EARTH SCIENCE DIVISION
2006

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ANNUAL REPORT

NASA Ames Research Center

Earth Science Division Annual Report 2006

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http://earthscience.arc.nasa.gov

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EARTH SCIENCE DIVISION: OVERVIEW

R. Stephen Hipskind
Chief

NASA's goal in Earth Science is to "study the Earth from space to advance scientific understanding and meet societal needs." The purpose of NASA's Earth science program is to develop a scientific understanding of Earth's system and its response to natural or human-induced changes and to improve prediction of climate, weather and natural hazards.

The Earth Science Program is unique within NASA. While scientific discovery from space is inherent in the Agency's mission, NASA's programs in Earth science also are central to three important Presidential initiatives: the Climate Change Research Initiative, Global Earth Observation and the Oceans Action Plan.

The Earth Science Division at Ames supports the strategic goals of NASA by addressing the objectives of the Earth Science Research and Applied Sciences Programs administered by the Science Mission Directorate at NASA Headquarters. Six science focus areas comprise the Earth Science Research program: climate change and variability, carbon cycle and ecosystems, Earth surface and interior, atmospheric composition, weather, water and energy cycle. Earth science research projects and tasks at Ames address the priorities established in the science focus areas through development of new instrumentation for Earth observations, calibration and validation of airborne and space borne instruments, ecosystem modeling, evaluation of biospheric processes, and advanced computation and data management. The results from NASA's Earth science research, with the observations, models, and data systems employed to obtain those results, are the input for the Applied Sciences Program. Through partnerships with user organizations, including federal and state agencies, educational institutions, and the commercial sector, the Earth Science Division at Ames extends the utilization of NASA's Earth science research to maximize the benefits to society from the investment in science.

Ames supports NASA's Earth science goals and objectives through a robust program in atmospheric and biospheric science. The Earth Science division has a long heritage in Earth observation and analysis for research and applied science. Unique areas of expertise within the Division include merging of airborne with satellite based observations, numerical modeling, lab studies, instrumentation and information systems development. The Ames Earth Science Division also has the agency lead, through the Earth Science Project Office, of managing NASA major Earth science field campaigns, which span the globe, are multi-center, multi-agency and often conducted with international partners. The division applies the knowledge gained from Earth science research to applications for societal benefit, and maintains a program of education outreach. Key components of the Earth Science Division's research programs include the study of the physical and chemical processes of biogeochemical cycling; the dynamics of terrestrial ecosystems; the chemical and transport processes that determine atmospheric composition, dynamics, and climate; and the physical processes that determine the behavior of the atmosphere on the earth and other solar system bodies.

The Division applies the knowledge gained from Earth science research to applications for societal benefit

Research efforts include environmental concerns related to stratospheric ozone depletion, perturbations in the chemical composition of the atmosphere, and climatic changes resulting from clouds, aerosols, and increasing amounts of greenhouse gases in the Earth's atmosphere. Numerous state-of-the-art instruments are flown successfully each year, and critical data are collected for stratospheric and tropospheric research. At Ames, scientists and technical personnel design, develop, and perform both remote sensing and in situ experimental measurements. In addition they perform computer simulations of atmospheric processes and ecosystems processes to understand exchanges between the biosphere and the atmosphere using both airborne and satellite sensor data. The scientists conceive and develop advanced instrumentation to satisfy the measurement requirements of all supported enterprises emphasizing both airborne and selected spacecraft sensors. Project managers and project scientists provide science mission management and science leadership for major NASA science programs and other agency science programs. Staff scientists conceive and develop applications programs utilizing proven and developing technology. Additionally they transfer developed scientific knowledge and technology to commercial and private interests, national and international governmental agencies and ministries, other disciplines, and educational institutions.

The Airborne Science and Technology Lab (ASTL, formerly the Airborne Sensor Facility), is a research and development effort within the Earth Science Division, which is affiliated with the Ames University Affiliated Research Center (UARC) managed by the University of California at Santa Cruz. The Airborne Sensor Facility (ASF) develops instrumentation for Earth Science investigations, and for calibration and validation studies for the Earth Observing System (EOS). It is tasked with maintaining and operating a suite of facility sensors that are made available to the science community at large through the NASA flight request process. The sensors are flown on various NASA, U.S. Department of Energy, and other aircraft, as required. The ASTL has component laboratories for data processing, flight operations, sensor calibration, systems development, and data telemetry. Current activities are focused on the development and deployment of a new modular remote sensing instrument with selectable spectral coverage. Facility sensors include the Moderate Resolution Imaging Spectrometer (MODIS) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) airborne simulators (the MODIS Airborne Simulator, MAS and the MODIS ASTER instrument, MASTER), which are being used to characterize calibration sites and develop algorithms for the new Terra (EOS AM-1) satellite systems. These data are processed into a calibrated Level-1B product at the ASTL, and delivered to the instrument science teams via the EOS Distributed Active Archive Centers (DAACs). Research results and technology developments are published in the scientific literature. Additionally, many of these results are disseminated to the commercial and educational communities contributing to a better public understanding of Earth Science within NASA.

This report summarizes accomplishments at Ames in research and applied science during 2006. The report focuses first on the science results in the Atmospheric and Biospheric Science branches and the extension of those results to the broader community. Projects and tasks are described separately and linked to the NASA Earth science elements each supports. The reports also includes updates on the support services the Division supplies for airborne science and notes the linkages of aircraft operations to research and applied sciences. Points of contact are included for all the program elements. Readers are invited to contact the appropriate personnel within the Division for more information.

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ATMOSPHERIC SCIENCE BRANCH

Warren J. Gore
Branch Chief

The Atmospheric Science Branch conducts scientific research to advance the scientific knowledge and understanding of the processes that determine the behavior of the atmosphere on Earth. We investigate important environmental and climatic issues in stratospheric chemistry and ozone depletion, climatic changes due to clouds, aerosols, and greenhouse gases, stratosphere-troposphere exchange, atmospheric transport process, tropospheric chemistry, and global pollution.

Our research foci align with NASA's Earth Science program goals to develop a scientific understanding of the Earth system. In addition, branch researchers participate in projects sponsored by the Department of Energy (DoE) Atmospheric Radiation Measurement (ARM) program, National Oceanic and Atmospheric Administration (NOAA), and U.S. Environmental Protection Agency (EPA).

To implement our research goals we use a variety of scientific tools including field measurements, laboratory studies, and numerical modeling and analysis.

By utilizing leading edge and information technologies, we have developed many highly sensitive and state-of-the-art instruments. We deploy them and make observations at ground sites and on a variety of platforms including aircraft, balloons, unmanned aerial systems (UAS), and ship. Many have been in a variety of field campaigns sponsored by NASA as well as other research organizations. Argus is a tunable diode laser instrument that measures the important, long-lived chemical tracer species, N_2O, and methane. Cadenza and its UAS version measure aerosol optical properties such as extinction and scattering coefficients at two wavelengths. The Meteorological Measurement System (MMS) provides accurate, fast response measurements of pressure, temperature, and three-dimensional wind components. PANAK is an instrument that makes tropospheric measurements of PAN (peroxyacetyl nitrate), acetones, and ketones. The Solar Spectral Flux Radiometer (SSFR) is a moderate resolution spectrometer that measures the spectrally resolved net solar irradiance. The 6- and 14-channel Ames Airborne Tracking Sunphotometers (AATS) measure transmission spectra used to obtain aerosol optical depths, water vapor and ozone. Branch members also collaborate closely with NASA Langley Research Center to field the Diode Laser Hygrometer (DLH) to measure water vapor in the atmosphere.

To understand how the dynamic chemical interactions occur in Earth's highly complex atmosphere, we perform experiments in the controlled setting of our sophisticated Atmospheric Chemistry Laboratory. Our laboratory results can then be used in an integrated analysis with field measurements and modeling studies to produce a more complete understanding of our environment.

We develop unique models of clouds, chemistry, dynamics, and radiative transfer processes to understand and elucidate controlling mechanisms. The Integrated MicroPhysical and Aerosol Chemistry on Trajectories (IMPACT) model is used to understand the characteristics and effects of Polar Stratospheric Clouds and their effects on ozone depletion. Production of Ozone by Gauging of Organics: Formaldehyde and NO (POGO-FAN) provides empirical indicators for the local chemical production of smog, ozone and NOx-sensitivity of air parcels. We have a variety of cloud models, including one-, two-, and three-dimensional models with prescribed dynamics and a large eddy simulation model. These cloud models are very generalized and can be adapted to simulate a variety of cloud types.

Members of our branch are engaged in project management of airborne field campaigns as part of the Earth Science Project Office (ESPO). They participate in the advocacy, planning, and execution of selected field projects for NASA's Earth Science Division.

Specifically our research areas are as follows:

- Aerosol and Cloud Microphysics
- Applied Trace Gas Detection of Science, Exploration Systems, and Aeronautics
- Argus Instrument to study important, long-lived chemical tracer species

- Atmospheric Chemistry Laboratory for the Study of heterogeneous chemical processes
- Atmospheric Radiation Instrumentation (SSFR)
- Cloud Modeling
- Meteorological Analysis of the Upper Troposphere and Lower Stratosphere
- Meteorological Measurements System (MMS)
- Reactive Nitrogen and Oxygenated Species (PANAK) Research
- Stratospheric Ozone Depletion
- Sunphotometer-Satellite (AATS)
- Tropospheric Ozone and Global Pollution

Besides our extensive relationship with colleagues at NASA Ames Research Center (among them: Earth Science Division, Space Science and Astrobiology Division, and Information Systems), we have enjoyed collaborative programs worldwide. Some of these collaborators include other NASA centers (Goddard, Langley, Dryden, Johnson, and Glen), NASA Goddard Institute for Space Studies (GISS), and NASA Jet Propulsion Laboratory (JPL). Collaborators in other federal research laboratories include DoE Atmospheric Radiation Measurement (ARM) Program, Pacific Northwest National Laboratory (PNNL), Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, DOE Sandia National Laboratories, Office of Naval Research, U.S. Environmental Protection Agency (EPA), and the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS). Academic collaborators include: University of Colorado, University of California campuses of Berkeley, Davis, Los Angeles, Santa Cruz, and U.C. San Diego, Scripps Institution of Oceanography, Stanford University, Harvard University, Colorado State University, University of Washington, San Jose State University, Pennsylvania State University, and San Francisco State University. Some of the nonprofit research organizations are the Bay Area Environmental Research Institute (BAERI), National Center for Atmospheric Research (NCAR), Search for Extra-Terrestrial Intelligence (SETI), Carnegie Institute, Desert Research Institute (DRI), Stanford Research Institute (SRI), and Oak Ridge Associated Universities. Lockheed Martin Palo Alto Advanced Research Center, Los Gatos Research, Inc., Novawave Technologies, Inc., and General Atomics Aeronautical Systems, Inc. are among our industrial partners. International partners include the Max Planck Institute for Chemistry, Brazil Center for Weather Forecasting and Climate Studies, and Germany's Forschungszentrum Julich.

Our researchers are recognized for their outstanding scientific contributions and expertise: Mission Scientist for the Intercontinental Chemical Transport Experiment (INEX-B), INTEX-B/MILAGRO J-31 Lead Principal Investigator, Project Scientist for the 2006 Costa Rica Aura Validation

Experiment (CRAVE), 2006 NASA Exceptional Achievement Medal, Executive Editor for the Journal of Atmospheric Environment, Editorial Board of the Journal of Aerosol Science, and the 2006 Ames Honor Award for Project Manager.

We are members of international science committees, national science teams, review panels, and planning communities: member of the Commission on Atmospheric Chemistry and Global Pollution (CACGP), member of the International Global Atmospheric Chemistry/International Transport and Chemical Transformation (IGAC/ITCT), member of the Steering Committee for the International Polar Year/Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport (IPY/POLARCAT), co-authors to the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS white paper, lead of MILAGRO Science Meeting Breakout Group on Aerosol Optical Properties and Radiative Effects, member of NASA Aerosol Strategy Planning Team, co-lead of INTEX-B Data Review Meeting Breakout Group on Aerosol Optical Properties and Radiative Effects, co-chair of the Stratospheric Processes and their Role in Climate (SPARC) Polar Stratospheric Cloud Assessment (lead author for "Using Models to Assess PSC Understanding), co-author of the 2006 United Nations Environment Programme/World Meteorological Organization (UNEP/WMO) Scientific Assessment of Ozone Depletion Chapter on "Polar Ozone: Past and Present", member of the Technical Committee for the 9th-International Conference on Carbonaceous Particles in the Atmosphere (ICCPA), and member of the Department Advisory Committee for San Jose State University Aerospace Engineering Program.

We are also mentors to various educational and public outreach programs: NASA Postdoctoral Program (NPP), Educational Associate Program (EAP), National Research Council (NRC), presenter at the 2006 Sally Ride Science Camp, invited participant at the 2006 California State Climate Science Day to educated state lawmakers and staffers, NASA news releases, and local and national TV and radio interviews.

To foster technology development we are proposal reviewers and Contracting Officer's Technical Representatives (COTRs) to the NASA Small Business Innovation Research (SBIR) program.

Highlights of research activities of the Atmospheric Science Branch include:

Science Results

We have identified background sulfate aerosol as the primary source of chlorine activation that destroys polar ozone, rather than the infrequently occurring Polar Stratospheric Clouds (PSCs).

Modeling and analysis of tropical tropopause layer (TTL) cirrus observed during the CR-AVE field campaign were performed. Growth-sedimentation calculations suggest that the relatively large crystals observed could only have formed under highly supersaturated conditions. The existence of these crystals has implications for the TTL water vapor concentrations.

We have discovered that acetic acid may be the dominant dissolved oxygenated organic compound in the upper troposphere/lower stratosphere aerosols and question if the presence of acetic acid will affect the uptake of other compound.

We have traced effects of pollutant-laden combustion in the Indian Subcontinent. Tropospheric ozone as retrieved from the TOMS satellite for Indian Ocean region was linked to anthropogenic pollution in the region, but ozone also traveled long distance in the subtropical wind systems from Northern Africa.

Missions and Experiments

There were three field campaigns that the Earth Science Project Office managed very successfully in 2006. These are large international experiments with participation from multiple research organizations. The Atmospheric Science Branch involvements were multifaceted and important to the success of the experiments.

- Project Scientist, meteorological support, and Principal Investigators (Argus, MMS) on the WB-57F during the CR-AVE, a mission designed to explore the tropical upper troposphere and lower stratosphere (UTLS) and to provide information for comparison to satellite observations.

- Mission Scientist, meteorological and modeling support, Principal Investigator (PANAK), Co-I (DLH) on the DC-8, Lead Principal Investigator on the J-31, Principal Investigator (AATS-14), and Co-PI (SSFR) on the J-31 during INTEX-B in its first phase studied the Mexico City pollution outflow, while the second phase focused on Asian pollution outflow.

- Principal Investigators (MMS, COBALT), Co-I (DLH) on DC-8 during the NAMMA campaign that examined the formation and evolution of tropical hurricanes in the eastern and central Atlantic and their impact on the U.S. east coast. Also studied the composition and structure of the Saharan Air Layer, and whether aerosols affect cloud precipitation and influence cyclone development.

The Atmospheric Radiation Instrument Group in collaboration with the University of Colorado participated in the NOAA 2006 Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS) field campaign by using Solar Spectral Flux Radiometer systems to make measurements from the CIRPAS Twin Otter and the NOAA Ship Ron Brown. GoMACCS was a multi-institutional intensive field program to characterize marine/continental chemical and meteorological processes to improve the simulation of the radiative forcing of climate change by lower-atmosphere ozone and aerosols. A rich data set was obtained to improve our knowledge of aerosol radiative processes and their influence on climate.

In summer 2006 the Aerosol and Cloud Microphysics Group participated in the Caldecott Tunnel Experiment. They used Cadenza, an instrument that uses cavity ring-down technique, to measure the radiative properties of vehicle emissions in real world situation and assess the effects of aerosol on regional climate.

The Ticosonde/Vernanillo campaign took place in July 2006 in Costa Rica. It was part of a series of meteorological balloon sounding campaigns to measure water vapor, ozone, temperature, and wind. This data is used to study a number of science questions, including the problem of the dehydration of the stratosphere, equatorial waves, and the climatology of the “Vernanillo de San Juan” phenomenon: a two- to three-week period of reduced rainfall in the middle of the annual rainy season in Costa Rica.

The Argus instrument team successfully participated in the Western States Fire Mission 2006 Campaign. The Campaign showcased emerging technologies related to real-time disaster event. Argus flew on the Altair UAS 22-hour mission.

New Technologies

Technologists from the Atmospheric Science Branch are collaborating with fellow technologists from the Biospheric Science Branch to build up the Systems Integration Evaluation Remote Research Aircraft (SIERRA). It is designed to carry experimental Unmanned Aerial System payloads up to 100 lbs. for testing, evaluation, and demonstration.

In collaboration with Los Gatos Research, Inc. Branch researchers are developing a unique instrument capable of measuring aerosol radiative properties from an Unmanned Aerial System. The instrument named AERO3X uses off-axis cavity ring-down (OA-CRD) technique to measure aerosol extinction coefficient at two wavelengths and simultaneously measure the total and back scattering coefficient at both wavelengths using a reciprocal nephelometer concept.

For details of these and other Atmospheric Science Branch research activities please read the accompanying articles written by the researchers or go to our home page at http://earthscience.arc.nasa.gov/sgg/index.html.

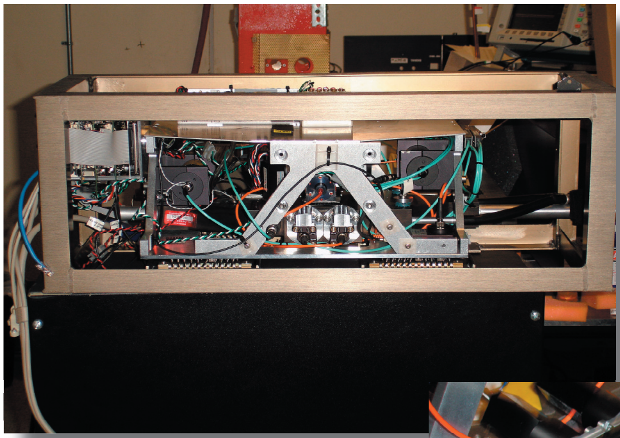
AEROSOL OPTICAL PROPERTY MEASUREMENTS ON UNINHABITED AERIAL SYSTEMS

Anthony W. Strawa, Project Principal Investigator

Program Support: NASA, Small Business Innovation Research

This project is a collaboration between NASA's aerosol Lab and Los Gatos Research, Inc. Its objective is the development of a unique instrument capable of measuring aerosol radiative properties from an Uninhabited Aerial System (UAS, formerly known as UAV). The instrument will be capable of measuring extinction and scattering coefficients at 2 wavelengths, and obtaining absorption coefficient, single scattering albedo, and asymmetry parameter at these wavelengths, and NO_2 concentration.

It is well known that aerosol have a profound effect on regional and global climate, however, there still exist large uncertainties in the measurement of key aerosol radiative properties, such



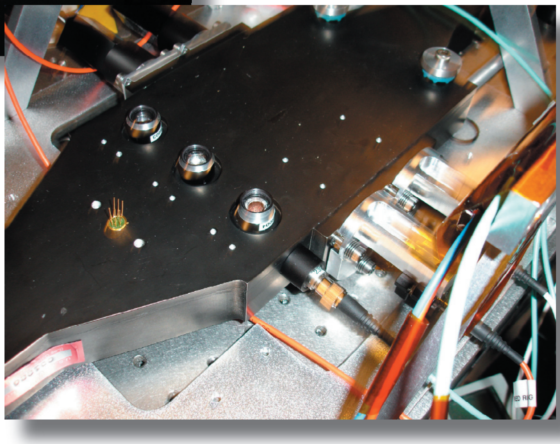
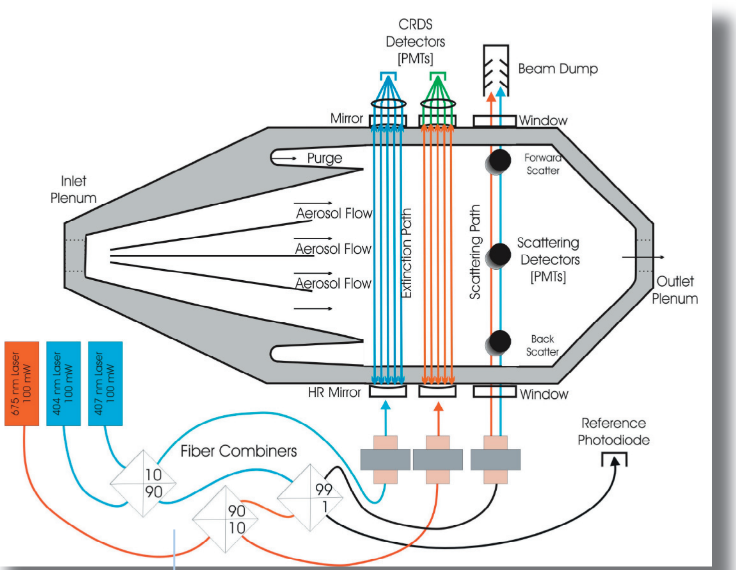


Photo of the instrument cage in the lab at Los Gatos Research, Inc. (above), and a close-up of the instrument itself (right). The instrument cage is 10" x 10" x 19" and weighs about 20 lbs.



Schematic of the instrument.

as absorption and single scattering albedo and their distribution in the atmosphere. These effects are felt directly, through direct scattering and absorption of solar radiation and indirectly by modifying cloud properties and precipitation. Single scattering albedo, the ratio of scattering to extinction, is an important metric for aerosol radiative effects and an important input into global climate models.

Features of the Instrument

The instrument design is based on Cadenza [Strawa et al., 2003; Strawa et al., 2006]. It uses off-axis cavity ring-down (OA-CRD) to measure the aerosol extinction coefficient at wavelengths of 675 nm and 410 nm, and simultaneously measure the total and forward and back scattering coefficient at both wavelengths using a reciprocal nephelometer [Mulholland and Bryner, 1994] concept. All measurements are made in the same optical and flow cell at exactly the same conditions with a temporal resolution of about 1 sec. Absorption coefficient is obtained from the difference of measured extinction and scattering within the instrument and single scattering albedo from their ratio.

Applications

This instrument will be very useful in determining the vertical distribution of aerosol optical properties that are critical to accurate climate modeling. I t can be mounted in a pod and carried under the wing of larger UAS or manned aircraft or it can be carried in the fuselage of smaller UAS. Its small size, light weight and excellent response time (1 sec.) make it ideal for these applications.

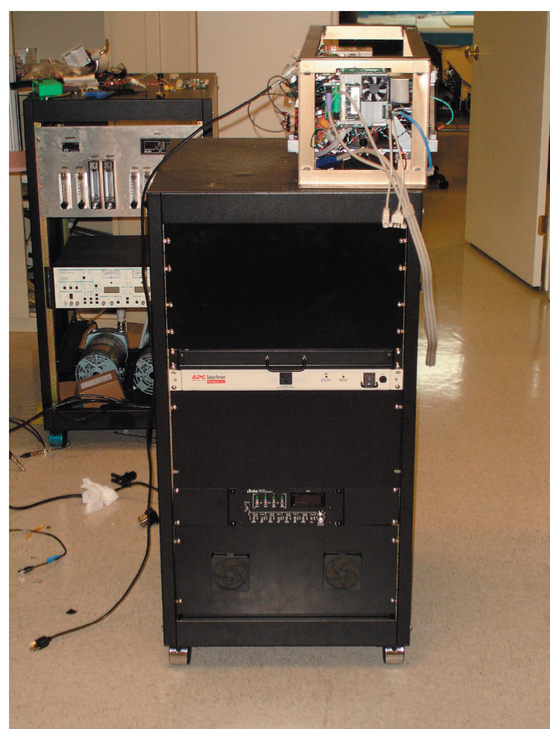


Photo of the ground support station

The instrument is sensitive enough to make measurements in the mid troposphere where aerosol extinction coefficients can be below 0.1 Mm-1.

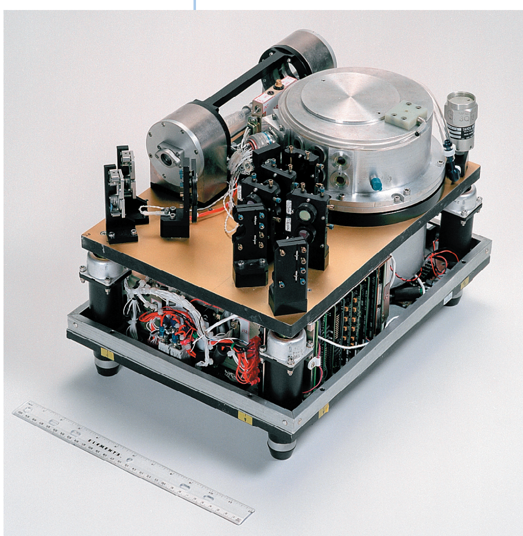
The instrument is portable and can be used in ground sites, such as the Caldecott tunnel (described on another page) to measure the emission factor from cars and trucks.

Web site: http://geo.arc.nasa.gov/sgp/aerocloud_web/homepage.html

AMES ARGUS INSTRUMENT LABORATORY

Max Loewenstein, Project Principal Investigator

Program Support: NASA, Upper Atmosphere Research Program, Michael J. Kurylo



NASA-Ames Research Center Argus instrument.

