. In addition to high quality imagery, 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. These mesoscale soundings are improving NOAA's numerical forecasts of local weather. The GOES project scientist at Goddard provides free public access to real-time weather images for regions all over the western hemisphere via the World Wide Web (http://rsd.gsfc.nasa.gov/goes/). For more information, contact Dennis Chesters (Dennis.Chesters.1@gsfc.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@gsfc.nasa.gov).

Solar Backscatter Ultraviolet/2

NASA has the responsibility to determine and monitor the pre-launch 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.

We have recently applied an upgraded version 7 algorithm for the total column ozone product being produced from the SBUV/2 data. The algorithm is similar to that now being used to produce TOMS data. It goes further than the TOMS algorithm because the SBUV/2 has extra, shorter wavelengths designed for determination of the profile of concentration of ozone with altitude. One of these wavelengths, 305.6 nm, provides a sensitive measure of total ozone at the equator, where the sun is directly overhead and the column ozone amount is low. We use these equatorial measurements at this so-called "D-pair" wavelength to stabilize any long-term drift in calibration.

Because the SBUV data are now expected to have a stable calibration over time, we have used them to determine possible changes in the calibration of the TOMS instruments. We have adjusted all of the SBUV and TOMS measurements to a common calibration and produced a single merged data set that extends from November 1978 through the end of 2000. This data is available on the Web at http://code916.gsfc.nasa.gov/Data_services/merged/. For more information, contact Richard Stolarski (Richard.S.Stolarski.1@gsfc.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 Operation Algorithm Teams (SOAT), 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 2ppm (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@gsfc.nasa.gov).

For OMPS, Laboratory scientists continue to support the IPO through the Ozone Operational Algorithm Science Team. The team conducts algorithm research and provides oversight for the OMPS developer. We are developing an algorithm to analyze SAGE III data when SAGE III operates in a limb scattering mode. We'll use the algorithm to simulate retrievals expected from the OMPS profiler. This work is an extension of the retrievals used for the SOLSE/LORE mission. 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 (VIS) 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 is supporting a reflight of SOLSE/LORE in the summer of 2001 as a risk mitigation effort related to the OMPS. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

CrIS is a high-spectral-resolution interferometer infrared sounder with capabilities similar to those of the Atmospheric Infrared Sounder (AIRS). CrIS will fly with AMSU A and the Humidity Sounder Brazil (HSB) on the EOS Aqua platform, to be launched in 2001. Scientific personnel have been involved in developing the AIRS Science Team algorithm to analyze the AIRS/AMSU/HSB data. These data 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@gsfc.nasa.gov).

Tropospheric wind 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 on a global scale. The IPO is supporting the effort through their IGS program. For more information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The Instrument Incubator Program is supporting the development of a visible and infrared imaging radiometer based on advanced-technology array detectors. The goal is an imaging radiometer smaller, less costly, and more capable than previous instruments. The program is developing an instrument based on advanced microbolometer array (MBA) warm thermal detectors. A prototype MBA-based instrument, the ISIR, flew as a shuttle small attached payload in August 1997. Its performance proved the capability and advantages for MBA detectors in space applications. The Compact Visible and Infrared Imaging Radiometer (COVIR) is an engineering model of an operational flight instrument and will be completed and tested in 2001. A shuttle flight experiment is planned for early 2003. For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The IPO supports the development of Holographic Scanning Lidar Telescope technology as a risk reduction for lidar applications on NPOESS, including, but not limited to, a direct detection (edge) wind lidar system. 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 our current large aperture scanning receivers by another factor of three. For more information, on the Holographic Optical Telescope and Scanner (HOTS), visit the Web site at http://virl.gsfc.nasa.gov/lazer/index.html or contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.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 III lists project and deputy project scientists for current missions.