Instrument Description

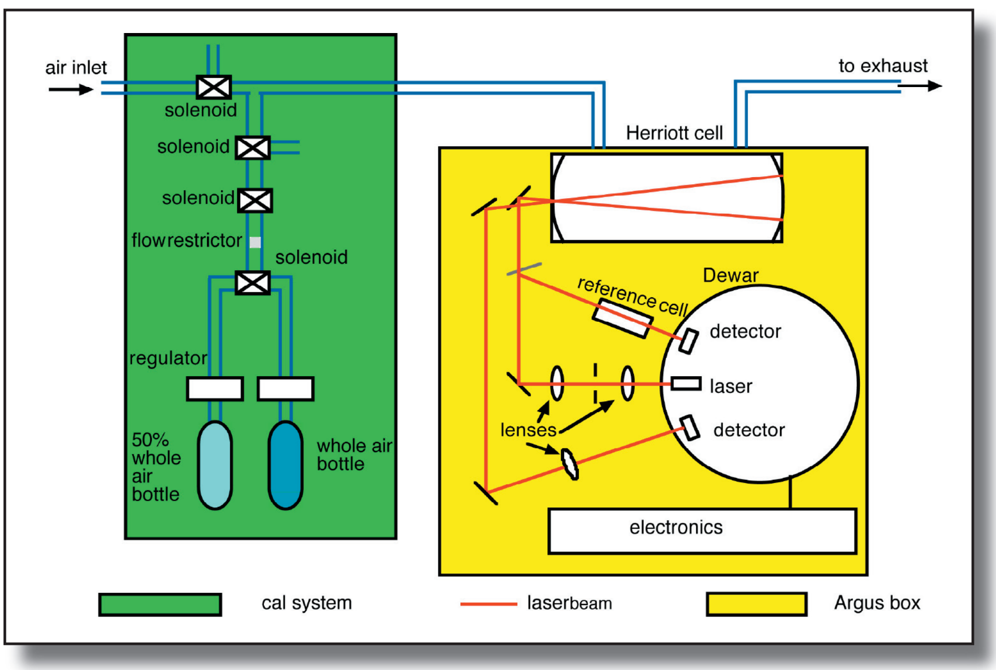
Argus is a two channel, tunable diode laser instrument set up for the simultaneous, in situ measurement of CO (carbon monoxide), N_2O (nitrous oxide) and CH_4 (methane) in the troposphere and lower stratosphere. The instrument measures 40 x 30 x 30 cm and weighs 21 kg. An auxiliary, in-flight calibration system has dimensions 42 x 26 x 34 cm and weighs 17 kg.

The instrument is an absorption spectrometer operating in rapid scan, second-harmonic mode using frequency-modulated tunable lead-salt diode lasers emitting in the mid-infrared. Spectra are co-added for two seconds and are stored on a solid state disk for later analysis. The diode laser infrared beam is shaped by two anti-refection coated lenses into an f/40 beam focused at the entrance aperture of a multi-pass Herriott cell. The Herriott cell is common to both optical channels and is a modified astigmatic cell (New Focus Inc., Santa Clara, California).

The aspherical mirrors are coated with protected silver for optimal infrared reflectivity. The cell is set up for a 182-pass state for a total path of 36m. The pass number can be confirmed by visual spot pattern verification on the mirrors observed through the glass cell body when the cell is illuminated with a visible laser beam. However, instrument calibration is always carried out using calibrated gas standards with the Argus instrument operating at its infrared design wavelengths, 3.3 and 4.7 micrometers respectively for CH_4 and CO detection. The electronic processing of the second harmonic spectra is done by standard phase sensitive amplifier techniques with demodulation occurring at twice the laser modulation frequency of 40 kHz. To optimize the second-harmonic signal amplitude in a changing ambient pressure environment the laser modulation amplitude is updated every 2 seconds to its optimal theoretical value based upon the measured pressure in the Herriott cell.

Calibration

Argus is regularly calibrated in the laboratory against a CMDL (Climate Monitoring and Diagnostics Lab) whole air standard for CH_4 and CO. Flow-mixing of this standard with a zero gas provides us with absolute calibration and linearity data as inputs to the in situ flight recorded analysis. During field operations Argus is calibrated in the lab both before and after every flight operation with the instrument maintained in its flight setup configuration throughout the calibrations. Argus also employs an in-flight calibration system providing real time calibrations and tightly constrained uncertainty estimates of the returned data.

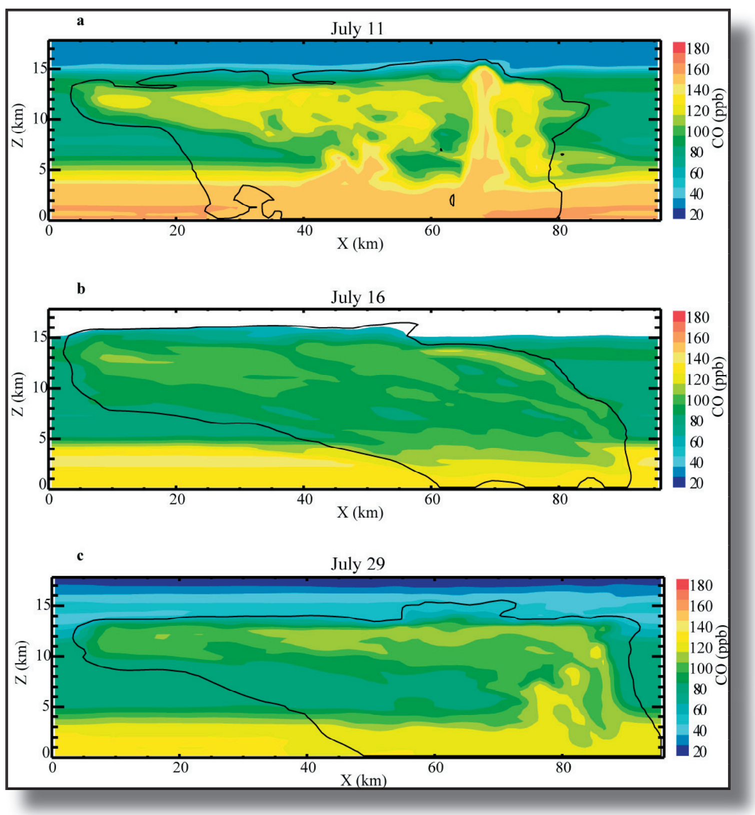


Argus flight configuration. During flight, Argus flies with a calibration system that allows switching between ambient air and highly calibrated whole and half air. Typically for every 30 minutes of flight, there is 1 minute of calibration.

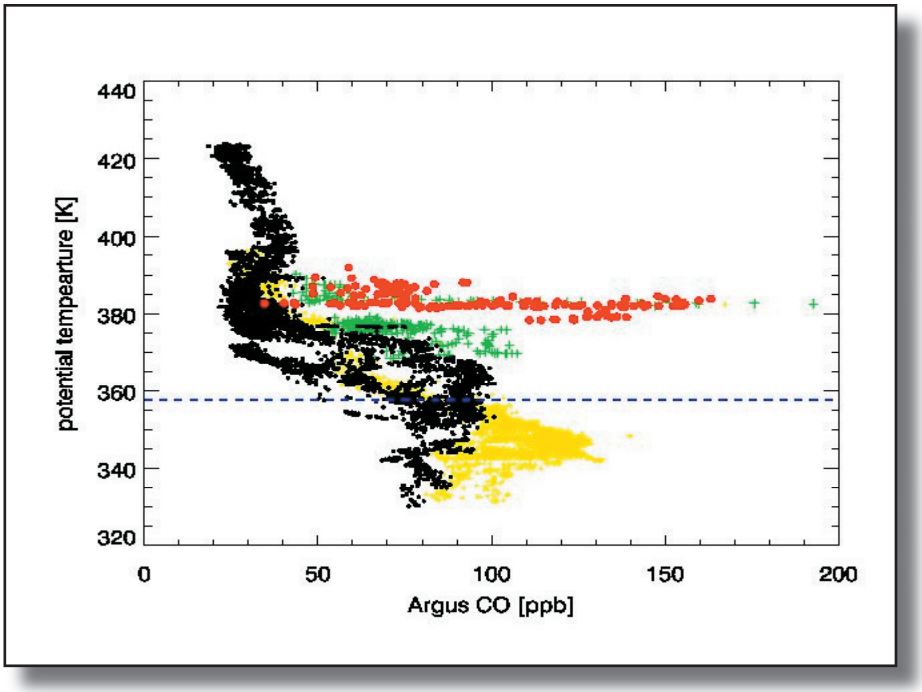
Data Analysis

The post-flight data reduction uses a non-linear, least squares Marquardt-Levenberg fitting procedure where theoretical fitting function is the second Fourier component of the modulated Voigt absorption line-shape. One parameter returned by the fitting procedure is the molecule number density (CO and CH_4) in the Herriott cell. This is converted to mixing ratio using the measured gas density in the cell. Argus then reports molecule mixing ratio at 0.5 Hz data rate to the data archive.

Convective systems are an important mechanism in the transport of boundary layer air into the upper troposphere. The CRYSTAL-FACE campaign, in July 2002, was developed as a comprehensive atmospheric mission to improve knowledge of subtropical cirrus systems and their roles in regional and global climate. In situ CO measurements aboard NASA's WB-57F aircraft and U.S. Navy's Twin Otter aircraft were used to study the role of convective transport. Three flights sampled convective outflow on July 11, 16 and 29 found varying degrees of CO enhancement



Instantaneous CO cross-section of the three-dimensional model simulations, at a time corresponding to the middle of each flight, at the model location of peak total CO in the convective cores for each flight day.

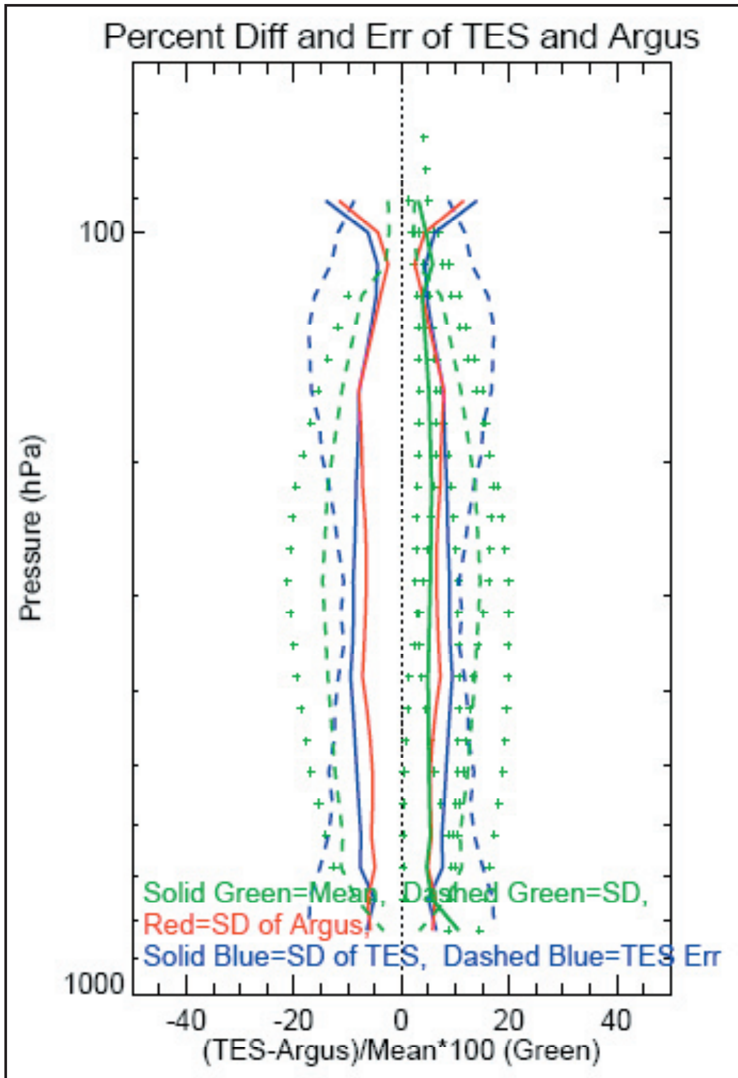


Elevated CO deep into the stratosphere during CRYSTAL-FACE.
Blue dashed lie shows location of the tropopause.

relative to the free troposphere. A cloud-resolving model used the in situ CO observations and meteorological fields to study these three systems by properly constraining the model to characterize convective transport.   Several methods of filtering the observations were devised here using ice water content, relative humidity with respect to ice, and particle number concentration as a means to statistically sample the model results to represent the flight tracks. A weighted histogram based on ice water content observations was then used to sample the simulations for the three flights. In addition, because the observations occurred in the convective outflow cirrus and not in the storm cores, the model was used to estimate the maximum CO within the convective systems. In general, anvil-level air parcels contained an estimated 20-40% boundary layer air in the analyzed storms.

Recent Argus CO measurements during the CRYSTAL-FACE mission showed that mesoscale convective systems helped or triggered by large forest fires inject plumes several kilometers into the stratosphere. A plume was observed 10 days after the injection several thousand kilometers away. Carbon monoxide concentrations increased to 180 ppb, more than 4 times the usual lower stratospheric concentration. Particle concentrations were enhanced, water vapor and CO_2 were

(*Continued on page 21*)



Comparison of Argus CO data with the TES CO data on the AURA satellite during the CR-AVE campaign in 2006. TES averaging kernel has been applied to the Argus vertical profile. Argus measurements always fall between the TES retrieval errors.

increased, and ozone was lower compared to typical values at these altitudes. The single particle analyzer, PALMS, showed a clear biomass burning signature. The CRYSTAL-FACE measurements were the first to unambiguously show that plumes from fires can be injected relatively high into the stratosphere in mid latitudes and that they remain there for many days.

Since the launch of the EOS Aura satellite in mid-2004 we have been carrying out validation measurements for instruments on the satellite. Our main objective is to provide data to help validate profile measurements of CH_4 and CO to be made from the ground to 35 km by TES. Additionally some CO, CH_4 and N2O data will be useful in the validation of MLS (Microwave Limb Sounder; CO and N_2O above 10 km) and HIRDLS (High Resolution Dynamics Limb Sounder; CH_4 and N_2O above 8 km).

Website: Max.Loewenstein-1@nasa.gov

AMES ATMOSPHERIC CHEMISTRY LAB

Laura Iraci, Project Principal Investigator

Program Support:
• NASA, Upper Atmosphere Research Program, Michael J. Kurylo
• NASA Radiation Sciences Program, Hal Maring
• NASA, Tropospheric Chemistry Program, James Crawford
• NASA, Planetary Atmospheres, P. Crane

Aerosol Composition and Chemistry

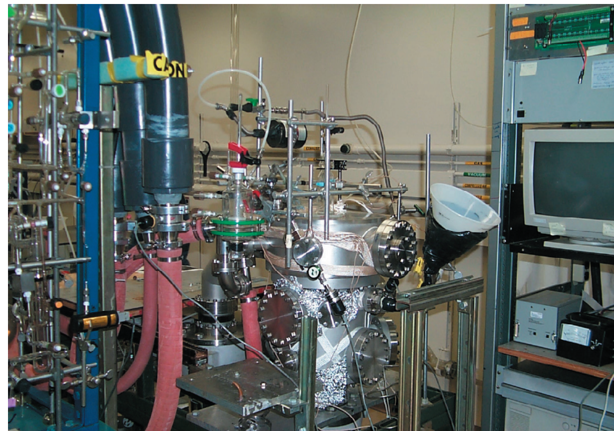
Interactions between gases and particles occur throughout the Earth's atmosphere and can have consequences such as the formation of acid rain and the destruction of stratospheric ozone. To understand how these processes occur in Earth's highly complex atmosphere, our research group studies aerosol processes in a controlled laboratory setting. By carefully varying parameters such as temperature, relative humidity, and particle composition, we can isolate the response due to changes in each of these conditions in the real atmosphere. Our results can then be used in an integrated analysis with field measurements and modeling studies to produce a more complete understanding of our environment and to predict how future changes in temperature or particulates may, in turn, affect the chemistry of the atmosphere. Questions of interest to us include:

- How does the atmosphere affect particle composition?
  - What is the nature of the organic material in stratospheric sulfate particles?

(Left to right) Laura Iraci, Patrick Hamill and Kim Biggle in the Atmospheric Chemistry lab.

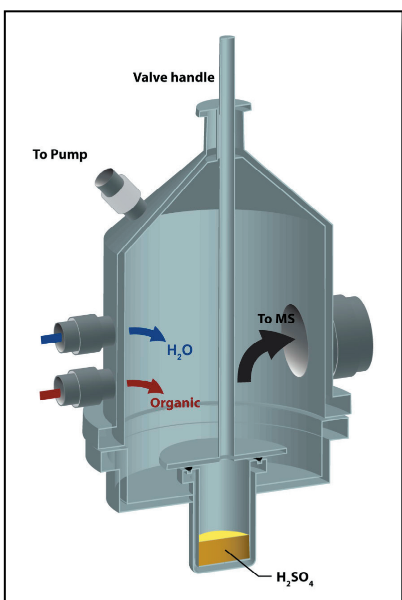
– Does particle composition change due to human activities?

- How does the chemistry of particulate matter affect the atmosphere?
  - Can particles serve as temporary reservoirs for organic material, transporting it from one region to another?
  - Can particles facilitate reactions that don't occur in the gas phase?
- Can we understand and predict processes which control particle behavior and composition?
  - What chemical and physical factors control uptake of organics into mixed sulfuric acid/water solutions?
  - Do we understand the solubility & reaction of small organics in acid solutions?
- Does particle composition affect the formation of clouds?
  - Are humans affecting the radiative balance by changing cloud properties?

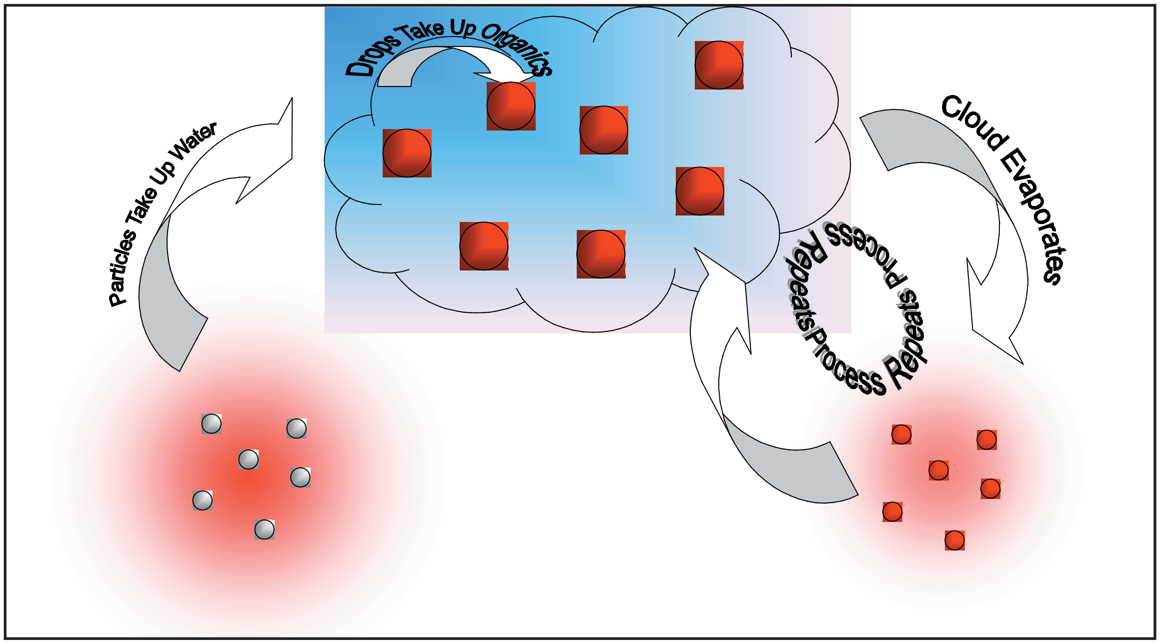


This Knudsen cell apparatus is used to study the interaction of gases with sulfuric acid or other low-vapor-pressure liquids. A quadrupole mass spectro-meter detects changes in the gas of in-terest when exposed to the acid. The glass Knudsen cell is held together with a large green clamp to the left of center in the photo.

Recent research results include solubility and reactivity studies of methanol, ethanol, acetaldehyde, acetic and trifluoroacetic acid. We have discovered that acetic acid may be the dominant dissolved oxygenated organic compound in UT/LS aerosols and must ask if the presence of acetic acid will affect the uptake of other compounds. Ethanol and acetaldehyde solubilities in H_2SO_4/H_2O solutions have been mapped out under upper tropospheric and lower stratospheric conditions. Ethanol may be a dominant reactive component in particles, despite low levels observed in the gas phase. Propanal reacts easily in 50 and 60 wt% H_2SO_4 solution, and a surface film layer forms under some conditions. Will it affect uptake of water or other gases? Methyl nitrate is formed from the reaction



Schematic drawing of the Knudsen cell, showing the valve separating the gases from the liquid before reaction is initiated.

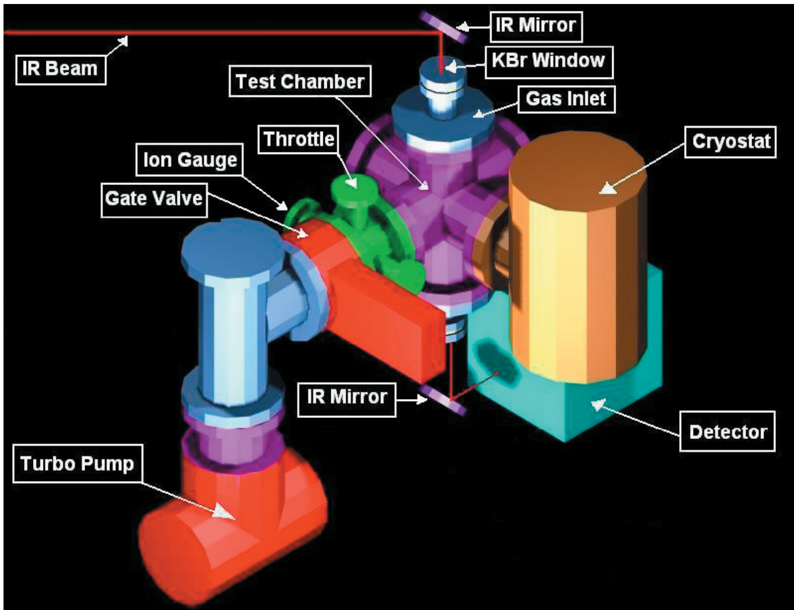


of methanol with nitric acid in H_2SO_4/H_2O solutions. Nitrobenzene may be formed in similar mixtures.

Cloud Growth: Microphysical Measurements and Effects on Aerosol Particles

New projects in development will study cloud growth and chemical effects in the atmospheres of Earth and other planets. As aerosol particles activate into cloud droplets, they experience radical changes in composition, viscosity, and pH. These cloud conditions will favor different chemical behavior than did the starting conditions, but this evolution is not considered in chemical models of the particles in our atmosphere. Further, as non-precipitating cloud droplets dry out and return to the aerosol state, they will be changed relative to their original state. While the science community is starting to acknowledge probable changes to the physical

Liquid nitrogen dewar and copper sample holder will cool and support martian dust analog materials in the beam of an infrared spectrometer, which can detect water ice formation.



Schematic drawing of the Mars Cloud Chamber, which will allow ice to be grown on dust samples held at pressure and temperature conditions representative of the martian atmosphere.

Multiphase reactor allows temperature-controlled studies of aqueous processes. The gases in equilibrium with solution are monitored with infrared spectroscopy.

form of aerosol particles during processes such as these, the potential chemical changes have not been explored.

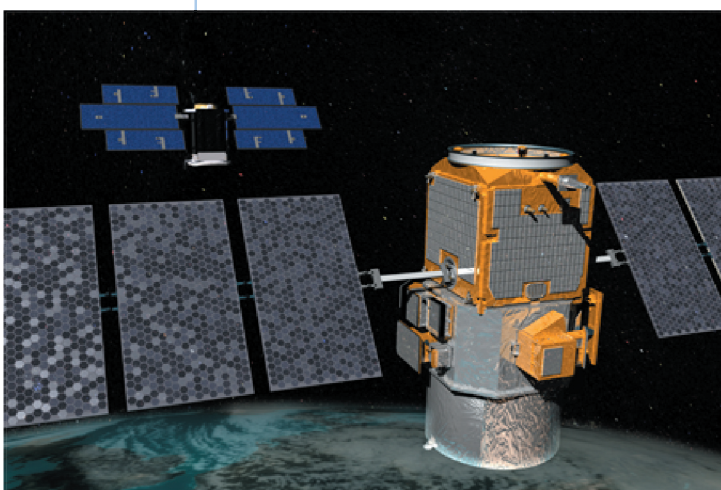
Our newest apparatus is being constructed to examine the growth of water ice clouds on present and past Mars to assist in the interpretation and modeling of results from the Mars Global Surveyor and Mars Odyssey missions. We will determine the super-saturation conditions needed to initiate ice cloud growth on martian dust particles. This number is crucial for modeling the cloud formation on Mars and understanding the heat balance of the atmosphere, yet values used currently have no experimental foundation. The importance of the

THE CALIPSO-CLOUDSAT VALIDATION EXPERIMENT (CC-VEx)

Chip Trepte, CC-VEx Project Scientist

Ian McCubbin, CC-VEx Project Manager

Program Support:
- *CALIPSO, Chip Trepte, NASA LRC*
- *CloudSat, Deborah G. Vane, JPL*
- *Radiation Sciences Program, Hal Maring*



CloudSat and CALIPSO pairing set a new standard in terms of precision placement of Earth-orbiting satellites. Both satellites look at the same clouds in the atmosphere.

The CALIPSO-CloudSat Validation Experiment (CC-VEx) was conducted between July 24 and August 14, 2006 and was designed to provide coincident observations of cloud and aerosol (small particles) layers needed to support calibration and validation studies for two new satellite missions: CALIPSO and CloudSat. These missions provide valuable new information on vertical structure and properties of aerosols and clouds needed to improve our understanding of climate, weather, and air quality. They were launched together on a Delta II launch vehicle on April 28, 2006 and placed in formation with three other earth observing satellites into what is commonly known as the "A-Train" satellite constellation. CALIPSO is a joint mission between NASA and the French space agency, CNES, and its payload consists of an innovative two-wavelength polarization-sensitive lidar, an infrared imaging radiometer, and a wide field-of-view camera. CloudSat is a partnership between NASA, the Canadian space agency, and the United States Air Force, and its payload consists of a state-of-the-art cloud profiling radar operating at 94 GHz.

For initial validation studies, both CALIPSO and CloudSat needed measurements of layers of clouds and aerosols over a range of altitudes and thicknesses with varying composition to compare with the satellite observations. To meet these requirements, three aircraft were used during CC-VEx: the NASA ER-2, the Weather Modification, Inc LearJet, and the NASA B-200 King Air aircraft. The ER-2 payload included a lidar, radar, and imaging spectrometer with instrument characteristics similar to CALIPSO and CloudSat. The Learjet carried a suite of cloud particle measurements, and the King Air supported a newer lidar design. Flights were designed to fly over different cloud and aerosol features at specific locations timed for coincident satellite overpasses.

Base operations for the ER-2 and the LearJet were located at Warner Robbins Air Force Base in Georgia and hosted by the 78th Air Base Wing and the 116th Air Command Wing. Two B-200 flights were conducted from NASA Langley and another from Warner Robbins.

During CC-VEx, 12 comparison flights were conducted by the ER-2, including four at night. The Learjet made seven flights, and the B-200 King Air made three flights. All planned mission objectives were successfully obtained with measurements of thick and thin cirrus, mid-layer clouds, precipitating clouds, clouds with ice, water, and mixed phases, and aerosols (including scenes with thin cirrus) along the satellite track. Early satellite validation studies using CC-VEx observations led to improvements in the quality of CALIPSO and CloudSat data products released in late 2006.

B-200 King Air.

ER-2

CR-AVE: COSTA RICA - AURA VALIDATION EXPERIMENT

Kent Shiffer, Project Principal Investigator

Program Support:
- *NASA, Radiation Sciences Program, Hal Maring*
- *NASA, Upper Atmosphere Research Program, Michael J. Kurylo*

The Costa Rica Aura Validation Experiment (CR-AVE) mission was conducted from January 14 – February 11, 2006 at the Juan Santamaria airport in San Jose, Costa Rica. The purpose of the mission was to explore the tropical upper troposphere and lower stratosphere (UTLS) portions of the atmosphere, and to provide information for comparison to satellite observations (especially Aura).

Interest in the UTLS comes from our understanding that this region has a major impact on both the recovery of the ozone layer and on climate change. Climate change may cause increased temperature and water vapor levels in the tropics. These increases will in turn modify upper tropospheric transport, chemical composition, and clouds, as well as the radiative balance of the UTLS. These changes will both affect the recovery of ozone and serve as potentially important climate change feedbacks. The tropical region between 30 N

WB-57 on the ramp in Houston for instrument test flight prior to deployment to Costa Rica.

Paul Bui preparing the MMS instrument for installation onto the WB-57.

WB-57 Pilot, Bill Rieke, preparing for flight.

and 30 S comprises half of the Earth's surface, yet is relatively unsampled in comparison to the mid-latitude of the Northern Hemisphere. In addition, observations above typical aircraft altitudes (40,000 feet or 12 km) are even less frequent, making the tropical upper troposphere and lower stratosphere one of the most sparsely sampled regions of our atmosphere.

The scientific objectives of the CR-AVE mission were to: (1) examine the ozone budget at high altitudes of the tropics, (2) measure water vapor, (3) investigate high altitude "sub-visible" cirrus, and (4) measure the size and shapes of cloud ice crystals. Data collected for each of these objectives is used to understand the state of tropical clouds, ozone, and water and their role in climate change

The NASA WB-57F aircraft, with a suite of 29 science instruments, was the primary research platform for CR-AVE. The WB-57F payload included instruments to analyze data related to both ozone recovery and climate change. The payload was divided into two types of science data acquisition, an in situ air sampling payload, and a remote sending payload. A unique aspect of this mission was the successful change-out of the payload during the middle of the mission at the deployment site. Twelve successful flights divided into two separate payloads, including six in-situ and six remote sensing flights, for a total of 60 flight hours.

Some science highlights from the mission include:

- Good correlative measurements were made for TES, MLS, and HIRDLS instrument validation.
- UTLS temperatures were much colder than average, resulting in extensive observations of sub-visual cirrus.
- Observations of water, water isotopes, and VSLS indicates TTL impacted by convection of ice from boundary layer air.
- First observations of black carbon provide basic constraints on GHG radiative forcings.
- Particle observations show that TTL is dominated by neutral organic aerosols while the stratosphere is dominated by acidic sulfate aerosols - a scientific puzzle.
- Organic bromine in TTL is dominated by known species (methyl bromide and halons): Conclusion, if a major source of Br is being injected into the stratosphere than it must be in inorganic form (e.g., BrO).
- TTL cirrus observations indicated predominance of quasi-spherical, surprisingly large ice crystals.

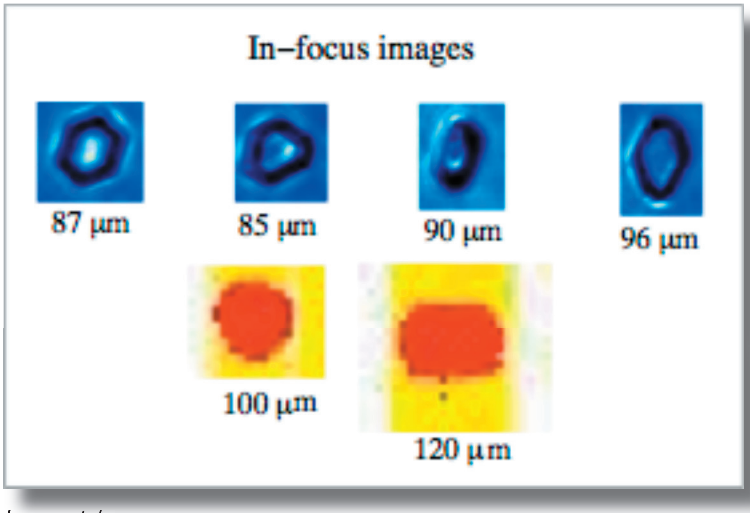
For more information, the CR-AVE mission web site is located at: http://cloud1.arc.nasa.gov/ave-costarica2.

FORMATION OF LARGE ICE CRYSTALS NEAR THE TROPICAL TROPOPAUSE

Eric J. Jensen, Project Principal Investigator

Program Support: NASA, Radiation Sciences Program, Hal Maring

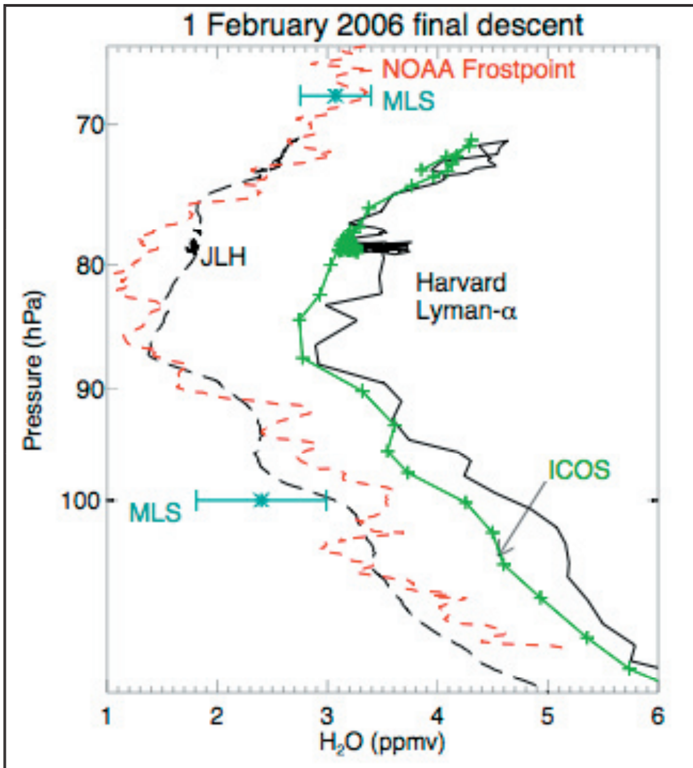
During the recent NASA Costa Rica Aura Validation Experiment (CRAVE) imaging instruments onboard the WB-57F aircraft indicated the presence of surprisingly large crystals near the tropical tropopause (see below). The CRAVE mission also identified significant discrepancies between water vapor measurements made by various instruments, with the Harvard Lyman-α and ICOS instruments reporting water vapor concentrations nearly a factor of two larger than the JLH,



Ice crystals.

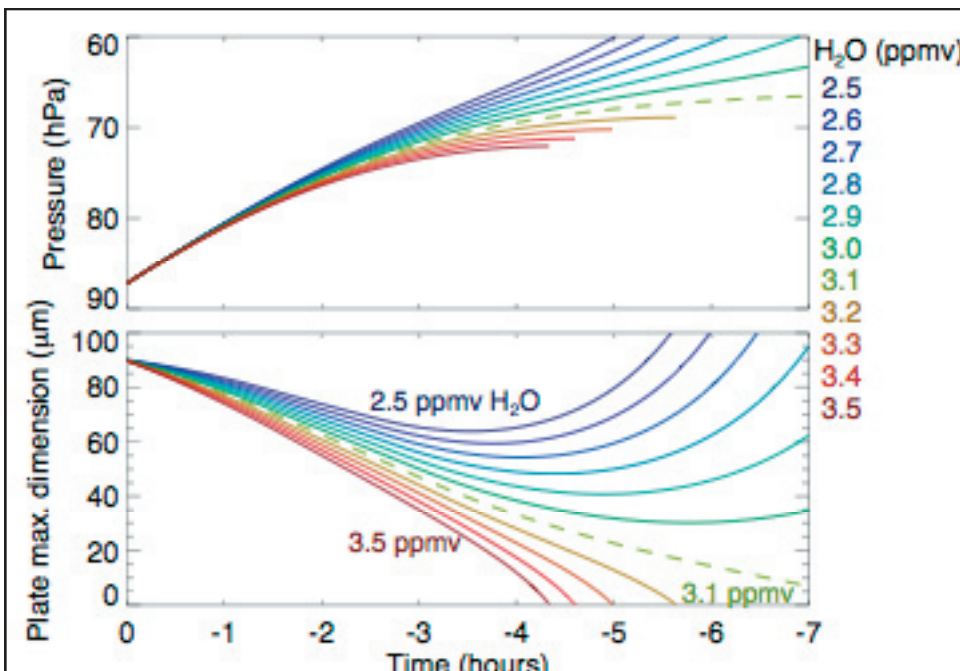
frostpoint balloon, and satellite remote-sensing instruments. Resolving these discrepancies is important for understanding dehydration of air entering the stratosphere (see "Feb. 2006 final descent" graph, next page). In this study, we investigate the formation of the large ice crystals and possible implications for water vapor concentrations.

Since the large crystals did not originate from deep convection, they must have nucleated and grown by deposition of water vapor in the narrow supersaturated layer near the cold tropopause.



We have conducted simple growth-sedimentation calculations as well as full simulations of the clouds with a detailed cloud model. We start at the time and location of the observed large crystals and integrate backwards in time, running simulations for a range of assumed water vapor concentrations. As shown below, if the water vapor concentration is less than about 3.1 ppmv, then the ice crystals do not reach zero radius before they ascend into the subsaturated stratosphere, and hence the H2O concentration must have been at least 3.1 ppmv in order to grow the large crystals. Detailed simulations of ice nucleation, transport, and interaction with water vapor suggest that the large crystals probably nucleated on very effective ice nuclei and most aerosols present did not nucleate ice in spite of very large supersaturations.

Graph depicting dehydration of the air entering the stratosphere.



As shown above, if the water vapor concentration is less than 3.1 ppmv, ice crystals do not reach zero radius before ascending into the subsaturated stratosphere. Hence, H_2O concentration must have been at least 3.1 ppmv in order to grow the large crystals.

HOW DO VEHICLE EMISSIONS AFFECT CLIMATE?

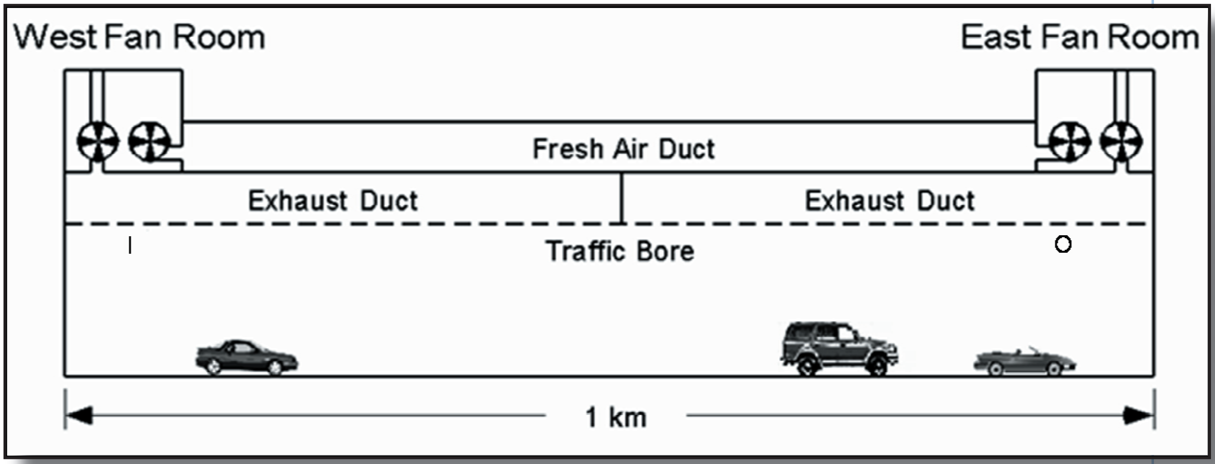
Anthony W. Strawa, Project Principal Investigator

Program Support: NASA, Radiation Sciences Program, Hal Maring

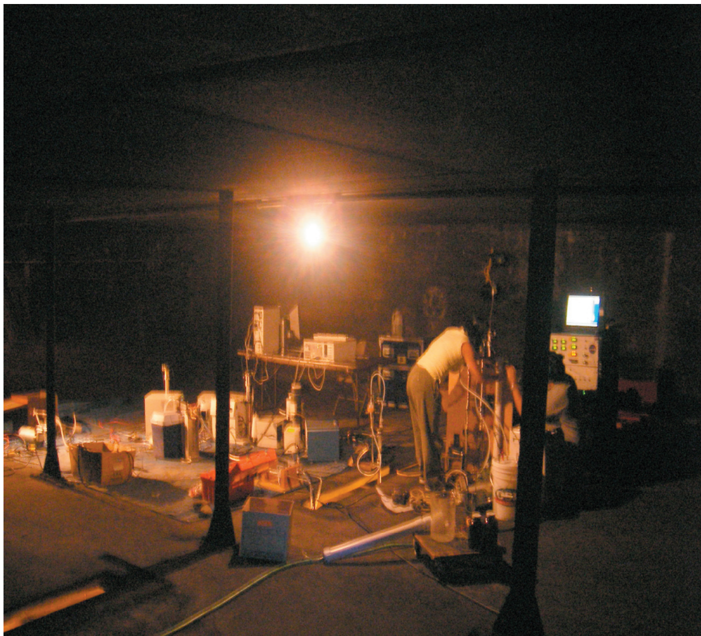
The objective of this study is to measure the radiative properties of vehicle emissions in a real world situation and assess the effects of aerosol on regional climate.

It is well known that aerosols have a profound effect on regional and global climate, however, large uncertainties remain in the measurement of key aerosol radiative properties, such as absorption and single scattering albedo and their distribution in the atmosphere. These effects are felt directly, through direct scattering and absorption of solar radiation, and indirectly by modifying cloud properties and precipitation. Single scattering albedo, the ratio of scattering to extinction, is an important metric for aerosol radiative effects and an important input into global climate models.

Heavy and light duty vehicles exiting the Caldecott Tunnel near San Francisco, CA.



Schematic layout of the Caldecott Tunnel. Our instrumentation was set up in an exhaust duct which is separated from the vehicle traffic.



Instrumentation in the ventilation area above the tunnel traffic bore.

The objective of this study is to measure the radiative properties of vehicle emissions in a real world situation and assess the effects of aerosol on regional climate.

Key Findings

Black Carbon (BC) dominates the radiatively active aerosol, especially during peak traffic periods. The single scattering albedo during these periods approaches that of pure BC emitted from a sooting diffusion flame.

The mass absorption efficiency of the tunnel aerosol is about 6 gm-2, which is at the low end of the range observed in the atmosphere. This suggests that the efficiency of BC emitted from trucks increases as it ages in the atmosphere.

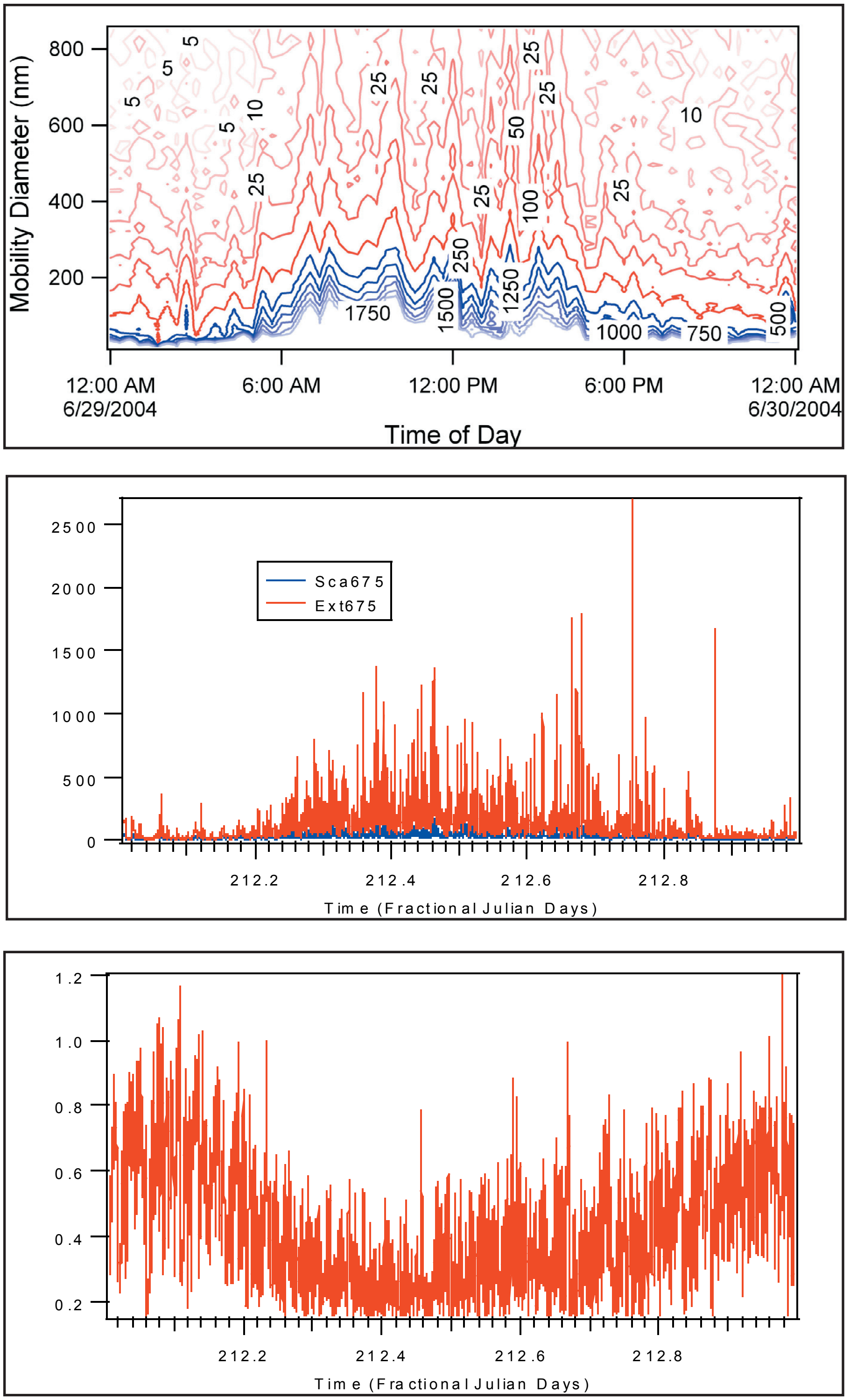
The number size distribution of aerosol is dominated by freshly nucleated particles, but there is a radiatively active soot accumulation mode (D-150 nm) and a larger mode (D-600 nm) of unknown composition.

Features of Cadenza

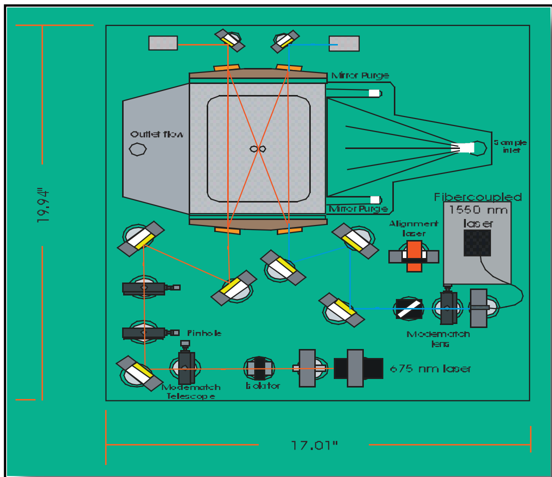
Cadenza [Strawa et al., 2003; Strawa et al., 2006] is a new instrument that uses continuous wave cavity ring-down (CW-CRD) to measure the aerosol extinction coefficient for 675 nm and 1550 nm light, and simultaneously measure the scattering coefficient at 675 nm using a reciprocal nephelometer [Mulholland and Bryner, 1994] concept. Both measurements are made in the same optical and flow cell at exactly the same conditions with a temporal resolution of about 1 sec. Absorption coefficient is obtained from the difference of measured extinction and scattering within the instrument and single scattering albedo from their ratio.

Observations

The measurements of optical properties show a distinct diurnal variation with peaks in the coefficients occurring during the midday commute. (*Continued on page 36.*)



Measurements of aerosol size distribution (top), extinction coefficient (middle), and single scattering albedo (bottom) during the day.



Schematic of Cadenza.

The single scattering albedo during the commute periods is very close to the values for pure black carbon. Values of optical coefficients are much lower on weekends and single scattering albedo is higher as expected.

While particle concentrations and optical coefficients are very high, they are not unlike those from other tunnel studies.

The magnitude of extinction and absorption coefficients was higher in the dual use bore than in the in the light duty bore, however, the single scattering albedo appears to be lower in the light duty bore. This is a surprising result and will be investigated further.

Web site: http://geo.arc.nasa.gov/sgp/aerocloud_web/homepage.html

IMPEX: INTERCONTINENTAL AND MEGA-CITY POLLUTION EXPERIMENT

Hanwant B. Singh, Co-Principal Investigator

Program Support: National Science Foundation, Anne-Marie Schmolter

The Intercontinental Mega-city Pollution Experiment (IMPEX) was managed by Ames' Earth Science Project Office that was based near Seattle, Washington. IMPEX was a collaborative effort between the NASA and the National Science Foundation (NSF) in using those agencies aircraft (the DC-8 and C-130, respectively) to measure the intercontinental flow of pollutants from Asia into North America. The IMPEX portion of the coordinated INTEX mission was designed to investigate several issues that occur out of Asia and into North America. The NASA DC-8 aircraft, based in Hawaii and Alaska, provided early interception of Asian pollution plumes traveling across the Pacific ocean. The NSF C-130 aircraft engaged the same air mass to characterize

National Science Foundation C-130 on the ramp at Paine Field, Seattle, WA.

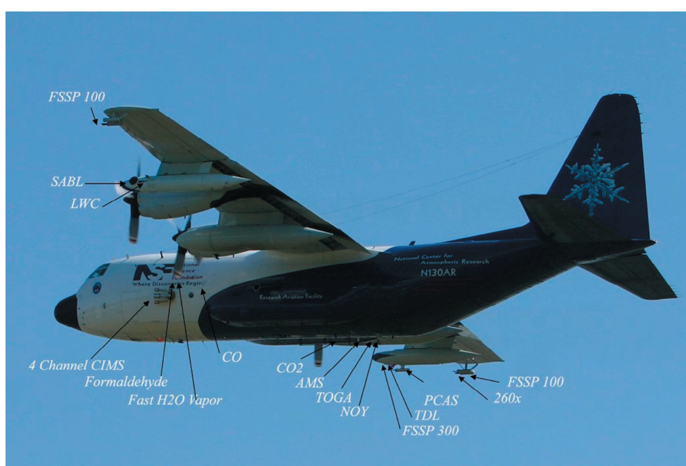
Instrument work being loaded onboard the C-130.

the aging of chemicals several days later, as they traveled into North America. In the experiment the Asian pollution plumes layered structure was also characterized.

The NSF C-130 platform was chosen because it is best suited for lower tropospheric and boundary layer (lower altitude) studies including processes of exchange with the free troposphere. Coordinated flights expanded the scale of measurements and study processes of evolution under a variety of conditions. Several inter-comparison flights with the NASA DC-8, as well as, over fixed points were conducted to develop a unified data set.

Web site: http://geo.arc.nasa.gov/sgg/singh/

Right: Inter-comparison flights wingtip to wingtip the NASA DC-8 provided instrument calibration between aircraft. Below: NSF C-130 Atmospheric Chemistry Instrument layout.



THE INTEX-B/MILAGRO NORTH AMERICAN FIELD EXPERIMENT 2006

Hanwant B. Singh, Lead Mission Scientist

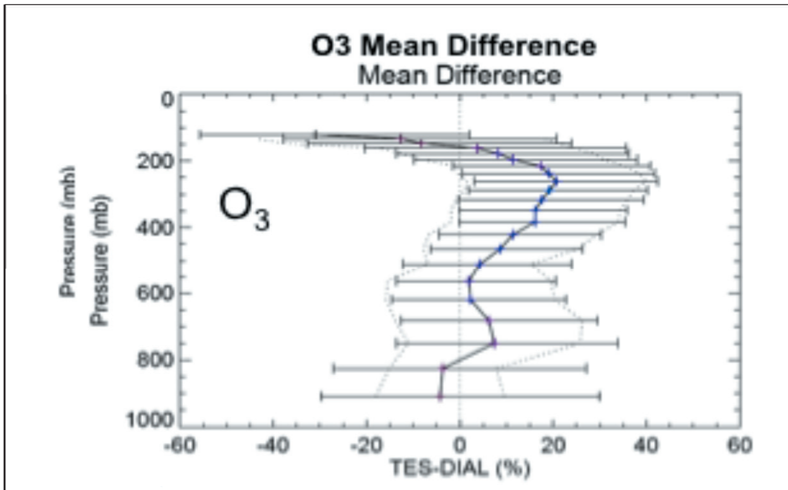
Program Support:
- *NASA, Radiation Sciences Program, Hal Maring*
- *NASA, Tropospheric Chemistry Program, Bruce Doddridge*

The goal of this experiment was to understand the impacts of intercontinental pollution transport on air quality and climate from local to global scales. INTEX-B/Milagro was a highly successful international campaign led by scientists from ARC (H. Singh, Lead Mission Scientist) with over 300 participants. It was an international collaboration of agencies from the United States (NASA, NSF, DOE), Mexico, Canada, and Germany.