Table III: Laboratory for Atmospheres Project and Deputy Project Scientists

PROJECT SCIENTISTS		DEPUTY PROJECT SCIENTISTS	
Name	**Project**	**Name**	**Project**
Pawan K. Bhartia	TOMS	Anne R. Douglass	UARS, EOS Aura
Dennis Chesters	GOES	Ernest Hilsenrath	EOS Aura
Jay Herman	Triana	Arthur Hou	TRMM
Yoram Kaufman*	EOS Terra	Si-Chee Tsay	EOS Terra
Robert Adler	TRMM		
Charles Jackman	UARS		
Mark Schoeberl	EOS Aura		
Joel Susskind	POES		
Robert Cahalan	EOS SORCE		
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	PICASSO-CENA
		P. Newman, M. Schoeberl	SOLVE
		Anne Thompson	SONEX
		Si-Chee Tsay	SAFARI-2000
		Si-Chee Tsay	PRiDE
		Lorraine Remer	PRiDE
		James Spinhirne	SPARCLE

* Through September, 2000, current Project Scientist is Jon Ranson, Code 920.

Interactions with Other Scientific Groups

Interactions with the Academic Community

The Laboratory depends on collaboration with university scientists to achieve its goals. Such relationships make optimum use of government facilities and capabilities and 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. 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.

Prime examples of collaboration between the academic community and the Laboratory include these cooperative agreements with universities:

- Earth System Science Interdisciplinary Center (ESSIC), with the University of Maryland, College Park;
- Joint Center for Earth Systems Technology (JCET), with the University of Maryland, Baltimore County;
- Goddard Earth Sciences and Technology Center (GEST Center), with the University of Maryland, Baltimore County, (and involving Howard University);
- Center for Earth-Atmosphere Studies (CEAS), with Colorado State 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; and
- Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA), with Howard University.

These joint centers have been organized to increase scientific interactions between the Earth Science Directorate at GSFC and the faculty and students at the participating universities.

University and other outside scientists visit the Laboratory for periods ranging from one day to as long as two years. (See Appendix 1 for 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 two years and carry out research in pre-established areas. Visiting Fellows are appointed for up to one 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 2000.)

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 interagency interaction is the new NASA/NOAA/NSF Joint Center for Satellite Data Assimilation (JCSDA), which will expand 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.

Laboratory scientists interact with about twenty foreign agencies, about an equal number of foreign universities, and two foreign companies. The collaborations vary from extended visits for joint missions to brief visits for giving seminars or, perhaps, working on papers. Following the joint US-Japan Workshop on Relationships and Intercomparison of Monsoon Climate Systems, held in our Laboratory, participants agreed to develop pilot research projects involving the US 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, SBIR's, and technology transfer activities. For example, the Goddard Technology Utilization Office (through a contract with Research Triangle) performed an assessment of the Shared Aperture Multiplexed (SAM) Holographic Telescope Invention Disclosure and is pursuing a patent on the invention. We have engaged Houston Advanced Research Center (HARC) and TerraPoint LLC as commercial partners for developing airborne lidar altimetry (terrain mapping) applications of the SAM technology. SAM technology enables large aperture scanning without the use of moving mechanical components. SAM is lighter, by an approximate factor of three, than our previous holographic scanning technology, or an order of magnitude lighter than an equivalent conventional scanning optical telescope. The current concept for the terrain mapping application is to use several wide-field-of-view Holographic Optical Elements (HOEs) multiplexed into a single optic with linear avalanche photodiode arrays to essentially create a push-broom lidar terrain imager. This technology is also contemplated for atmospheric lidar applications such as tropospheric wind sounders.

The Commercial Utilization Office co-sponsored the development of a concept for a low-cost satellite attitude-determination system. This technique will be employed by the ozone monitor to fly on NPOESS. A patent application has been filed.

Matt McGill was presented with the James J. Kerley Award for the year 2000 for his outstanding contributions to technology commercialization. The award is the highest given by the Technology Commercialization Office each year. Matt is the second winner of the award from the Laboratory for Atmospheres.

Successful technology transfer has occurred on a number of other programs in the past and new opportunities will become available in the future. Past examples include the Micro Pulse Lidar (MPL) and holographic optical scanner technology. Industry now develops and markets micro-pulse lidar systems to an international community. Twenty units have been sold and deployed thus far. A licensing agreement with industry permits the use of government-patented holographic telescope technology for commercial application in topographic mapping. 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.