The campaign was performed in the spring of 2006 in two parts: the first part (March) investigated pollution export from Mexico City and the second part (April-May) focused on the pollution export from Asia to North America. Multiple satellites, instrumented aircraft, ground stations, and models were utilized to achieve mission objectives.

INTEX-B Satellite and Aircraft Platforms

Aircraft Bases and DC-8 Flight Tracks

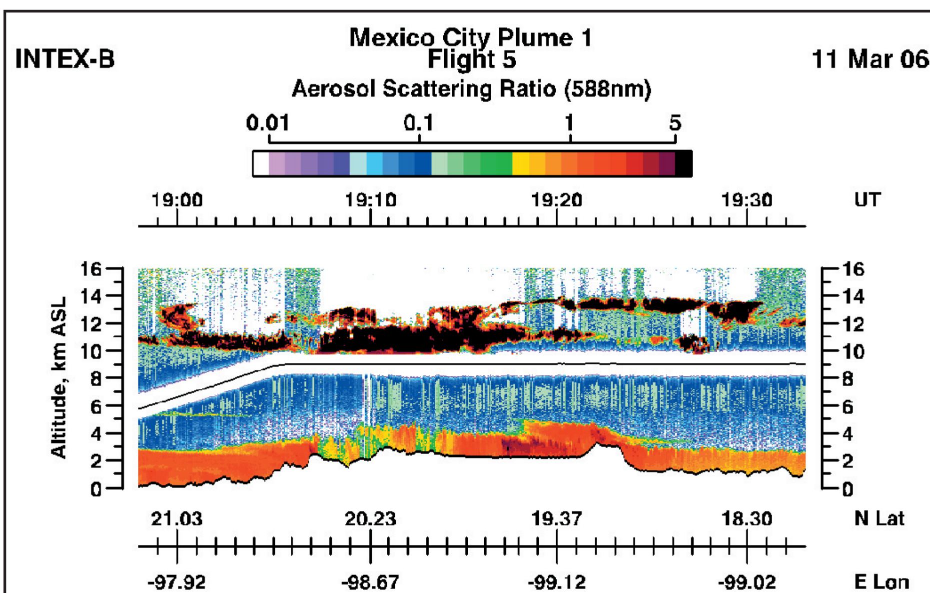


Ozone Comparisons from Satellite & DC-8

Scientific objectives of the experiment included the study of:

- Continental Outflow: Extent & persistence of the outflow of pollution from Mexico.
- Transpacific Pollution: Transport and evolution of Asian pollution & implications for air quality & climate.
- Air Quality: Relating atmospheric composition to sources & sinks & testing chemical transport models.
- Aerosol Radiative Forcing: Characterizing effects of aerosols on solar radiation.
- Satellite Validation: Validating space-borne observations of tropospheric composition.

INTEX-B/Milagro has provided a comprehensive and unique data set for investigating the transformation of gases and aerosols during long-range transport, for the radiation balance of the troposphere, and for validating a variety of satellite observations as well as models of chemistry and transport. These data are presently being analyzed and will be published in a series of papers in peer reviewed journals.



Small Particle Pollution Over Mexico City

J-31 INTEX-B/MILAGRO MISSION

Philip B. Russell, Project Principal Investigator

Program Support:
- *NASA, Radiation Sciences Program, Hal Maring*
- *NASA, Suborbital Science Program, Cheryl Yuhas*

In February and March 2006, as part of the INTEX-B/MILAGRO (Intercontinental Chemical Transport Experiment/Megacity Initiative; Local and Global Research Observations) mission, the Sky Research Jetstream 31, loaded with a suite of atmospheric science equipment, deployed to Veracruz, Mexico to measure the properties and radiative effects of aerosols, water vapor, clouds and surfaces.

The specific goals of the mission were to:

- Characterize the distributions, properties, and effects of aerosols and water vapor advecting from Mexico City and biomass fires toward and over the Gulf of Mexico, including, aerosol optical depth and extinction spectra.

Sky Research J-31 aircraft on the ramp at the General Heriberto Jara International airport, Veracruz, Mexico.

Science flight planning meeting at the MILAGRO Operations Center in Veracruz.

- Test the ability of Aura, other A-Train and Terra sensors, and airborne lidar to retrieve aerosol, cloud and water vapor properties.
- Characterize surface spectral albedo and bidirectional reflectance distribution function (BRDF) to help improve satellite retrievals.
- Quantify the relationships between the above and aerosol amounts and types.

To meet the above science goals, the J-31 carried a payload comprised of the following six instruments:

- Ames Airborne Tracking Sunphotometer (AATS-14), PI: Dr. Jens Redemann
- Solar Spectral Flux Radiometer (SSFR), PIs: Dr. Peter Pilewskie and Dr. Sebastian Schmidt
- Research Scanning Polarimeter (RSP), PI: Dr. Brian Cairns
- Cloud Absorption Radiometer (CAR), PIs: Dr. Charles Gatebe and Dr. Michael King
- Position and Orientation System (POS), PI: Rose Dominguez
- Meterological Sensors and Nav/Met Data System (Nav/Met), PI: Warren Gore

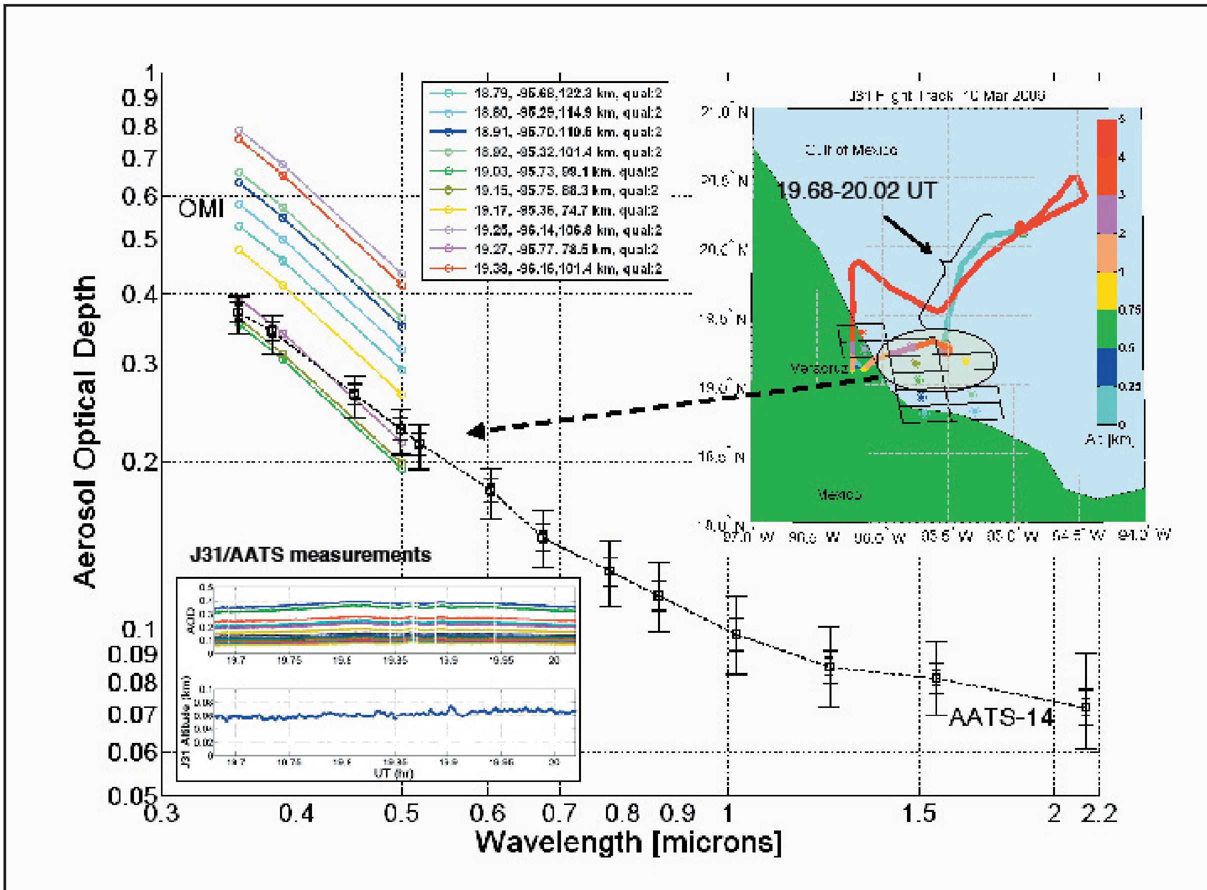
The Earth Science Division played a major role in this deployment. The J-31 Lead Principal Investigator, Dr. Phil Russell, led the instrument PIs in developing a consensus set of science goals.

He coordinated flight planning, including appointment of Flight Scientists. Ames provided three of the six instruments on-board the J-31, and monitored instrument integration by Sky Research, including the new installation of the CAR instrument on the nose of the aircraft. The Earth Science Project Office in SG managed the deployment to Veracruz, and worked with Mexican officials for all aspects of the deployment, including permits, shipping, visas, accommodations, security, ground support, etc.

Planning of this mission was a complex endeavor, requiring close coordination with the many MILAGRO science and operations groups. The J-31 team had to not only balance science flight objectives among the on-board instruments, but also had to coordinate flight plans with the other five U.S. aircraft participating in the campaign (along with additional ground elements), Mexican airspace air traffic restrictions, and coordinate with defined satellite overpass times. Continuously changing conditions over both Mexico City and the Gulf of Mexico required frequent changes to flight paths to maximize science data return. In all, measurements were made on thirteen successful flights out of Veracruz over a three-week deployment period.

Review of the science data is now underway, including comparisons of aerosol optical depth (AOD) values from the J-31 sunphotometer (AATS) to those from the OMI and MODIS satellite

J-31 flight over Mexico City metropolitan area showing local haze and pollution. March 6, 2006.



Comparison of OMI and AATS Aerosol Optical Depth. Corresponding J-31 flight track is shown.

instruments. Data are being archived in the INTEX-B archive at NASA Langley. Preliminary science results were presented at the first MILAGRO science meeting in Boulder, CO in October 2006, and further science results will be presented at the Fall 2006 AGU meeting in San Francisco in December and the INTEX-B science meeting in March 2006. Special sessions on INTEX-B/MILAGRO are planned for the Fall 2007 AGU meeting in San Francisco.

MEASURING SOLAR SPECTRAL IRRADIANCE DURING THE 2006 GULF OF MEXICO ATMOSPHERIC COMPOSITION AND CLIMATE STUDY

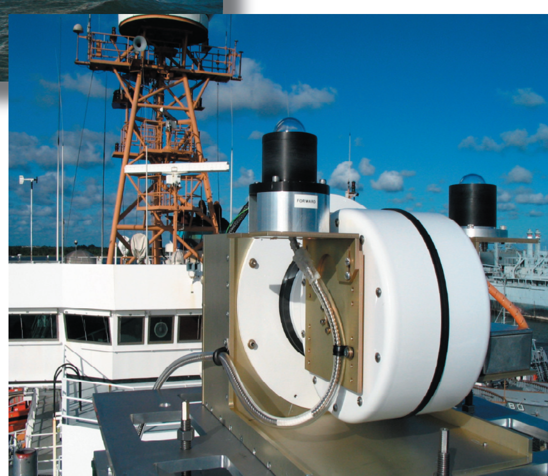
Warren J. Gore, Project Co-Principal Investigator

Program Support: NASA, Office of Global Programs, Kea Duckenfield

During the 2006 Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS) field campaign the Solar Spectral Flux Radiometer (SSFR) team from NASA Ames Research Center and the University of Colorado deployed a SSFR system on the CIRPAS Twin Otter to measure the spectrally resolved net solar irradiance over Texas and the Gulf of Mexico. A second SSFR system was also deployed on the NOAA Ship Ron Brown to measure the solar spectral irradiance and radiance at the surface.

NOAA Ship Ron Brown

GoMACCS was a NOAA-led multi-institutional intensive field program to characterize marine/continental chemical and meteorological processes to improve the simulation of the radiative forcing of climate change by lower-atmosphere ozone and aerosols. In addition to clear-



Light collectors on the stabilizing system sky radiative effects, GoMACCS also investigated the influence of aerosols on cloud properties and the role of clouds in chemical transformation.

The Solar Spectral Flux Radiometer is a moderate resolution flux (irradiance) spectrometer covering the wavelength range from 300 to 2200 nm.

The SSFR team uses the radiometric observations to:

- Quantify the solar spectral radiative energy budget in regions under the influence of industrial/urban pollutants.
- Determine the solar spectral absorption in atmospheric layers.
- Relate our findings to the chemical and physical properties of the aerosols.
- Compare findings to other in situ and remote sensing methods of measuring absorption.
- Aid in quantifying the effect of aerosols on cloud radiative properties by retrieving cloud effective radius and cloud water path from the spectral measurements and by identifying aerosol influence on cloud spectral reflectance.

(Left) Zenith light collector; (center, above) CIRPAS Twin Otter; and (right) Nadir light collector.

The long-term goal of this research is to improve our knowledge of aerosol radiative processes and their influence on climate and to facilitate the remote sensing of aerosol radiative properties from space to achieve global coverage.

The CIRPAS Twin Otter SSFR system measured upwelling and downwelling solar spectral irradiance above and below aerosol layers and above cloud systems. It was operational during 22 flights from 21 Aug. 2006 to 15 Sept. 2006. It acquired a total of 405,100 spectra (856 Mbytes) from these flights.

The Ron Brown SSFR system measured downwelling solar spectral irradiance and radiance. This system was implemented with a stabilizing system to constantly maintain the two light collectors in the vertical pointing orientation to within +/- 1 degree. The SSFR system operated successfully from 2 Aug. 2006 to 11 Sept. 2006. It operated from early morning to almost sunset. It acquired close to 1.5 million spectra (3.2 Gbytes) from the cruise.

SSFR system

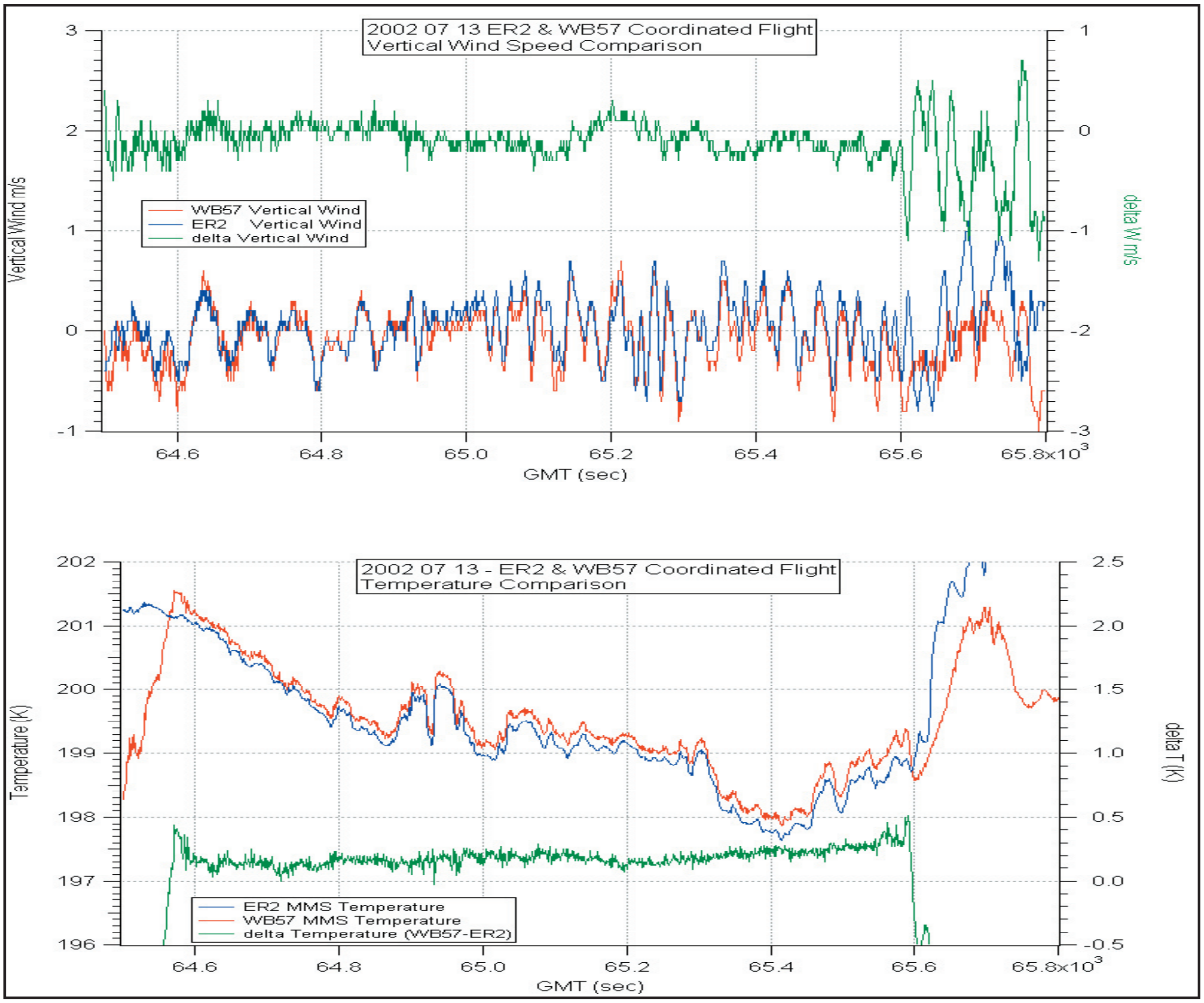
METEOROLOGICAL MEASUREMENT SYSTEMS (MMS)

T. Paul Bui, Project Principal Investigator

Program Support:
- *NASA, Radiation Sciences Program, Hal Maring*
- *NASA, Upper Atmosphere Research Program, Michael J. Kurylo*
- *NASA, Tropospheric Chemistry Program, James Crawford*
- *NASA, Suborbital Science Program, Cheryl Yuhas*

The Meteorological Measurement System (MMS) is a state-of-the-art instrument for measuring accurate, high resolution in situ airborne state parameters (pressure, temperature, turbulence index, and the 3-dimensional wind vector). These key measurements are crucial to our understanding of atmospheric dynamics, chemistry and microphysical processes.

The MMS is used to investigate atmospheric mesoscale (gravity and mountain lee waves) and microscale (turbulence) phenomena. An accurate characterization of the turbulence phenomenon is important for the understanding of dynamic processes in the atmosphere, such as the behavior of buoyant plumes within cirrus clouds, diffusions of chemical species within wake vortices generated by jet aircraft, and microphysical processes in breaking gravity waves. Accurate temperature and pressure data are needed to evaluate chemical reaction rates as well as to determine accurate mixing ratios. Accurate wind field data establish a detailed relationship with the various constituents and the measured wind also verifies numerical models used to evaluate air mass origin. Since the MMS provides quality information on atmospheric state variables, MMS data have been extensively used by many investigators to process and interpret the in situ experiments aboard the same aircraft. In addition to the original development on the high-altitude ER-2 aircraft, MMS systems had flown successfully on the NASA DC-8 and WB-57 aircraft. An MMS is currently under development for the Altair unmanned aerial systems (UAS). Because of its unique capabilities, the MMS has been competitively selected to fly on virtually all NASA airborne atmospheric science campaigns in the last 10 years. These international experiments have spanned the globe, from the North Pole to Antarctica and from the western Pacific to Scandinavia. Recent field campaigns included SOLVE, CAMEX-3/4, CRYSTAL-FACE, MideCix, and AURA Validation Experiment.



(Above): Sample data from MMS

The MMS instrumentation consists of three major systems:

- An air motion sensing system to measure the velocity of the air with respect to the aircraft, i.e., the true air speed.
- An inertial navigation system to measure the velocity of the aircraft with respect to the earth, i.e., the ground speed.
- A data acquisition system to sample, process and record the measured quantities.

The air motion sensing system consists of sensors, which measure temperature, pressures, and airflow angles (angle of attack and yaw angle). The Litton LN-100G

Embedded GPS Inertial Navigation System (INS) provides the aircraft attitude, position, velocity, and acceleration data. On the DC-8, the Trimble TANS Vector provides secondary attitude and navigation data. The TANS Vector utilizes the GPS carrier phase shift between multiple antennas to derive independent aircraft attitude. The Data Acquisition System samples the independent variables simultaneously and provides control over all system hardware.

The true airspeed vector depends on air data measurements, including static pressure, static temperature, pitot pressure, and air flow with respect to the fuselage. Accurate measurements of these quantities require judicious choices of sensor locations, repeated laboratory calibrations, and proper corrections for compressibility, adiabatic heating and flow distortion. The ground speed vector is derived from the integration of acceleration data using the appropriate numerical constraints and compensation. For example, the vertical acceleration data includes the compensation for distance above the surface (1/R2), centrifugal effects, and non-spherical earth effects. The integration is constrained by an altitude derived from the hydrostatic equation.

The system calibration of the MMS consists of:

1. Individual sensor calibrations.
2. Sensor dynamical response tests.
3. Laboratory determination of the dynamic behavior of the inertial navigation system.
4. In-flight calibration.
5. Comparison with radiosonde and radar-tracked balloons.

Web site: http://geo.arc.nasa.gov/sgg/mms/index.htm

NASA AFRICAN MONSOON MULTIDISCIPLINARY ANALYSES (NAMMA) MISSION

Michael Gaunce, Project Manager

Program Support: NASA, Atmospheric Dynamics Program, Ramesh Kakar

The NASA African Monsoon Multidisciplinary Activities (NAMMA) mission was a major 2006 field campaign based in the Cape Verde Islands, 350 miles off the coast of Senegal, designed to study tropical storm systems and the genesis process for hurricanes. The mission was designed to characterize the evolution and structure of African Easterly Waves (AEWs) and mesoscale convective systems over continental western Africa, the formation and evolution of tropical hurricanes in the eastern and central Atlantic, the composition and structure of the Saharan Air Layer, and whether aerosols affect cloud precipitation and influence cyclone development.

NAMMA utilized the NASA DC-8 research aircraft, with a total of 10 instruments and nearly 100 scientists in the field to sample tropical storm systems and provide valuable data to validate NASA's earth science satellites. The DC-8 was also flown in coordination with NASA's TOGA research weather radar, balloon soundings, and the SMART-COMMIT mobile research ground stations, measuring chemical, optical, microphysical, and radiative properties of the atmosphere.

The NAMMA science team receives a weather briefing by the forecast team. Daily weather forecasts are used in the field to help select the appropriate flight plan and operational constraints.

Some noteworthy highlights of the 30-day mission:

- NASA conducted 13 science flights that sampled seven major waves/circulations, including what is thought to be the genesis of tropical systems Debby,

NASA DC-8 aircraft on the ramp at the Amilcar Cabral International airport, Sal Island, Cape Verde.

Ernesto, Gordon, and Helene, from mid-August to mid-September of 2006.

- NASA flew a number of dedicated missions studying cloud microphysics and the Saharan Air Layer. The influence of the SAL and its associated mid-level jet will be studied for years to come with data never before available to the science community.

- NASA provided tropical system formation data which was passed to NOAA for further definition and study as the systems moved west toward the Caribbean and the North American continent.

The Earth Science Division played a major role in this deployment. The deployment was managed by the Earth Science Project Office, which provided overall project management and logistics for the mission, including the set-up of four separate operational sites. In addition, three of the science instruments on the DC-8 were led by Ames Principal Investigators: the Diode Laser Hygrometer, the Meteorological Measurement System, and the Carbon mOnoxide By Attenuation of Laser Transmission (COBALT) instrument. In addition, excellent photo and video coverage of the mission was provided by the Ames Video Production Group of Public Affairs.

Due to the current media interest in global climate change and the events of the 2005 hurricane season, this mission received extensive media coverage. Subsequent to a NASA news release and press conference on July 26, 2006, the story received wide coverage in all 50 states and around the world, especially from Web and print media, including the New York Times, USA Today, and the Washington Post. A profile of the mission was also featured on National Public Radio. International coverage included stories from Australia, Canada, Cape Verde, China, Denmark, Germany, India, Kazakhstan, Malaysia, Netherlands, Nigeria, Portugal, Romania, South Africa, Spain, and the United Kingdom.

Dr. Ed Browell of NASA Langley discusses lidar science on-board the DC-8 with Cape Verdean high school students.

Phillip Parker monitors the RTMM while aboard the DC-8.

The mission was a collaboration between NASA, the National Oceanic and Atmospheric Administration (NOAA) Hurricane Research Division, several universities, the U.S. Air Force, and the Cape Verdean National Institute of Meteorology and Geophysics (INMG). NAMMA was also conducted in close cooperation with the AMMA mission, another major, multi-national (25+ countries) field experiment to study West African monsoons and their effect on water resources and climate in western Africa.

Dr. Jim Podolske of the Atmospheric Science Branch examines laser absorption spectrometer data of water vapor and carbon monoxide during a NAMMA science flight.

NAMMA was sponsored by the Atmospheric Dynamics and Radiation Sciences programs at NASA Headquarters. Dr. Ramesh Kakar and Dr. Hal Maring are the Headquarters program sponsors.

Data from the mission has been checked, calibrated, and archived in the NAMMA data archive at NASA Marshall. Review of the science data soon followed. The first NAMMA science meeting occurred, Spring 2007.

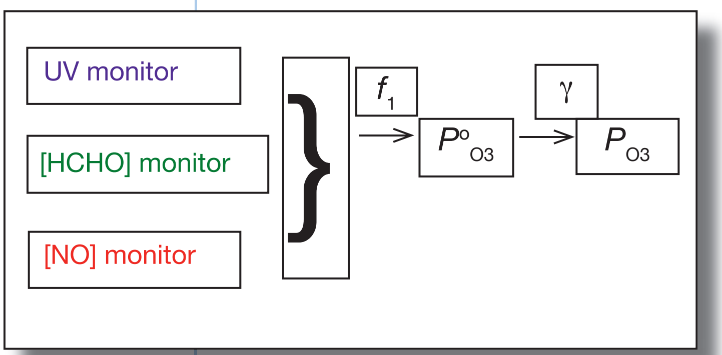
Web site: http://namma.nsstc.nasa.gov

Cindy Twohy, Aaron Pratt, and Tamara Batte aboard the DC-8.

QUANTIFYING SMOG OZONE PRODUCTION AND TRANSPORT

Robert B. Chatfield, Project Principal Investigator

Program Support: NASA, Tropospheric Chemistry Program, James Crawford

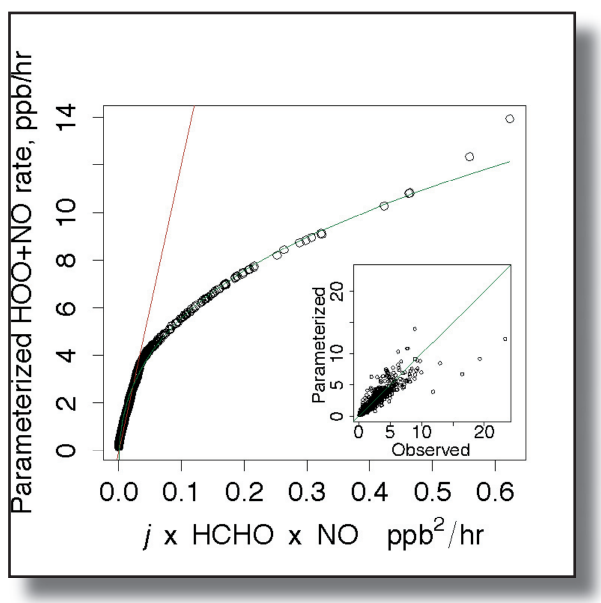


Simple surface measurement setup that is useful for augmented surface air pollution sites.

NASA research on board the Tropospheric Chemistry Program's DC-8 laboratory has provided a promising description of regional and continental smog ozone production. A method to quantify the chemical processes that create smog ozone unexpectedly appeared from analyzing data obtained during the Intercontinental Transport Experiment (INTEX) airborne campaigns in 2004 and 2006. Ozone production can be quantified by measuring the reactive flow of volatile organic carbon (VOC) species in combination with nitric oxide that converts VOC-derived radicals to smog ozone. A simple formula,

$$P_{O3} = \gamma f_1 \left(j_{HCHO} [HCHO] [NO] \right)$$

The function f_1 relating the α = simple product of a photolysis rate, the formaldehyde concentration, and the NO concentration of a near-surface air sample to the "principle" ozone production rate of the air. The function bends downward in slope, reflecting the fact that ozone is produced less efficiently at high concentrations. Good correlation of the prediction and observations is shown in inset.

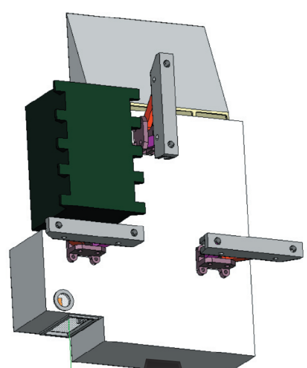


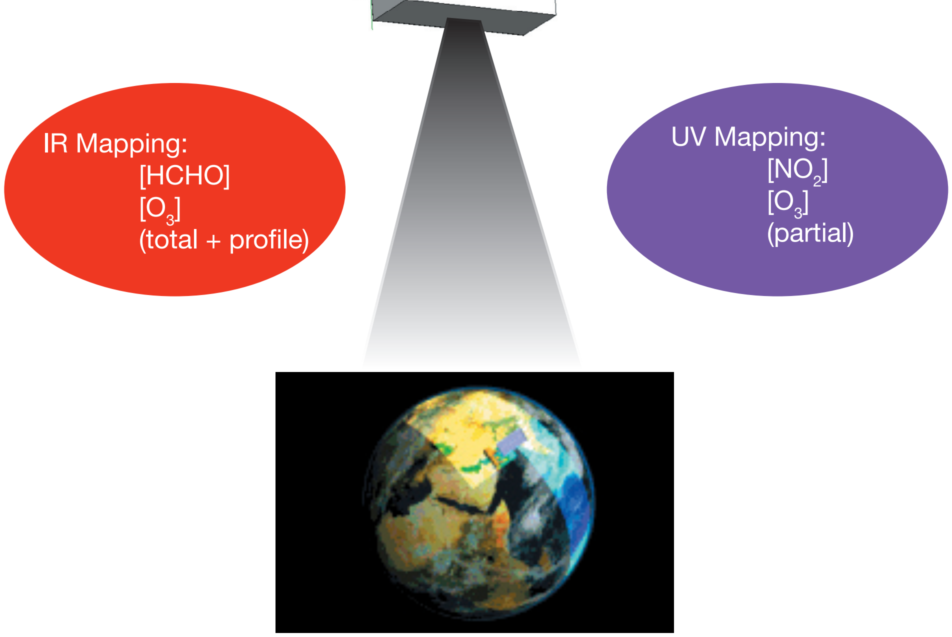
may be applied using measurements of formaldehyde, nitric oxide, and UV radiation, suitable for surface and airborne monitoring; and where f_1 appears to be nearly a universal function, the conversion parameter γ varies predictably over a small range. This work uses measurements by instruments developed at Penn State (Brune, Ren) and NCAR (Fried, Shetter). A second function closely related to f_1, F_2, should be useful in evaluating which ozone precursors are most effective in a regionally controlled strategy.

The function f_1 also suggests that remotely sensed measurements of lower-tropospheric formaldehyde, nitrogen oxides, and UV radiation can usefully inform and constrain our understanding of smog ozone production. HCHO measurements help quantify ozone production, while measurements of smog-layer O_3 itself helps define transport. Transport and production are often difficult to distinguish in pollution-control situations.

Web site: http://geo.arc.nasa.gov/sgg/chatfield/index.html

The Tropospheric Infrared Mapping Spectrometer concept (courtesy J. Kumer, Lockheed-Martin) and a depiction of how formaldehyde (HCHO) and tropospheric O_3 may be accurately sampled from space with a proposed mid-infrared sensing technology. Ozone, UV radiation and NO_2 may be sampled using UV technology such as the Ozone Monitoring Instrument.





RE-EXAMINING POLAR OZONE LOSS

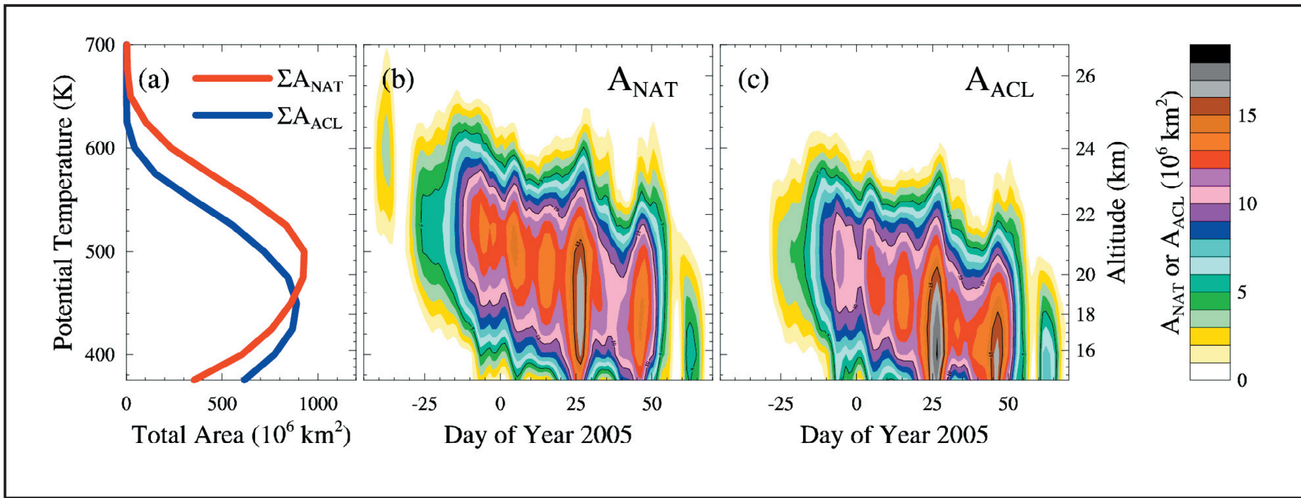
Katja Drdla, Project Principal Investigator

Program Support: NASA, Atmospheric Chemistry and Analysis Program, Phil DeCola

Over the last two decades, dramatic ozone loss has occurred every winter over the south pole. This phenomenon, commonly known as the "ozone hole," continues to be of concern, as demonstrated by the record ozone hole that occurred in October 2006, even though international regulations limiting the production of the responsible chemicals have taken effect.

The earliest studies on ozone loss inferred that the polar stratospheric clouds (PSCs) from each winter played a critical role in the ozone depletion, because PSC chemistry can activate the chlorine that destroys ozone. But revisions to PSC microphysics and chemistry have decreased the PSC reactivity by orders of magnitude relative to initial estimates. Research at Ames has re-evaluated the fundamental factors that control chlorine activation, and thus control ozone loss. This research has identified background sulfate aerosol, that is always present in the stratosphere, as the primary source of chlorine activation, rather than the infrequently occurring PSCs. The shift from clouds to aerosol implies that aerosol properties, rather than PSC microphysics and PSC-related parameters, determine when and where chlorine activation and subsequent ozone loss occur. For example, the aerosol properties are more sensitive to changes in the earth's atmosphere that may occur over the next few decades.

Research at Ames will continue to investigate the implications of sulfate aerosol for polar ozone loss. New parameterizations of ozone loss are being developed for incorporation into large scale models such as climate models and numerical weather prediction models. Analysis of Arctic and Antarctic ozone loss over the last two decades will be examined for further evidence of the role of sulfate aerosol. The sensitivity of future ozone loss to factors such as volcanic eruptions, temperature changes, and humidity changes will continue to be explored.

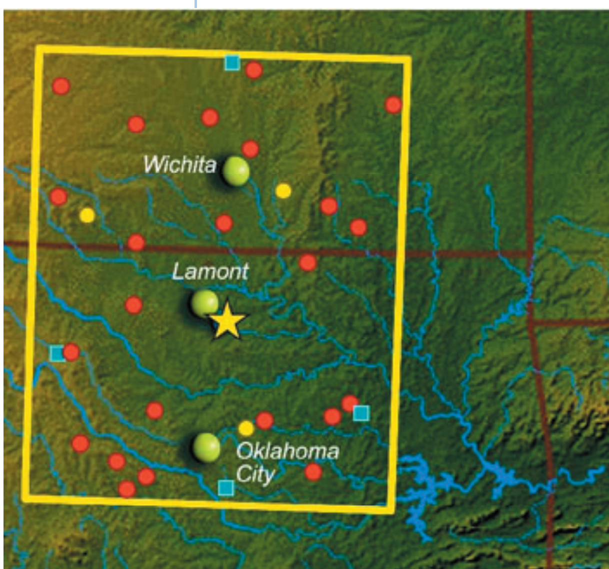


The extent of calculated Arctic chlorine activation, comparing the traditional metric (ANAT) with the new proposed metric (AACL). Note the differences in vertical extent between the two calculations, and the difference in the initial onset of activation.

SHORTWAVE SPECTRORADIOMETER (SWS)

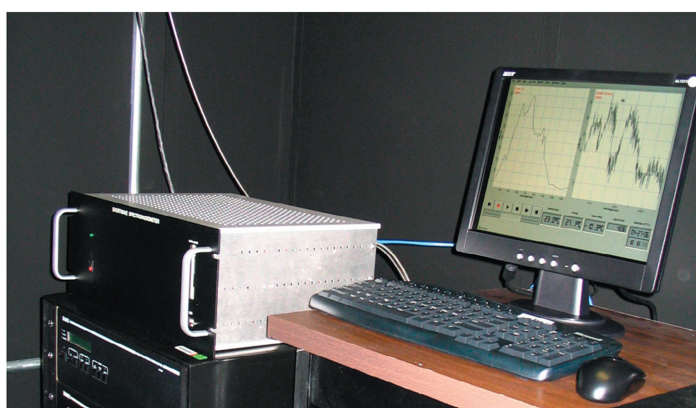
Warren J. Gore, Project Co-Principal Investigator

Program Support:
DOE Atmospheric Radiation Measurement Program



On April 27, 2006 the Atmospheric Radiation Group installed the Shortwave Spectroradiometer (SWS) at the Department of Energy Atmospheric Radiation Measurement Climate Research Facility (ACRF) in north central Oklahoma. The development of the SWS is supported by a grant from the Department of Energy. It joins other ground instruments at the ACRF Southern Great Plains (SGP) site to observe cloud formation processes and their influence on radiative transfer. This contributes to advancing scientific knowledge of the Earth systems.

The Shortwave Spectroradiometer design came from our highly successful airborne Solar Spectral Flux Radiometer (SSFR). The SWS measures the absolute visible and near infrared spectral radiance (units of watts per meter square per nanometer per steradian) of the zenith directly above the instrument. It is a moderate resolution sensor comprised of two Zeiss



Shortwave Spectrometer in Operation

spectrometers (MMS 1 NIR enhanced and NIR-PGS 2.2) for visible and near-infrared detection in the wavelength range 300 – 2200 nm. The sampling frequency is 1 Hz. The spectral resolution is 8 nm for the MMS 1 NIR and 12 nm for the NIR-PGS 2.2. The light collector has a narrow field of view (1.4^{o}) collimator at the front end of a high-grade custom-made fiber optic bundle. Its operation is autonomous and capable of daily day-time measurement of at least 12 hours. Data uploading is done hourly via the internet to the archive at the Pacific Northwest National Lab (PNNL) in Richland, WA. SWS control and data monitoring can be done remotely from Ames.

The SWS measurements can be used to:

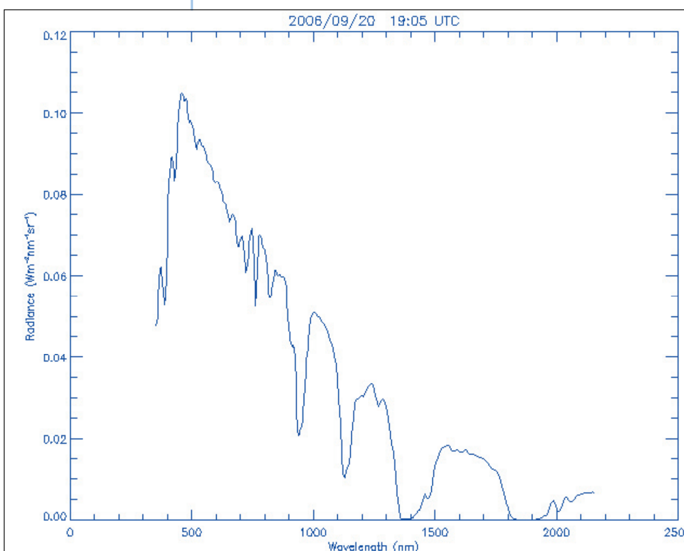
- Retrieve cloud optical depth, particle size and cloud water path.
- Test the cloud optical depth retrieval for overcast and broken cloud fields.
- Validation/comparison with SGP surface remote sensors and future cloud intensive operational period (IOP) campaigns.
- Multivariate analysis to derive information content in hyper spectral data sets and to improve cloud retrieval algorithm development.
- Compare with radiative transfer models for testing and validating retrieval procedures.

Peter Pilewskie (formerly with NASA Ames) of the University of Colorado in Boulder is the instrument mentor.

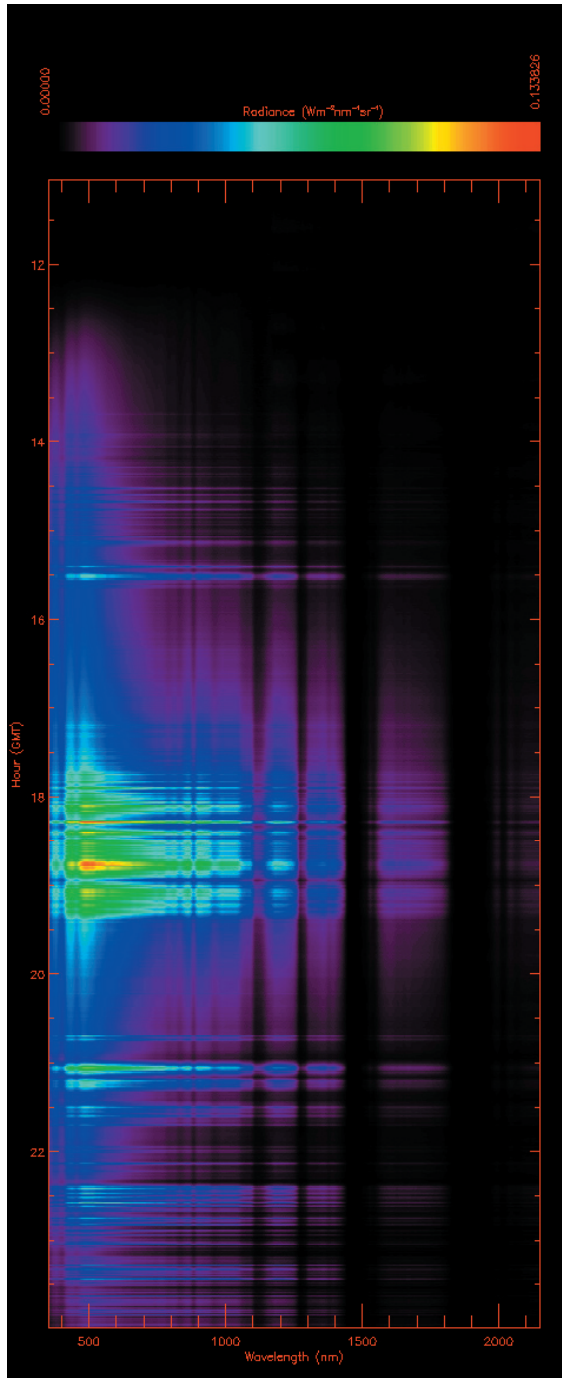
Total Sky Imager

Light Collector on Top of Optical Trailer

Below is a comparison of data obtained from the Shortwave Spectroradiometer and the Total Sky Imager on 20 Sept. 2006 under cirrus sky condition.



SWS Spectrum at 1905 UTC



SWS Full-day Image

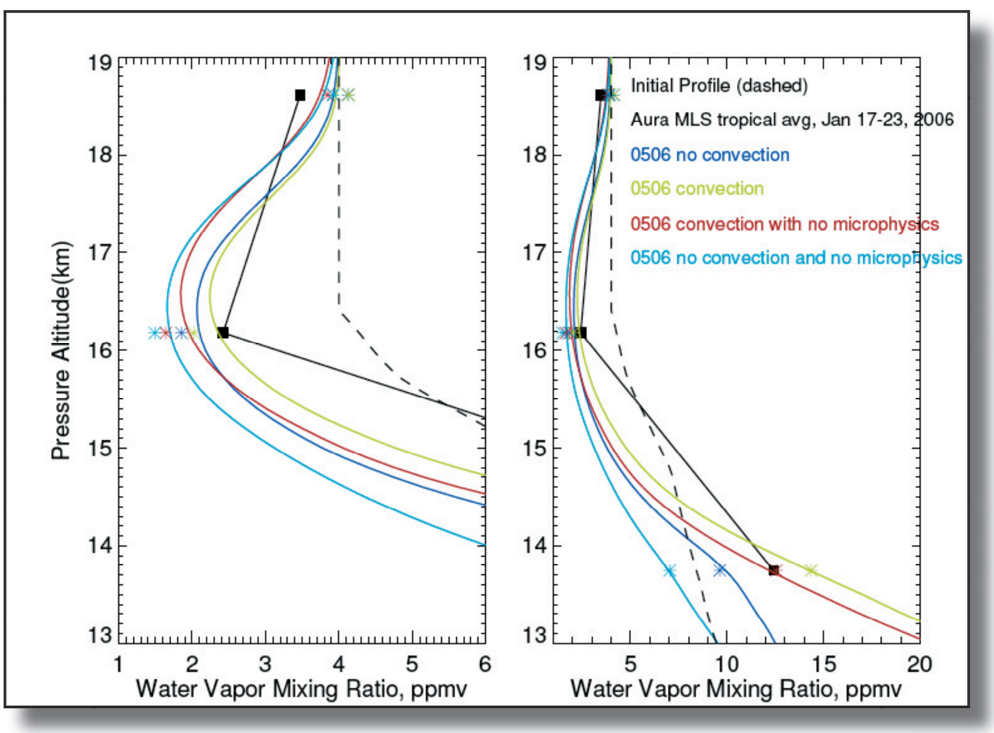
SIMULATION OF WATER VAPOR AT THE TROPICAL TROPOPAUSE

Leonhard Pfister, Principal Investigator

Program Support: NASA, Upper Atmosphere Research Program, Michael J. Kurylo

Understanding the processes that determine water vapor at the tropical tropopause is important for forecasting water vapor trends in the stratosphere (which contribute to Ozone trends) and evaluating the radiative forcing due to clouds at the tropical tropopause.

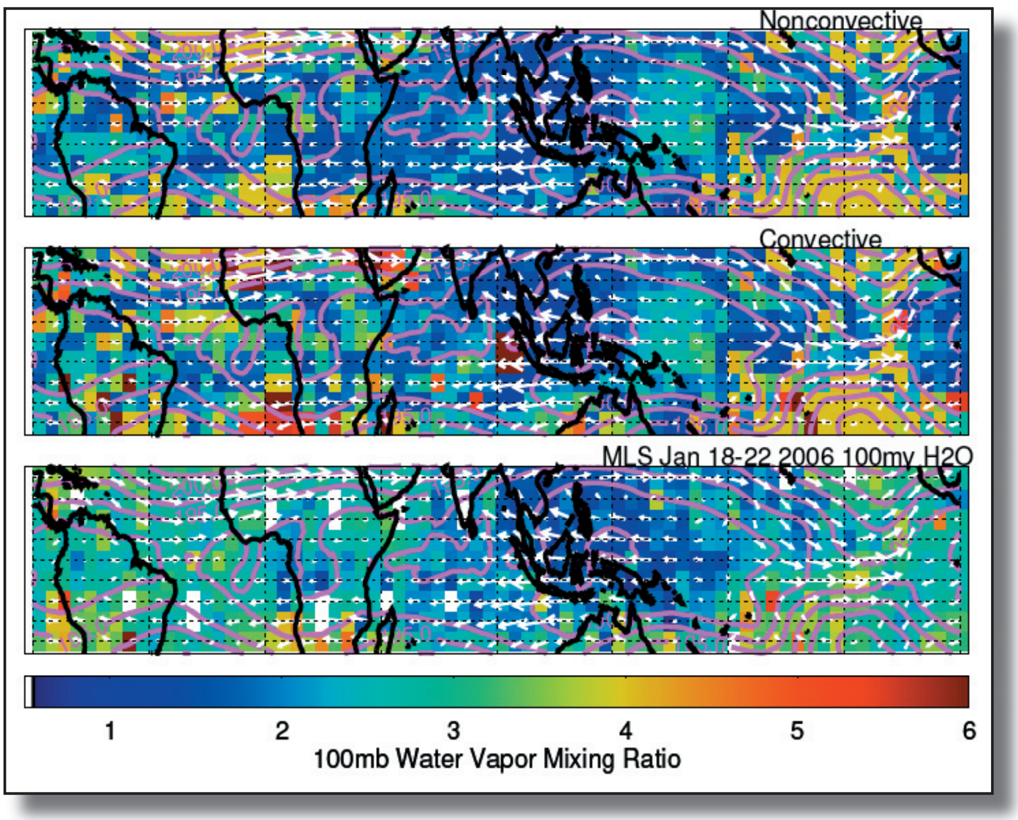
Using a trajectory based microphysical model, we are now able to actually simulate water vapor at the tropical tropopause to the kind of precision that solving the above two problems entails. At left are the tropically averaged vertical profiles for a number of simulations as compared with data from the Microwave Limb Sounder instrument aboard NASA's Aura satellite. The figure below illustrates three points. First, by including all the known physical processes (including ice particle formation, fallout, and reevaporation, as well as convection -- light green curve) we are able to simulate observed Aura values to less than .5 ppmv at the tropical tropopause (about 16 km,



close to MLS' 100mb observation point). Second, convection is clearly important for determining reasonable values, not only at lower levels at 13.5 km but at the tropopause itself. Third, excluding the complex microphysical processes (especially in the absence of convection -- light blue curve) yields a tropopause that is too dry by 30%.

The figure below shows a comparison of the simulation with MLS at 16 km, with temperatures (magenta) and winds (white) superimposed. The broad outlines of the horizontal structure are captured well by the model.

Web site: Leonhard.Pfister-1@nasa.gov



SOLAR SPECTRAL FLUX RADIOMETER (SSFR) IN INTEX-B/MILAGRO

Warren Gore, Project Co-Principal Investigator

Program Support: NASA, Radiation Sciences Program, Hal Maring

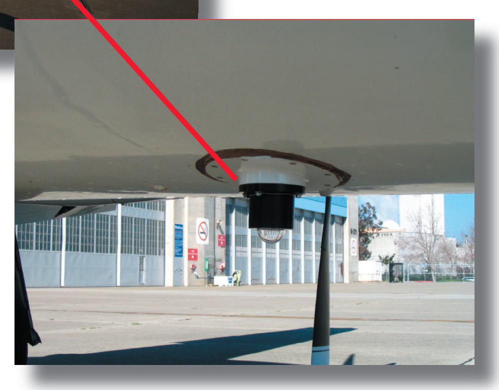
During the 2006 Intercontinental Chemical Transport Experiment (INTEX-B)/Megacity Initiative: Local and Global Research Observations (MILAGRO) field campaign a team from NASA Ames Research Center and the University of Colorado flew the Solar Spectral Flux Radiometer (SSFR) aboard the Sky Research Jetstream-31 (J-31) to measure the spectrally resolved net solar irradiance in the Mexico City outflow region toward and over the Gulf of Mexico. These radiometric observations are used to: quantify the solar spectral radiative energy budget; determine the solar spectral absorption in the atmospheric layers; relate our findings to the chemical and physical properties of aerosol; compare findings to other in situ and remote sensing methods of measuring absorption; quantify the effect of aerosols on cloud radiative properties (the "indirect effect"). The long term goal of this research is to improve our knowledge of aerosol radiative processes and their influence on climate and to facilitate the remote sensing of aerosol radiative properties from space.

Below and right: SSFR integrated system on-board the J-31.

The Solar Spectral Flux Radiometer is a moderate resolution flux (irradiance) spectrometer.

Specifications:

- Wavelength range: 300 nm to 2200 nm
- Spectral resolution: ~ 8-12 nm
- Simultaneous zenith and nadir viewing
- Hemispherical field-of-view
- Accuracy: ~ 3%; Precision: 0.5%
- Measured quantities: Upwelling and downwelling spectral irradiance ($Wm^{-2}nm^{-1}$)
- Derived quantities: Spectral albedo, net flux, flux divergence (absorption), and fractional absorption
- Retrieved quantities: r_e, τ, liquid water path



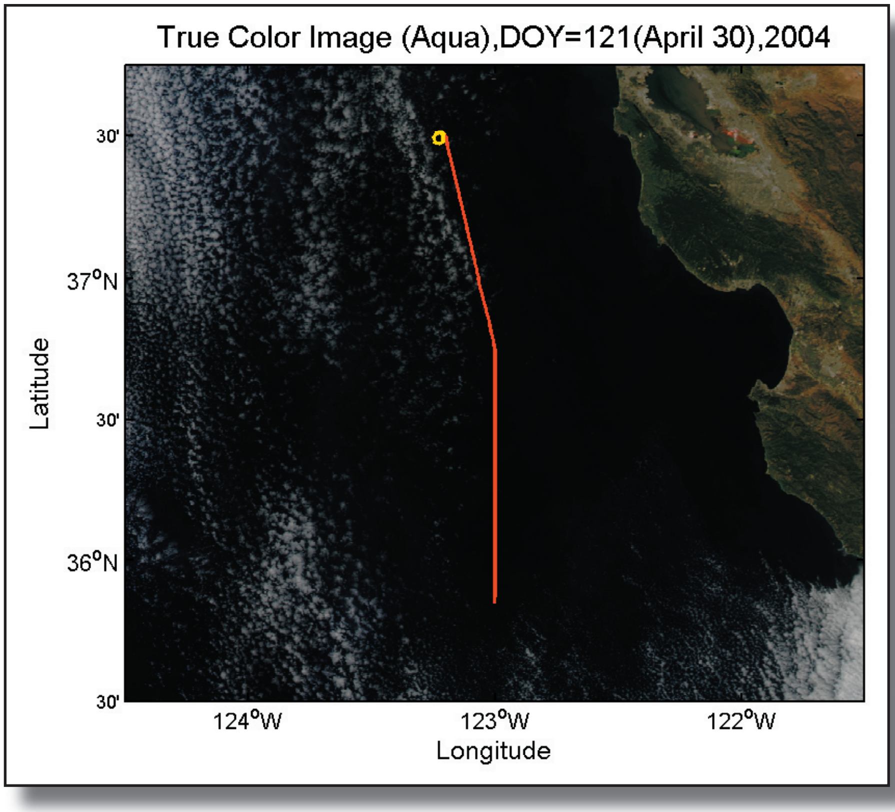
SSFR installation on the Sky Research J-31: (left) zenith light collector, and (bottom, right) nadir light collector.

SPATIAL VARIABILITY OF MODIS AND MISR DERIVED ATMOSPHERIC DATA PRODUCTS

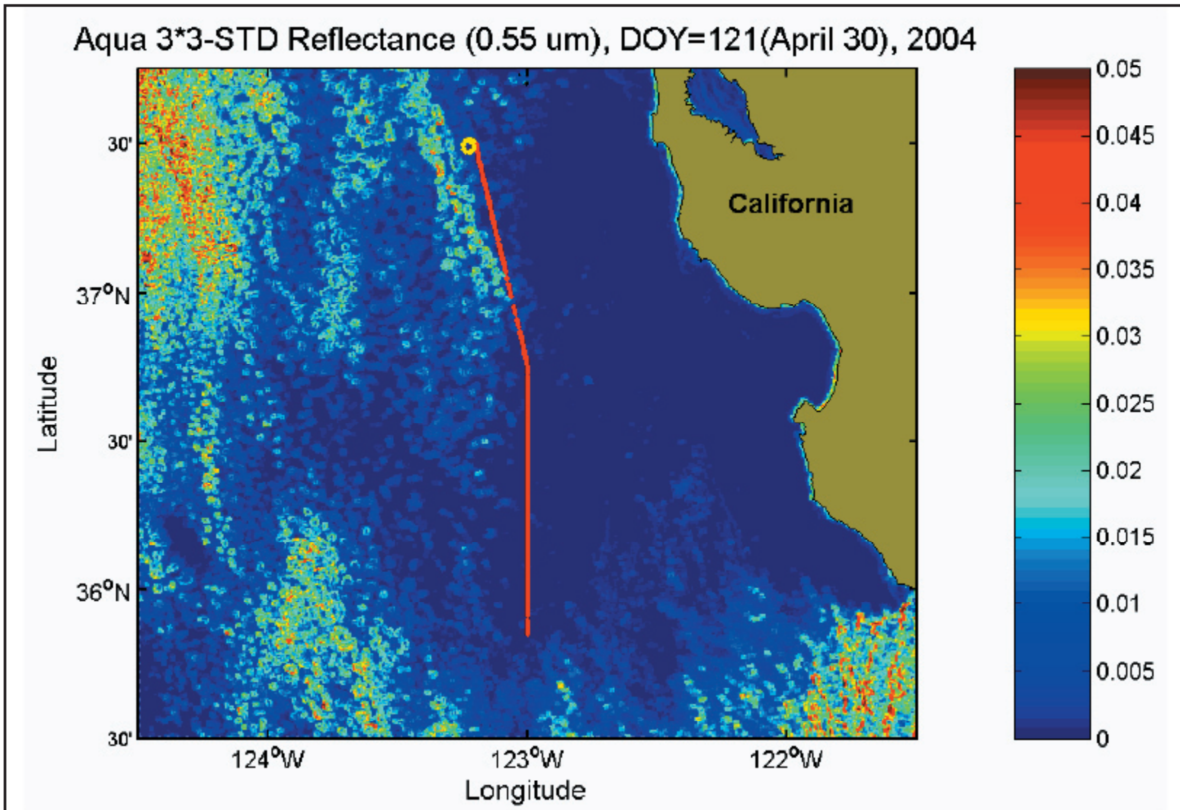
Jens Redemann, Project Principal Investigator

Program Support: NASA, Radiation Sciences Program, Hal Maring

Spatial variability of aerosol optical depth on scales of a few hundred meters is crucial for understanding the spatial separation of cloudy and cloud-free pixels in satellite remote sensing and for assessing the feasibility of comparing modeled and observed aerosol data at different spatial scales. The work under this grant is aimed at the combined analysis of suborbital and EOS satellite measurements of aerosol optical depth and columnar water vapor collected during recent field experiments. In particular, we proposed to investigate the spatial variability in MODIS- and MISR-derived data products using suborbital sensors and to assess how well this variability is captured by satellite sensors and their data products. The stated goals of our study are (i) to



Flight track of EVE flight CIR06 (red), April 30, 2004, superimposed on MODIS-Aqua true color image.



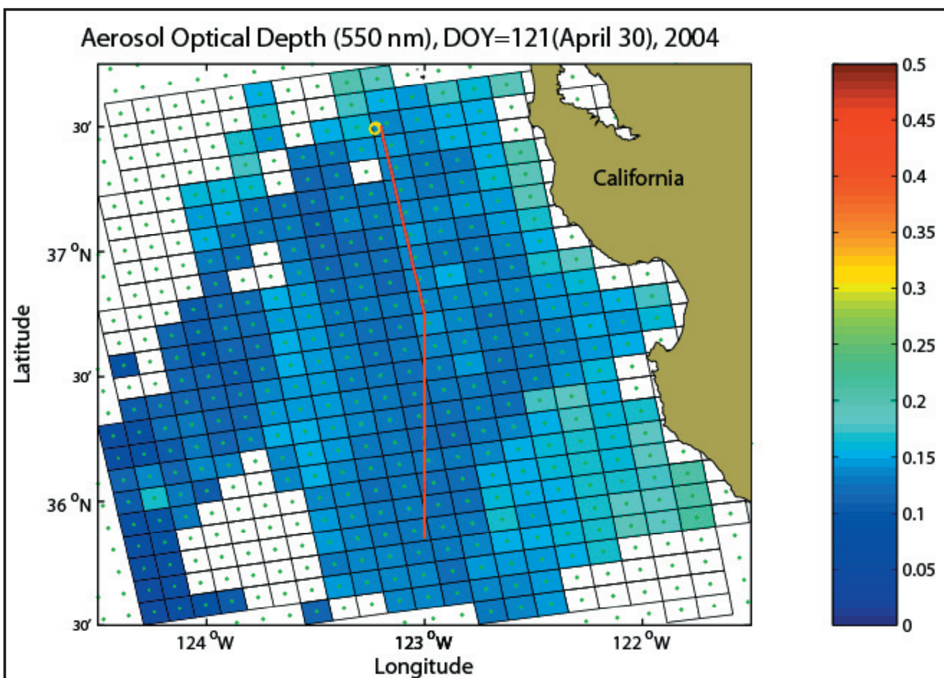
Standard deviation of groups of 3-by-3 MODIS L1B reflectance at 553nm.

determine the spatial variability of aerosol optical depth in the vicinity of clouds and assess how well current EOS satellite sensors capture or suppress such variability within their processing algorithms, (ii) to determine what fraction of the direct aerosol radiative forcing of climate may be undetected because the aerosol optical depth in the vicinity of clouds is erroneously filtered out or masked as cloud by current EOS sensor retrievals, (iii) to compare the spatial variability in aerosol optical depth and columnar water vapor in different geographical regions, thereby assessing the performance of current EOS sensor algorithms under a variety of regional and climatic conditions.

The major accomplishments in the first two years of this project include the completion of the analysis of the EVE (Extended-MODIS-Validation Experiment) data set, the publication of a GRL-manuscript dealing with MODIS near-IR aerosol products and their spatial variability, and the extension of our spatial variability analysis to the MODIS L1B-reflectance product (see above).

EVE is an airborne field campaign conducted out of Monterey, CA in spring of 2004. The primary purpose of the EVE experiment (http: //geo.arc.nasa.gov/ sgg/EVE-website/) was to validate the over-ocean MODIS aerosol optical depth (AOD) measurements at 1.6 and 2.1μm aboard the Terra and Aqua platforms using the 14-channel NASA Ames Airborne Tracking Sunphotometer, AATS-14.

In EVE, a total of 35 and 49 coincident over-ocean suborbital measurements at the nominal level-2 retrieval scale of 10 km x 10 km were collected for Terra and Aqua, respectively. For MODIS-Terra about 80% of the AOD retrievals were within the estimated uncertainty, ; this was true for both the visible (here defined to include 466 – 855 nm) and near-IR (here defined to include 1243 – 2119 nm) retrievals.



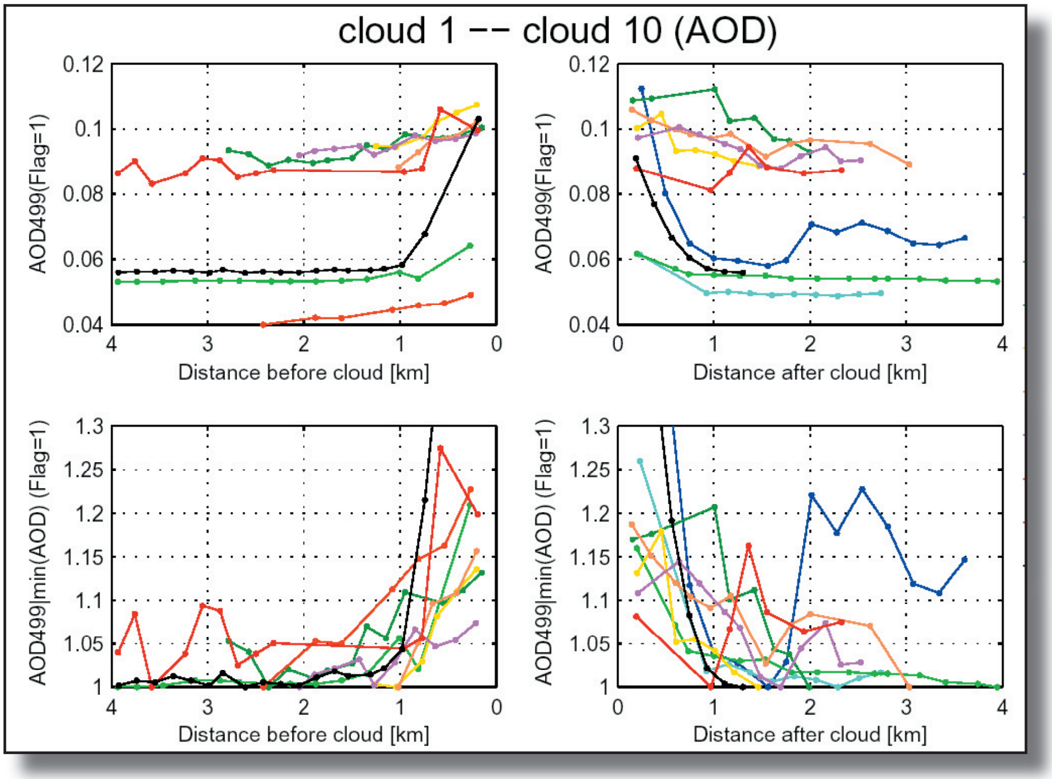
MODIS Level 2 aerosol optical depth retrieval for this day.

For MODIS-Aqua about 45% of the AOD retrievals were within ; the fraction of near-IR retrievals that fell within this uncertainty range was about 27%. We found an rms difference of 0.71 between the sunphotometer and MODIS-Aqua estimates of the visible (553-855 nm) Ångstrom exponent, while the MODIS-Terra visible Ångstrom exponents showed an rms difference of only 0.29 when compared to AATS. The cause of the differences in performance between MODIS-Terra and MODIS-Aqua could be instrument calibration and needs to be explored further.

The spatial variability of AOD between retrieval boxes as derived by MODIS was generally larger than that indicated by the sunphotometer measurements. Spatial variability in MODIS-derived Ångstrom exponents between retrieval boxes was considerably larger than that indicated by the sunphotometer measurements. These results are summarized by Redemann et al., 2006.

In our recent efforts we have focused on studying the aerosol-cloud boundary using combined suborbital and satellite observations. In a preliminary study of AOD data near cloud edges collected in the EVE field we found that in 75% of the cases there was an increase of 5-25% in AOD in the closest 2 km near the clouds. Concurrently, the MODIS-observed mid-visible reflectances in the vicinity of the suborbital cloud observations also show an increase with decreasing distance to cloud edge. Possible causes include 3-D radiative effects, but also the increased variability in the aerosol fields near clouds as indicated by the suborbital observations.

Web site: http://geo.arc.nasa.gov/sgg/AATS-website



Suborbital AOD observations near 10 clouds in EVE, 2004.

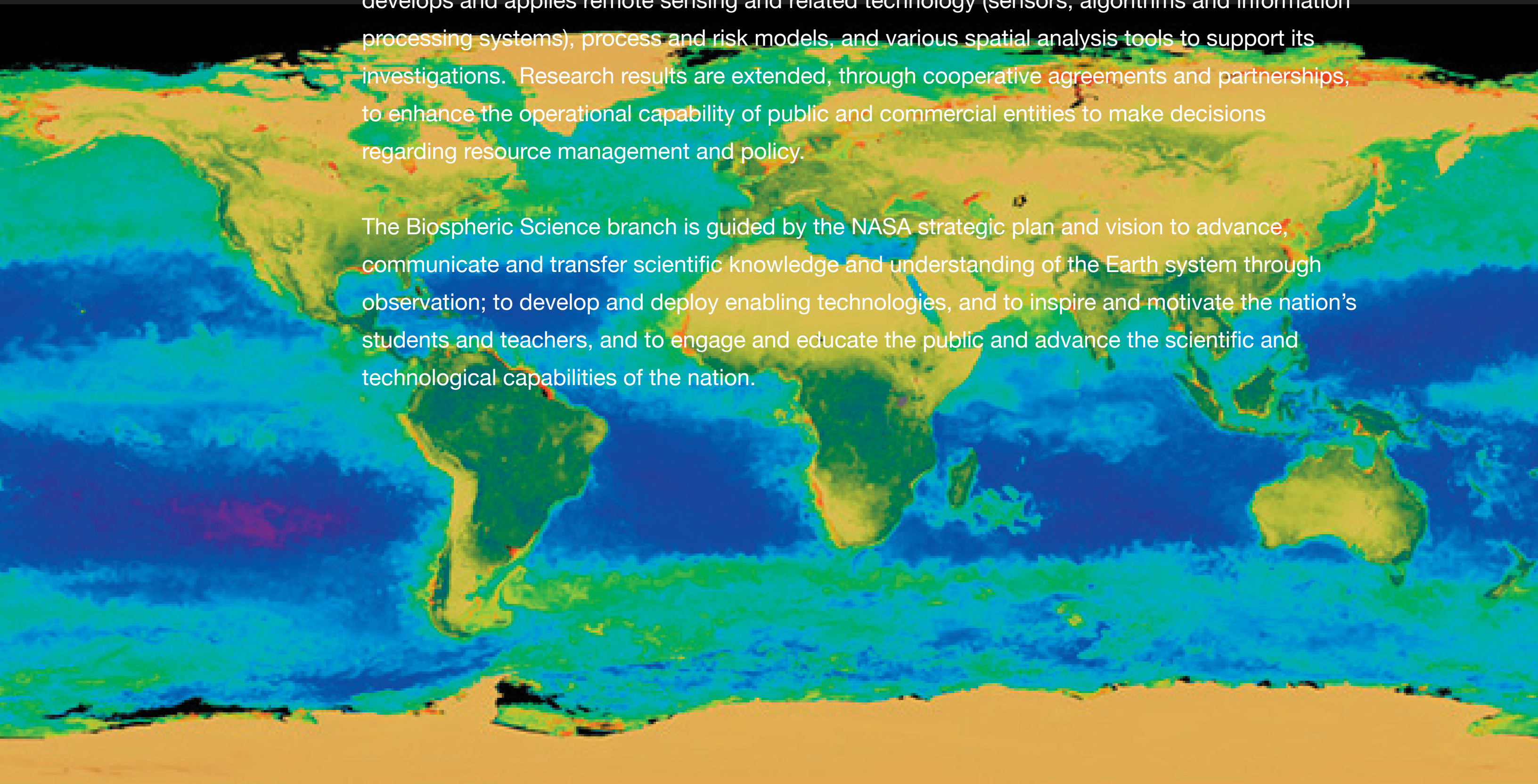
BIOSPHERIC SCIENCE BRANCH

James A. Brass
Branch Chief

The Biospheric Science Branch responds to the research and applied science priorities of NASA Earth science by advancing, communicating and transferring scientific knowledge and understanding of the Earth system through observations and predictive models, by developing and validating enabling technologies, and by inspiring and motivating students and teachers. The Branch engages the public and commercial sectors to educate and advance the scientific and technological capabilities of the nation.

Branch scientists seek to understand biospheric and ecosystem processes and functions in terrestrial and aquatic environments and how those processes and functions are changing, or may change, in response to climate change, land cover and land use change. The Branch develops and applies remote sensing and related technology (sensors, algorithms and information processing systems), process and risk models, and various spatial analysis tools to support its investigations. Research results are extended, through cooperative agreements and partnerships, to enhance the operational capability of public and commercial entities to make decisions regarding resource management and policy.

The Biospheric Science branch is guided by the NASA strategic plan and vision to advance, communicate and transfer scientific knowledge and understanding of the Earth system through observation; to develop and deploy enabling technologies, and to inspire and motivate the nation's students and teachers, and to engage and educate the public and advance the scientific and technological capabilities of the nation.



Branch scientists strive to understand terrestrial and microbial ecosystem processes, to predict how these processes are changing in response to disturbance, land use and climate change, and to determine the relationships between these changes and the condition and health of ecosystems and humankind. With these aims in mind, the Branch develops relevant remote sensing technology (sensors, algorithms and information processing systems), process and risk models, and various spatial analysis tools to support these investigations. In addition to the scientific publications of the Branch, both the applied science and technology are translated into practical everyday solutions and transferred through cooperative arrangements and partnership training and education to end users in the private and public sectors.

In 2006, research and applied science activities within the Branch focused on eight areas to:

(1) Assess the biological productivity of Earth's terrestrial and microbial ecosystems and to predict how productivity will change in response to various cycles and trends in land use, disturbance and climate change over the next 50 years.

(2) Measure and model chemical exchanges between the biosphere and the atmosphere, identifying biotic and abiotic factors controlling these fluxes, and predict how these fluxes will change in response to short- and long-term trends in land use, disturbance and climate change.

(3) Model and predict the impact of climate change on regional and global ecosystem characteristics, such as productivity and health, and risk of resource loss.

(4) Articulate the measurement requirements for global, regional and local ecosystem assessments, and to develop technology to satisfy these requirements.

(5) Transfer the knowledge and technology derived from research to the public and private sectors, and the education community, through partnerships with end users.

(6) Foster human capital development to extend NASA science research to local communities using students to demonstrate to community leaders prototype applications of NASA science measurements and predictions addressing local policy issues.

(7) Develop and deploy NASA sensor, platform (manned and unmanned), information processing, and communication technology to address the real-time requirements of disaster management and mitigation, particularly for wild land fires; and

(8) Study how rapid rates of change affect emergent ecosystem properties as part of the larger effort in Astrobiology.

Forty-eight earth scientists, engineers, programmers, geographers, chemists and educators comprise the Branch and cover a range of disciplines from ecology to engineering to computer science. A number of staff are associated with Ames through cooperative agreements with California State University at Monterey Bay and San Jose State University. Other science staff supports branch research through on-site contracts, visiting professor programs and other educational grants and programs. The Branch hosted more than ten visiting scientists in 2006, several through the National Research Council (NRC) associates program, as well as several students from high school through post-graduate levels via Center and NASA-sponsored programs.

The staff collaborates with a large number of external and internal organizations, including colleagues from the University of Arizona, Woods Hole Research Institute, University of Wisconsin, Stanford University, Harvard University, Yale University, Washington University, Universities of California at Berkeley, Santa Barbara, Santa Cruz, San Francisco, and Davis, University of Montana, University of Minnesota, University of Michigan, University of Illinois, University of Vermont, Oregon State University, California State Universities at Monterey Bay, Hayward, and San Jose, Florida International University, Clark University, Monterey Bay Aquarium Research Institute, San Francisco Estuarine Institute, the College of San Mateo and more. The staff also collaborates with a number of foreign universities including Southampton in England, Sao Paulo and Brasilia in Brazil, Buenos Aires and Mar del Plata in Argentina, Lille in France, the National Remote Sensing Center in Egypt and others. Collaborative agreements with various federal agencies have long been an important aspect of how we conduct research. Branch staff work with scientists from the U.S. Department of Agriculture, Agricultural Research Service and the Forest Service; U.S. Fish and Wildlife Service; National Institutes of Health; Centers for Disease Control and Prevention; Environmental Protection Agency; U.S. Geological Survey; National Park Service; Department of Defense; and the Federal Emergency Management Agency. Internationally with the World Bank and the World Health Organization.

In much of the applied research, the Branch works with the public and private sectors. Private sector partners include: San Bernabe Winery; Lockheed Martin Corp.; Bay Area Shared Information Consortium, General Atomics and others. Public sector partners include: California Resources Agency, Office of Emergency Services, Los Angeles County; Santa Clara Water District; Santa Clara County; and more. Within Ames the Branch has collaborative relationships with the Center of Excellence in Information Technology, the Space Science Division, the Gravitational

Research Branch of the Life Sciences Division, the Space Projects Division, Computational Sciences and Human Factors Divisions, the Atmospheric branch within the Earth Science Division, and the Airborne Science and Technology Lab. These collaborations (and others not mentioned) are vital to the accomplishment of the mission, and, in particular, permit the Branch to find practical applications of earth science research.

The Biospheric Science branch, as part of NASA's Earth Science division supports the carbon cycle and ecosystem, water cycle and solid earth, and climate change vulnerability focus areas. The Branch participates in the Applied Science Program and helps NASA respond to three presidential initiatives: the Climate Change Research Initiative, Global Earth Observation, and the Oceans Action Plan. NASA has developed relationships with other federal agencies and state and local entities to improve the application of NASA's research, providing services in disaster assessment, ecosystem forecasting, environmental management and land use assessment. On the following pages are summaries of the branch's activities in climate change, earth observation and ocean studies.

ASTROBIOLOGY: HINDCASTING ECOSYSTEMS

Hector D'Antoni, Project Co-Principal Investigator

Program Support: NASA, Astrobiology Institute, Carl Pilcher

Hindcasting is a way of studying ecosystems by looking back into time to ascertain what vegetation communities and ecosystems might have been like in the past. This information is important for understanding ecosystems and the vegetation communities that are present today. It is also a way of predicting the vegetation composition of ecosystems in the future. Using information from current ecosystems and combining those data with information obtained from other sources, it is possible to hindcast past climate and then infer the vegetative composition present at that time.

The Hindcasting Ecosystem Model (HEMO) is a process model designed to reconstruct past ecosystems. It is built on proven ecological and plant physiological principles and uses linear and non-linear mathematics to investigate past vegetation communities and the environment in which those plants lived. Input data for HEMO are length of the growing season, potential evapotranspiration, inferred past vegetation index, and soil nitrogen concentration. Other input data are estimates of past climate drivers which include volcanic activity, solar energy output, and the state of the Earth's orbit; these data come from proxy records. Since some of these data are not readily available, we use tree-ring widths from many sites in South America as well as gas, isotopes and volcanic aerosol concentrations found in fossil ice to predict the missing data.

We chose South America as our study site because much of the continent is still pristine. Further, South America has very dry ecosystems in the high mountains, moderate ecosystems such as those found on the pampas, and very wet and warm ecosystems like those found in the Amazon basin.

HEMO has been calibrated using 20 years of Net Primary Production (NPP) predictions in 41 sites in South America by an independent model also developed at NASA Ames, the NASA-CASA model. The CASA model has been widely used to predict the carbon dynamics of many different types of ecosystems. It has also been used in many varied ecosystems around the globe to predict hydrologic fluxes and nitrogen trace gas emissions .

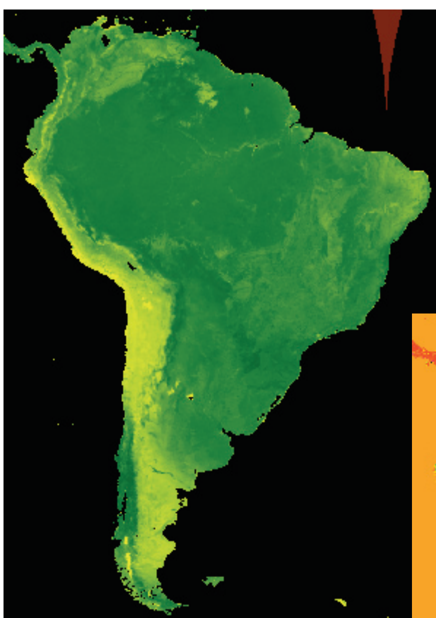
HEMO products include:

- An estimate of NPP at 41 sites with 8x8 km (64 km2) pixels selected because they include reliable stratigraphy, rock strata, that can help extend the hindcasts further into the past.

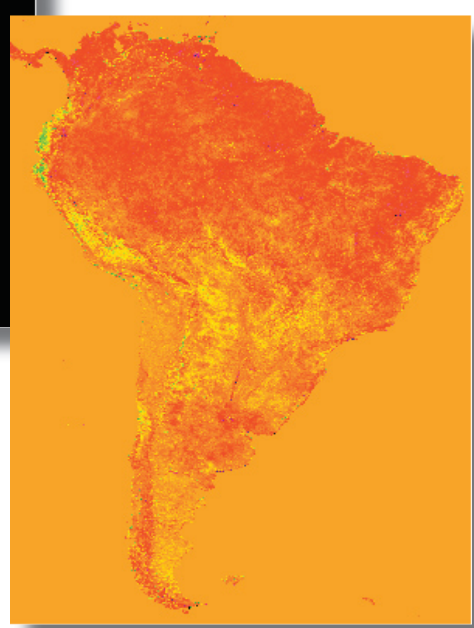
- Estimates of past Sea Surface Temperature (SST) for the Atlantic and Pacific Oceans.

- Yearly maps of South America showing the Normalized Difference Vegetation Index (NDVI). NDVI is a measure of how much vegetation is on the ground. It is calculated using satellite remotely sensed data.

- NDVI-Deviation maps that depict the effects of the "El Nino" southern Oscillation (ENSO) and other events on the vegetation of South America.



Mean annual vegetation index in South America for the 1982-2000 period.



Positive (green and yellow) and negative (red) deviations from the mean annual vegetation index after the "El Niño" of 1983 in South America.

Predicted past-SSTs corresponding to the expansion of the Inca Empire, show a time when the SST was low in both the Atlantic and Pacific Oceans. This cooled the continent and may have resulted in a reduction of agricultural land in the high mountains where the Inca civilization thrived, forcing them to expand.

To calibrate HEMO with real-world data, we have developed the following plan. First we expect to conduct long-term measurements in the riparian forest near Buenos Aires to obtain climate data and chlorophyll absorbance readings. In the agricultural area of Mar del Plata we will monitor two potato cultivars, to ascertain the response, this case the growth, to changes in the environment. We will monitor the Atuel Wetlands of La Pampa for ecosystem responses to variations in ice melting in the Andes. We also plan to take "snap-shot" measurements in the non-complaisant locations of the Subantarctic Forest on the eastern slopes of the Andes in Patagonia, and at locations dominated by *Nothofagus Antarctica*, *N. pumilio* and *N. betuloides*, in Tierra del Fuego. The genius *Nothofagus* has both deciduous and coniferous trees in it. These trees are wide spread in Argentina and Chile and are good indicators of changes in climate.

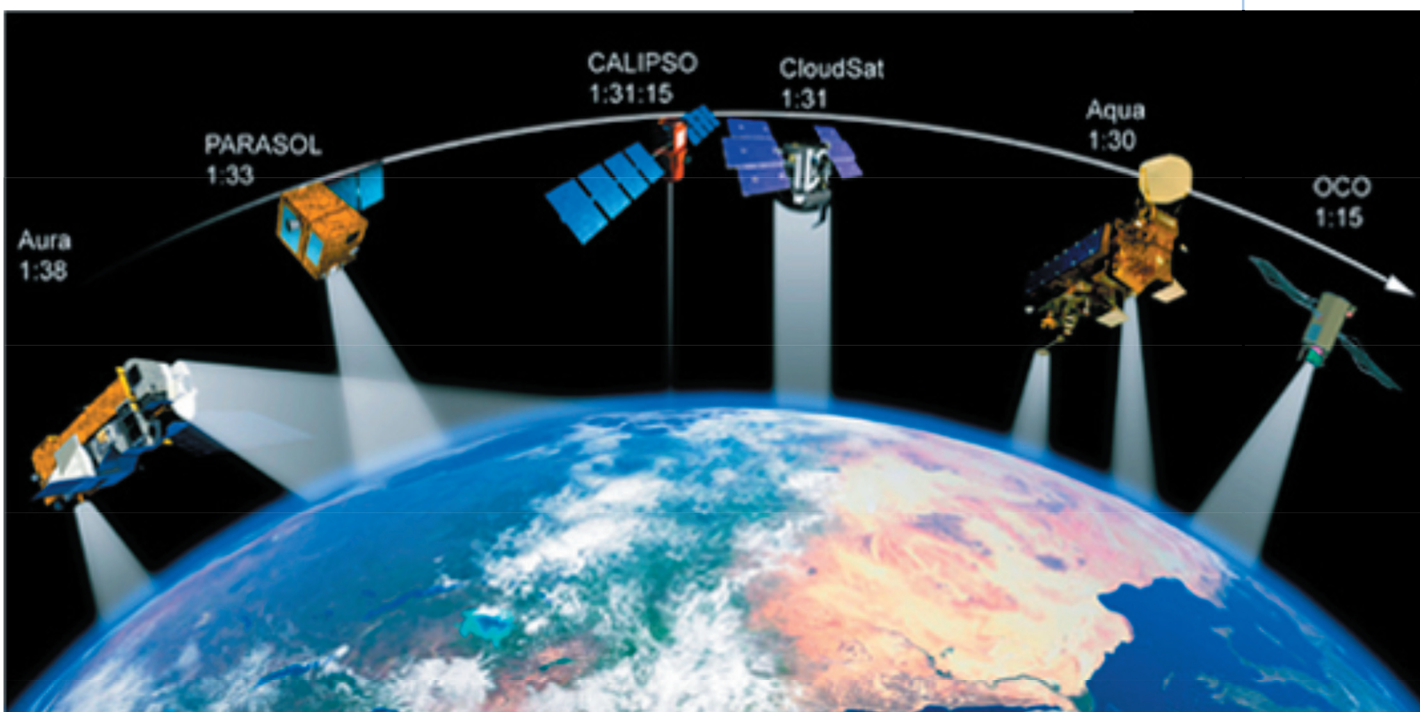
For field measurements we have assembled a miniaturized laboratory and a simple protocol for its using it in the field. The instruments have been tested at NASA's Ames Research Center and at various locations in South America.

This project links ecosystems research in Astrobiology with documenting and understanding global change.

COORDINATING EARTH OBSERVATIONS TO ENHANCE NASA EARTH SCIENCE

Jennifer Dungan, Project Co-Principal Investigator

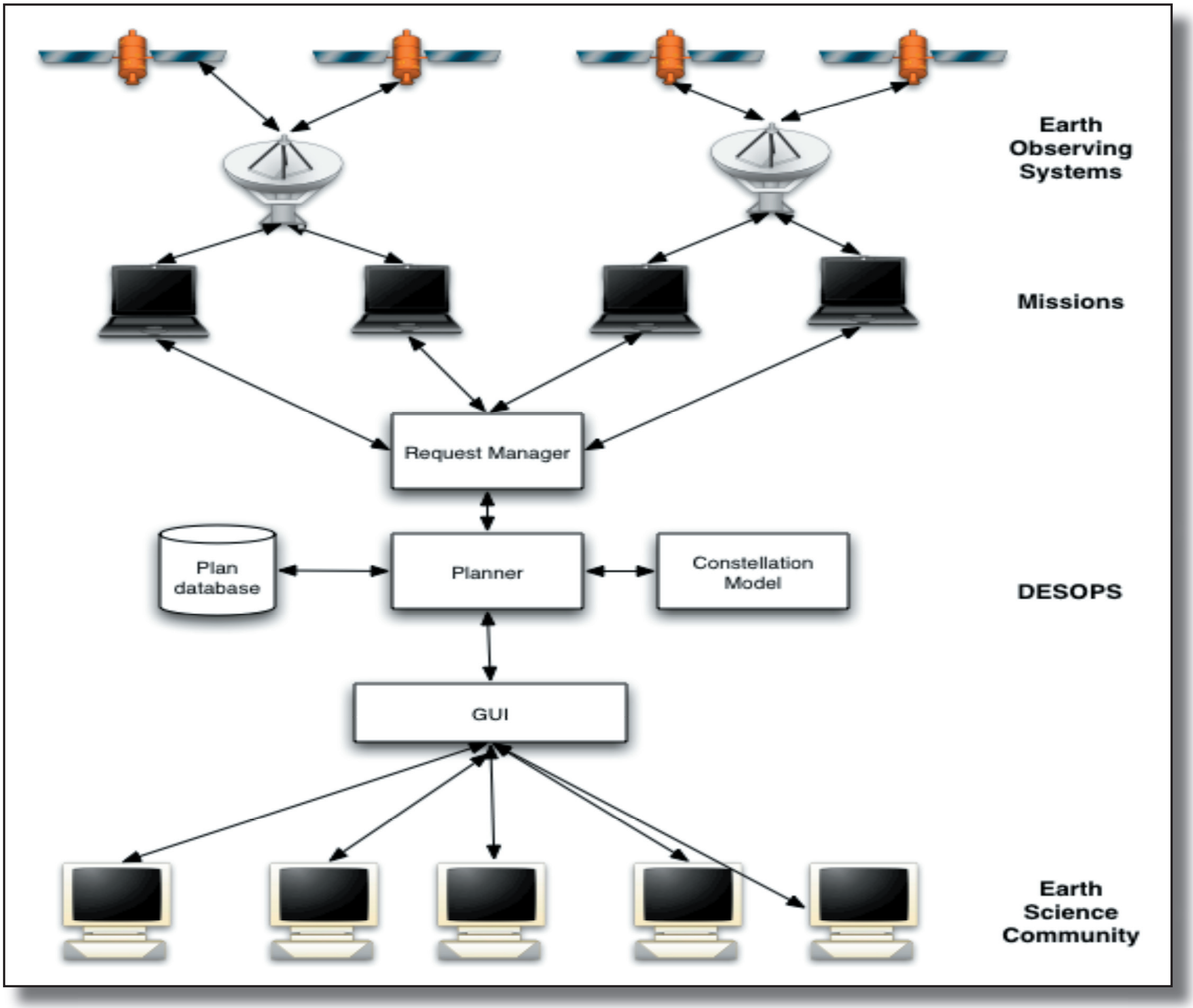
Program Support: NASA, Earth Science Technology Office, Advanced Information Systems Technology Program, Karen Moe and Steven Smith



NASA's A-train satellite constellation including sensors launched since 2000.

Future Earth observing missions will study different aspects and interacting pieces of the Earth's biosphere. Scientists are designing increasingly complex, interdisciplinary campaigns to exploit the diverse capabilities of multiple Earth sensing assets. In addition, spacecraft platforms are being configured into sensorwebs, clusters, trains, or other distributed organizations in order to improve the quality and frequency of observations. These simultaneous advances in science campaigns and the missions that will provide the sensing resources to support them offer new challenges in the coordination of data and operations not addressed by current practice. For example,

(Continued on page 79)



Conceptual architecture for the Distributed Earth Science Observation Planning and Scheduling (DESOPS) system.

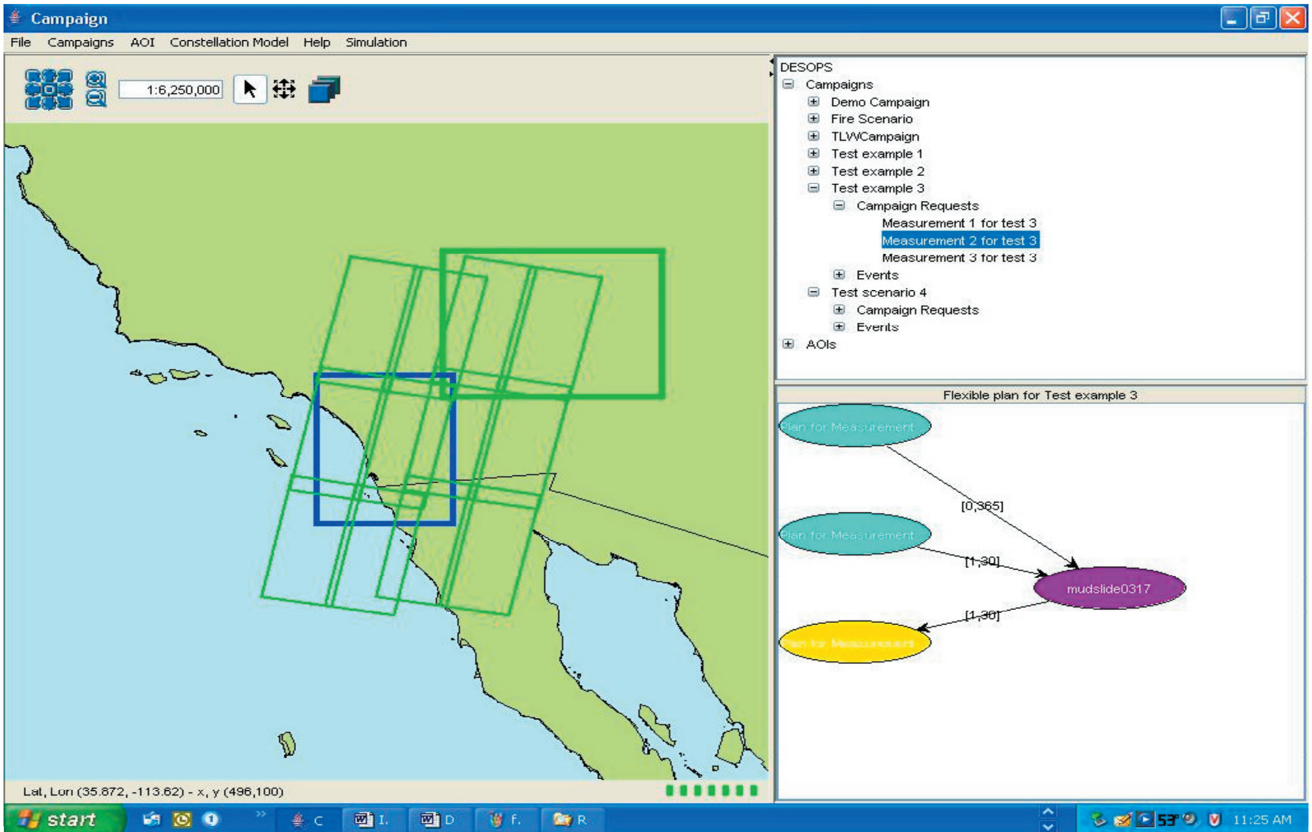
scheduling scientific observations for satellites now in low Earth orbit is requested independently by the OPC Center for each mission. Implementing an information infrastructure to enable coordinated scheduling of observations involving multiple sensors would enable science campaigns involving multiple assets.

This project studies the problem of coordinating the assignments of observation tasks among a collection of either remote sensors, or sub-orbital platforms such as ground, airborne, and balloon sensors configured into an organization (e.g., a train or a sensor web). The goal of the project is to define a set of capabilities that will, collectively, enable the coordination of observation activity for distributed, mobile, remote sensors. These capabilities have been implemented in a prototype system, called DESOPS (Distributed Earth Science Observation Planning and Scheduling) system.

The project has examined coordination in the context of Earth science campaign planning. An Earth science campaign is a sequence of observations over time that collectively realize an Earth science goal, such as validating an emissions model of aerosols released by a wild fire. Inspired by NASA's Earth science vision, we define the notion of model-based observation. Model-based observing is a correlation of planning and scheduling observation events to support Earth science campaign goals.

The overall envisioned architecture for coordinated observation is divided into layers. At the top layer are the resources, the remote sensing assets. Ownership of the assets is ascribed to the individual missions that manage them on a daily basis; these form the second layer. Landsat 7 mission operations are a model for daily mission scheduling operations. The third layer is coordination layer, the set of capabilities designed and implemented by DESOPS. The fourth and last layer is the Earth scientists.

The scientists access these resources indirectly using the distributed planning system comprised of both the system at the coordination layer, and the individual operations planning system. Scientists specify constraints that must be met in accomplishing the goals; primarily these constraints include sensor requirements, temporal requirements, location requirements, and cost. There are also constraints related to the resources themselves; constraints on when a sensor can take an observation at a location, as well as other constraints related to the spacecraft on which the sensor resides. In the distributed approach, the missions ensure that resource constraints are satisfied and the coordination layer ensures that the customer constraints are satisfied.



Screen-shot of the DESOPS prototype

The project principal investigator was Robert Morris of the Intelligent Systems Division, NASA Ames Research Center. Project collaborators were from the Earth Science Division and from NASA Goddard Space Flight Center.

CORAL REEFS AND CLIMATE CHANGE

Liane S. Guild, Project Principal Investigator

Program Support: NASA, Ocean Biogeochemistry Program, Paula Bontempi

Coral reefs provide essential habitat for marine biodiversity and coastline protection. Also, they often provide the first clues about marine ecosystem health because of their immediate response to environmental changes. Unfortunately, these "canaries of the oceans" are in peril due to climate and human impacts.

In late 2005, coral reefs in the wider Caribbean suffered the most severe and widespread bleaching event to date. Coral bleaching is associated with a variety of stresses including increased sea surface temperature, which causes corals to expel the pigmented, symbiotic microalgae living in their tissues, thereby appearing bleached. Bleaching can lead to death of the corals that provide critical habitats and nursery grounds for marine fisheries, tourist attraction, and protection of coastlines from severe storms and wave action.

(Above) Acropora palmata, or elkhorn coral with white band disease, and (right) comparison of healthy and diseased coral.

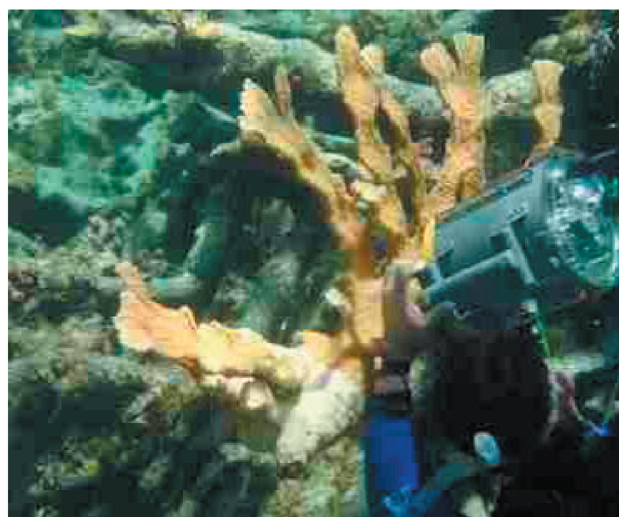
Bleached elkhorn coral, Puerto Rico, 2005.

In mid-December 2005, in response to the coral bleaching event in the Caribbean, NASA Ames Research Center scientists teamed with scientists from NOAA's Coral Reef Conservation and Biogeography Programs, JPL, the University of Puerto Rico at Mayaguez and the National Park Service (NPS) of the US Virgin Islands to investigate the status of coral bleaching in the Caribbean. This collaborative effort supported the US Coral Reef Task Force's (USCRTF) resolution passed in November 2005 to mobilize Task Force agencies to assess the coral reef bleaching event, coral mortality, coral recovery, and the ecological impact of the September-October 2005 coral bleaching event in Puerto Rico (PR) and the US Virgin Islands (USVI).

The assessment included evaluation of hyperspectral data obtained with the NASA Airborne Visible Infrared Imaging Spectrometer (AVIRIS) and the NASA Ames high resolution DCS camera supported by UC Santa Cruz Airborne Sensor Facility scientists. Field data collection by NASA Ames researchers in collaboration primarily with researchers from the University of Puerto Rico, NOAA's Biogeography Program, and the USVI National Park Service (NPS).

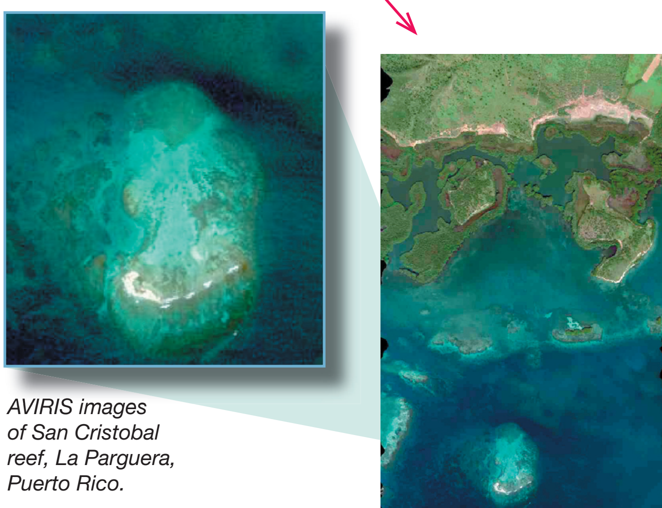
Aircraft-based sensors such as AVIRIS, provide high spectral and spatial resolution data that enhance our understanding of satellite data. For this study, visible spectrum light reflecting off of the coral reef and surrounding reef bottom will be used to quantify bleaching extent and coral health.

Field measurements taken in Puerto Rico and USVI will validate and complement the airborne data. Coupled remotely sensed



Researchers using handheld spectroradiometers measure reflected light readings from coral.

The NASA airborne mission imaged coral reefs of Puerto Rico and the US Virgin Islands in December 2005.



AVIRIS images of San Cristobal reef, La Parguera, Puerto Rico.

DCS image of Buck Island, St. Croix, USVI.

and in situ data will allow researchers to better understand the ecology of this region impacted by environmental events, and improve modeling of future bleaching events.

Previous AVIRIS missions over the Florida Keys and Puerto Rico in August 2004 and Kaneohe Bay, Hawaii, in March 2005 provide additional airborne hyperspectral imagery for quantifying coral reef biological and optical properties.

Web site: http://geo.arc.nasa.gov/sge/coral-health/

DEVELOP: A Human Capital Development Internship Program

Joseph W. Skiles, ARC DEVELOP Program Manager
Cynthia Schmidt, ARC DEVELOP Program Coordinator

Program Support: NASA, Applied Sciences Program,
Marty Frederick, Lucien Cox, Mike Ruiz

DEVELOP students, Summer 2006

DEVELOP is a Human Capital Development Internship Program funded by NASA's Applied Sciences Program of the Earth Science Division in the Science Mission Directorate at NASA Headquarters. Student run and student lead projects are conducted intensively during the summer. Students are responsible for designing projects in conjunction with the customers and collaborators, collecting the necessary satellite and field data, analyzing those data, presenting the results from the studies to the customers and collaborators, and writing papers on the study and the study results.

Students benefit from this program by receiving intensive training in the use of remote sensing, GIS, and visualization software. Students also benefit by learning about the obstacles and the rewards of working on a "real world" problem. The tribal or government agencies, learn a new approach to solve a particular long-term or short-term issue. NASA benefits by using students as "ambassadors" to extend the benefits of NASA Earth science research to government agencies.

Two projects undertaken by ARC DEVELOP interns in 2006 are listed below.

Sea Ice and Pacific Walrus Habitat

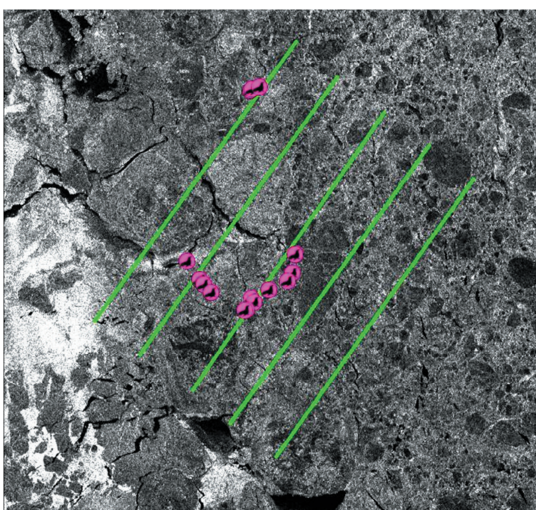
The Arctic ice pack is home to thousands of Pacific walrus. Their preferred habitat is an ice floe that has enough density and surface area to support a herd of twelve foot long, 3,000 lb. mammals. During the spring, walrus "haul out" or climb onto the ice to eat, sleep, mate and rear their young. In 2006, students from the DEVELOP student internship program collaborated with the

U.S. Fish and Wildlife Service (USFWS) in Alaska to determine the usefulness of satellite imagery for studying the effect of climate change on the Pacific walrus ice habitat in the Bering and Chukchi Seas.

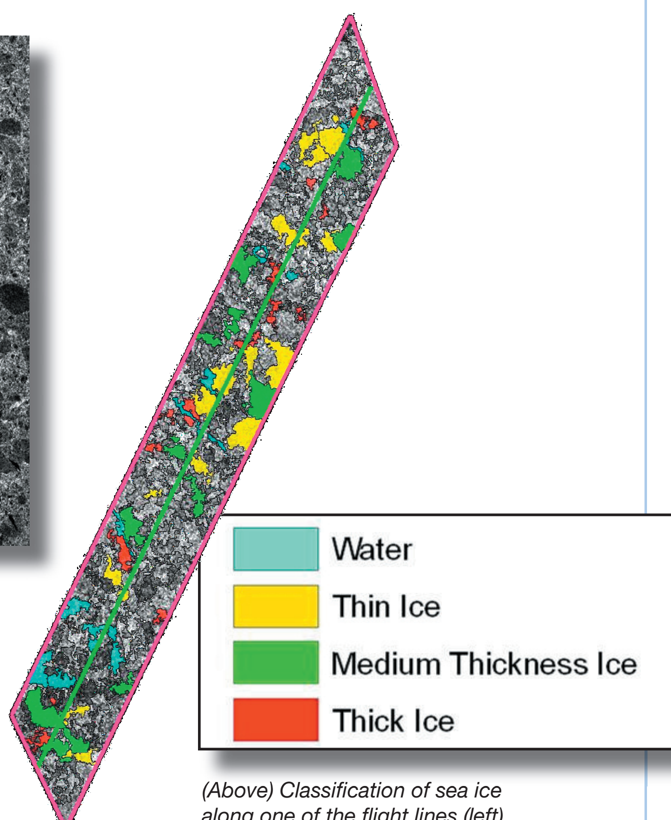
The Pacific walrus (*Odobenus rosmarus divergens*) is the only form of walrus that inhabits U.S. waters. The species is an important part of Alaska's economy and cultural subsistence: native Alaskans rely on a bountiful walrus population for their food, clothing, shelter, and as a spiritual totem. A sustained walrus population is crucial to their survival and way of life.

To study the population dynamics and habitats of the Pacific walrus, the student interns worked with the USFWS to determine the relationship between polar sea ice formations and the preferred habitat of the Pacific

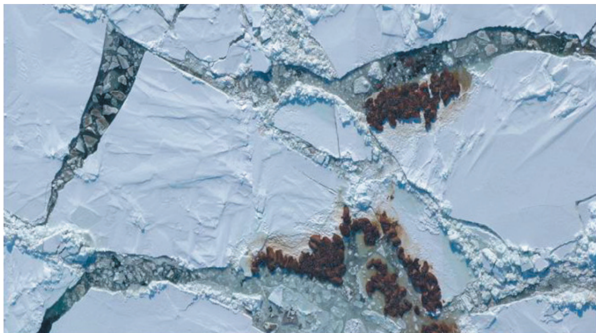
A Pacific walrus "hauled out" on an ice floe. Walrus are an important part of the native Alaskan economy and way of life.



(Above) A Synthetic Aperture Radar image (black, white and grey features). Image swaths are shown as green lines. Images swaths were taken by aircraft. Walrus population locations that coincide with the image swaths are shown in purple.



(Above) Classification of sea ice along one of the flight lines (left).



Several groups of Pacific walrus congregate on an ice floe in the Arctic. Note the proximity to thin ice and open water.

walrus. In order to penetrate the inevitable heavy cloud cover over the coast of Alaska, the students used Synthetic Aperture Radar (SAR). SAR has the ability to see through clouds and is excellent for determining different sizes of ice floes, which are important to the walrus.

Every five years, the USFWS conducts a walrus population survey. Last spring, the agency undertook the largest census ever done. The count took almost two months, required the use of ships and smaller craft, and airplanes with thermal sensors. This was a cooperative effort between the U.S. and the Russians. The Russians primarily collected information near the Russian coast. Although the USFWS uses advanced technology to conduct their surveys, it never knew the exact location of walruses. The USFWS simply searched an area with the boats and the aircraft until the walruses were found. Using satellite imagery to determine where to find the walrus has the potential to reduce the time and resources needed to monitor walrus survival rate and, subsequently, reduce the cost of the census.

To classify the image, the students used a segmentation technique rather than a standard per-pixel classification technique resulting in better characterization of the sea ice. Details within and between ice floes were maintained using the segmentation technique, while the per-pixel classification resulted in generalizing the floes. Additional work will be required to more accurately label the segmented polygons into different ice classifications. In addition, with georeferenced point locations of the walrus, future studies will be able to determine a more specific relationship between walrus and the ice floe type.

Understanding certain sea ice features such as size, density and proximity to open water are key to identifying the preferred habitat of the walrus. SAR imagery provides information on the pack ice that can be used to make the distinctions between surface roughness, ice thickness, fragmentation and other pack ice characteristics.

Utilizing MODIS LAI to Identify Vegetative Anomalies in Yosemite National Park

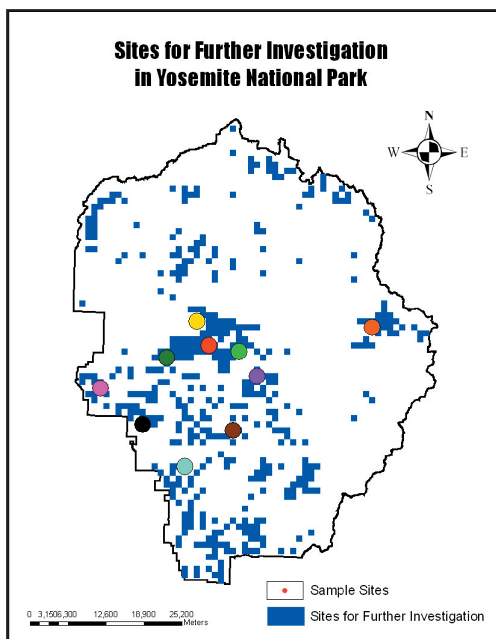
Vegetation disturbances were examined in Yosemite National Park using MODIS Leaf Area Index (LAI) data processed by the Terrestrial Observation and Prediction System (TOPS). The LAI data for each month was averaged over a four-year period from 2001-2005 and then compared with the monthly averages for summer 2005 to produce a map of LAI anomalies. These maps were then

DEVELOP intern taking a GPS location in Yosemite National Park

overlaid with known areas of insect infestations, snow cover, and recent wild fires to identify possible causes of low LAI. Fieldwork was conducted to verify the known causes and ascertain the causes of unexplained anomalies.

This project has laid out a method by which the Park Service may choose sites to investigate or for other scientists to use in their own studies. Due to strong correlations between allometric data and MODIS LAI as well as Landsat LAI and MODIS LAI, an automated change detection model could act as a powerful tool for forest management. Park officials could use this information to preview sites before beginning controlled burns, monitor the shifts in the tree line, and access a historic record of MODIS LAI data.

This study is a part of a larger, on-going NASA project led by Dr. Ramakrishna Nemani that focuses on ecological forecasting and intends to supply the National Park Service with landcover change model outputs. This system of monitoring will eventually extend to management in other national parks and forests.



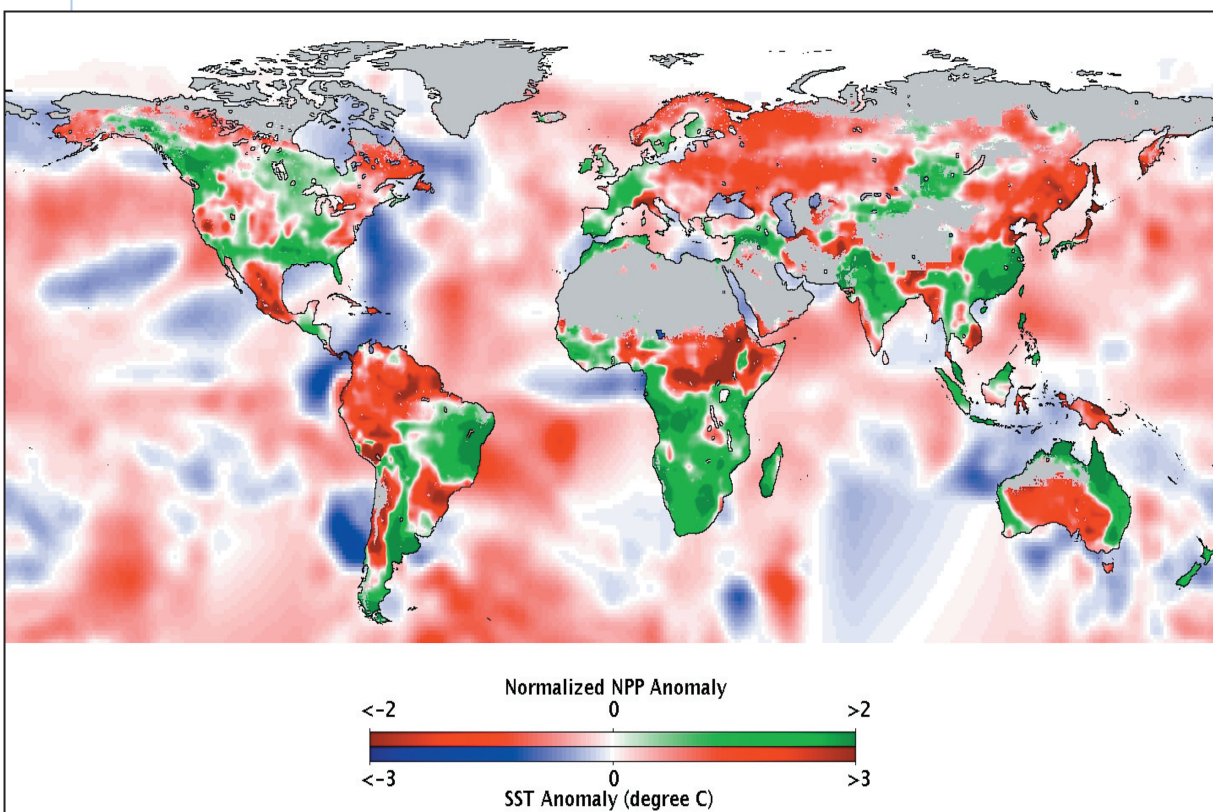
Yosemite National Park outline with sites (in blue) for further investigation by on-site personnel. Sample sites shown as colored circles are locations visited by the student team.

ECOLOGICAL FORECASTING

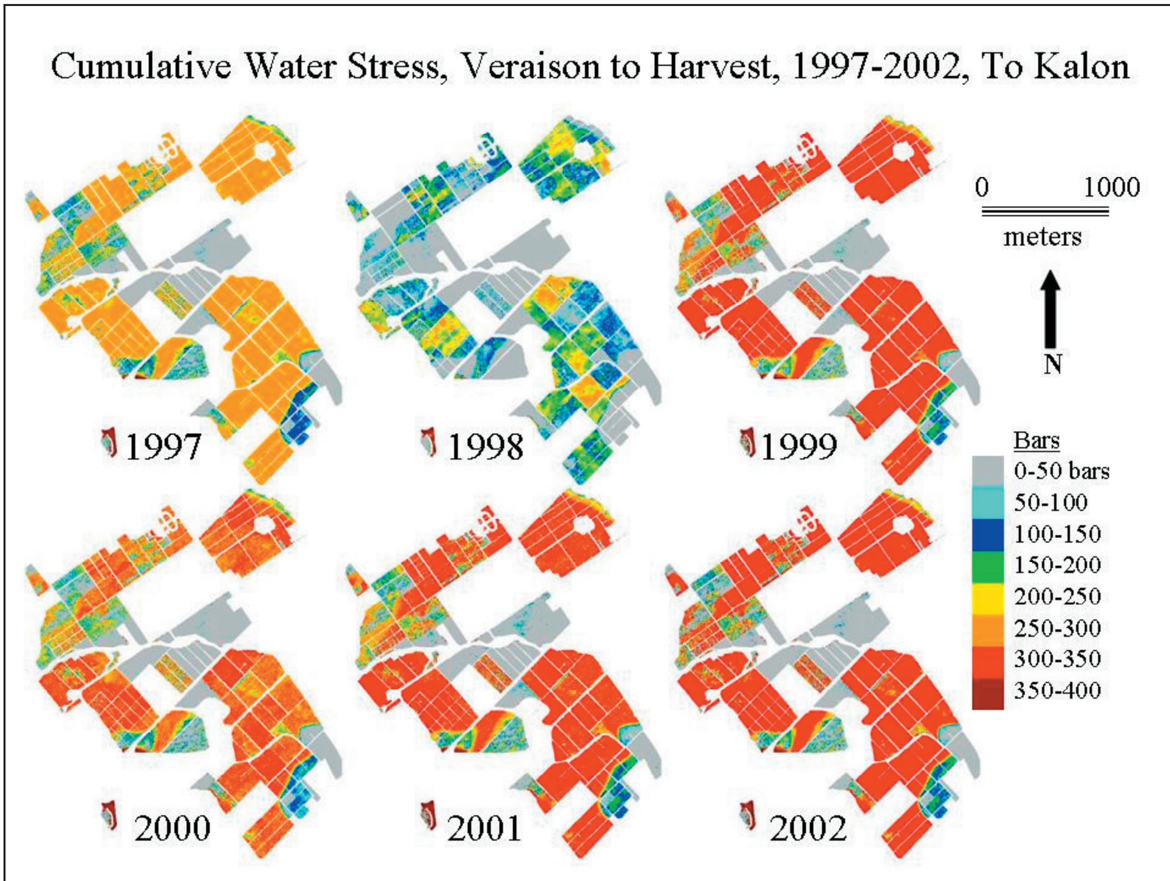
Rama Nemani, Project Principal Investigator

Program Support: • NASA, Carbon Cycle & Ecosystems, Diane Wickland
• NASA, Applied Science Program-Ecological Forecasting, Woody Turner

Over the past four decades, improvements in satellite observations, in situ measurements of environmental parameters, and numerical models have revolutionized the field of meteorology, developing the capacity to produce 14-day weather outlooks. The past two decades have also witnessed an increasing awareness of the role of climate variability and of the potential for cyclical phenomena, such as El Niño Southern Oscillation and Pacific Decadal Oscillation events, to drive large swaths of global climate. This awareness has resulted in attempts at seasonal to interannual



A global application of TOPS for monitoring and mapping net primary production anomalies over land and sea surface temperature anomalies over global oceans.



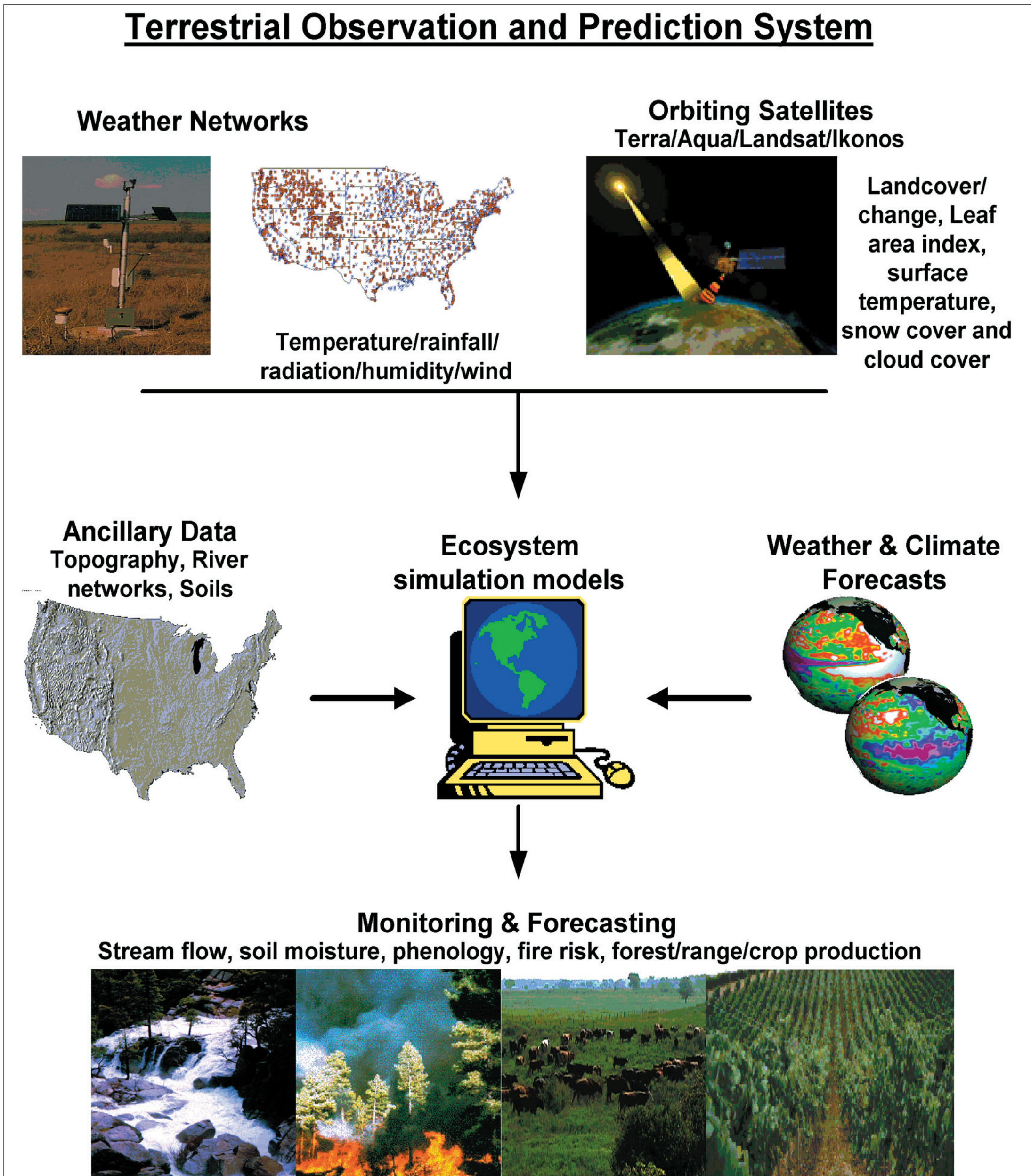
Interannual variability in water stress experienced by vines under natural conditions from Veraison (Fruit Set) to Harvest. Its thought that vines that undergo moderate stress levels during this period produce the best quality grapes. Grapes from 1997 fall under this category of moderate stress under natural conditions; therefore, the 1997 vintage is the best in the past 15 years. Our task is to allow vines to stay in this moderate stress category through scheduling irrigation. The color bar shows accumulated water stress values from veraison to harvest. The study was done at the "To Kalon" ranch of the Mondavi wineries in Napa valley.

climate prediction. The inclusion of geophysical parameters in ecological models and the growing list of biophysical parameters observable from space (e.g., vegetation indices, estimates of primary production) now hold out the promise of a true ecological forecasting capability. Ecological Forecasting is the ability to predict the effects of changes in the physical, chemical, and biological environments on ecosystem state and activity. Major advances in process-level understanding, climate mapping, computing technology, and the availability of a wide range of satellite- and ground-based sensors have dramatically improved our ability to describe and predict ecosystem behavior.

Bringing together these advances, the Terrestrial Observation and Prediction System (TOPS) seeks to catalyze the generation of ecological forecasts by providing predictions of critical environmental variables resulting from model runs driven by climatic and remotely sensed biophysical inputs. TOPS is a data and modeling software system designed to seamlessly integrate data from satellite, aircraft, and ground sensors, and weather/climate models with application models to quickly and reliably produce operational nowcasts and forecasts of ecological conditions.

The underlying technologies in TOPS are: 1) ecosystem models of several types including process-based models that combine satellite-derived inputs with surface climate data, and weather/climate forecasts, and empirical models that rely on historical relationships between climate and ecological phenomenon such as fire risk, disease/pest outbreaks, etc.; 2) planning and scheduling that facilitate a goal-based data collection and pre-processing so that all the necessary information is available in the required format for a given model run; and 3) causality analysis and model generation using advances in data mining and machine learning.

A variety of NASA data sets are used in TOPS. These data are available globally free of cost. TOPS routinely uses high resolution topography data from the SRTM (Shuttle Radar Topography Mission), triplicates of Landsat data for describing land cover/land use change, nearly 24 years of Advanced Very High Resolution Radiometer (AVHRR) for studying interannual variability and trends in global vegetation, eight years of precipitation from Tropical Rainfall Measuring Mission (TRMM) and over five years of Earth Observing System data. Current work on TOPS is focused on the production of ecological forecasts and nowcasts to support decision making for a wide range of applications. Examples of TOPS applications include protected area management (e.g., U.S. National Parks), mapping global net primary production for ecosystem monitoring, particularly famine-related warnings, agricultural production, and irrigation management in the premium wine industry in California.



The Terrestrial Observation and Prediction System (TOPS) integrates a wide variety of data sources at various space and time resolutions to produce ecological forecasts.

FIRE MAPPING EFFORTS ON ESPERANZA WILDFIRE IN SOUTHERN CALIFORNIA

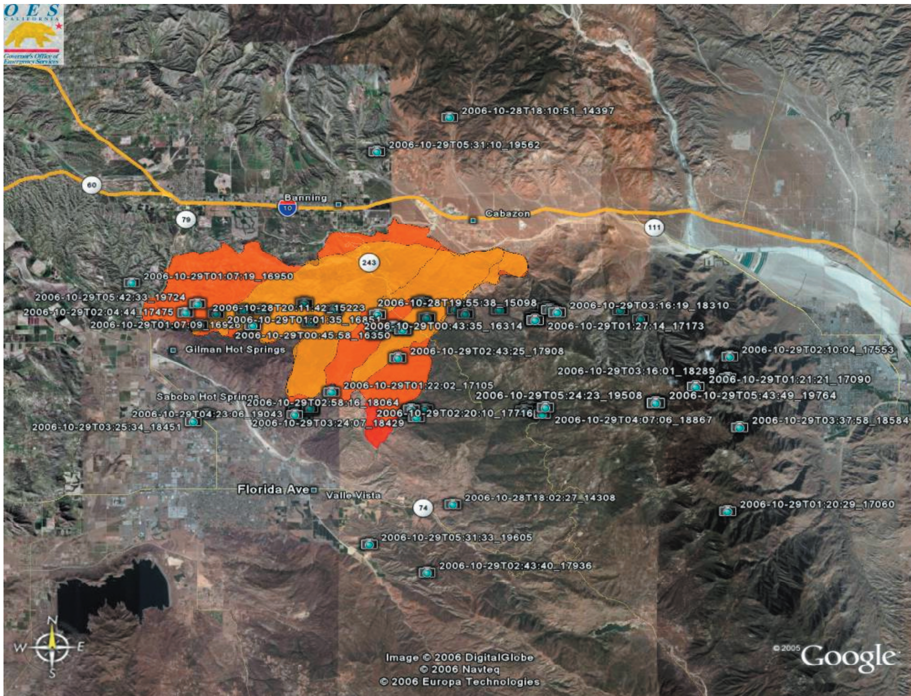
Vince Ambrosia, Project Principal Investigator

Program Support: NASA, Applied Science Program - Disaster Management, Steve Ambrose

General Atomics' Altair, with the AMS Wildfire Sensor installed in the belly pod, en-route to the Esperanza Fire.

A team composed of NASA-Ames, NASA-Dryden and U.S. Forest Service (USFS) personnel provided real-time thermal-infrared data from a General Atomics (GA) Altair UAV operating over the Esperanza Fire in southern California. The Esperanza Fire started early Thursday, October 26th. Fueled by powerful Santa Ana winds, the fire spread over 40,200 acres, killing five firefighters. The fire destroyed 34 homes and 20 other structures. The California Office of Emergency Services (OES) and the Incident Command Team (ICT) requested the NASA

High resolution image of fire, captured Oct. 26, 2006, by the Thematic Sensor on board NASA's Landsat 5 satellite.



AMS image collection location and date markers on fire perimeter sequence (CA-OES provided) for the Esperanza fire area

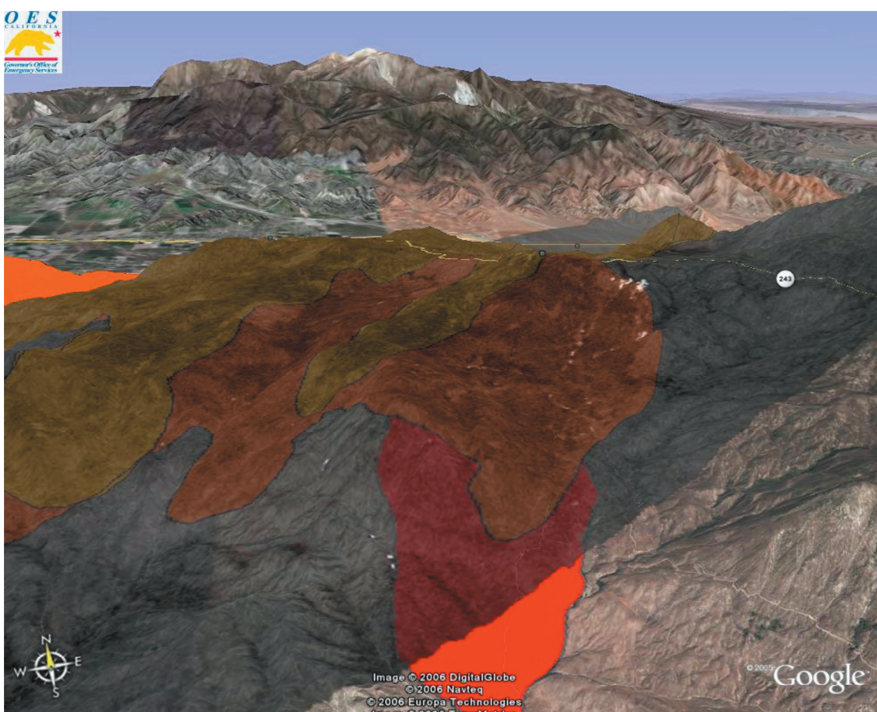
team's imaging and fire mapping assistance and, with the California Governor's Office, supported the application and receipt of an emergency amendment to a certificate of authorization to fly in the National Air Space.

The NASA-Ames and NASA-Dryden team had just completed its Wildfire Research and Applications Partnership (WRAP) Western States UAS Fire Imaging Mission tests for the 2006 western fire season. The team was de-mobilizing when it received the request to support efforts on the Esperanza Fire. With little advance time, the NASA team worked quickly to re-integrate the sensor system into the Altair's instrument pod and was prepared for the mission by Saturday afternoon, October 28.

The AMS-Wildfire, a NASA-developed sensing system, was designed for improved imaging capabilities and real-time processing and data delivery from UAS platforms to support incidents like the Esperanza Fire. The UAV launched from GA's Gray Butte Facility near Palmdale, California, for the long-endurance data collection mission over the fire. A team of NASA-ARC and USFS specialists traveled to the Esperanza Fire Incident Command Center after the launch to familiarize the situation unit and mapping teams with the format of the sensor data and the data accessing capabilities.

The aircraft rose to an altitude of 43,000 feet and lingered over the fire, for sixteen hours collecting and sending thermal data. These data were delivered from the ALTAIR through a satellite communications link to a server at NASA-Ames. At the collection point, the data were archived and redistributed in-real-time to a data visualization and integration package Decision Support System (DSS) Collaborative Decision Environment (CDE) for planning purposes by the fire management team.

The simplified DSS-CDE was familiar to fire management team personnel as it was provided on a GoogleEarth background map and image base. All the sensor data was visualized on that CDE along with other situational information including weather data, satellite data, local Remote Automated Weather Station (RAWS) readings and other critical fire data-base sources. The CDE also allowed the IC team and others to observe the track of the aircraft in real-time and use an



A 3D perspective showing a blend of TIR data over the fire perimeter. Notice the fire (within circles) extending beyond the perimeter.

on-board video camera feed to align the sensor system. All this information was streamed through NASA-ARC servers to the CDE and the fire teams in real-time. The CDE data were also accessed by personnel throughout the U.S. who were involved in the mission and imaging efforts.

The ICT used the thermal imagery and products to study the fire and prepare maps and briefing packages for distribution at the ICT morning briefing. The 7:00 a.m. briefing incorporated various intelligence received about the fire including the thermal data collected from the Altair platform. The data proved beneficial as other sources of airborne thermal IR data were unavailable for night operations.

The ALTAIR UAS with the AMS-Wildfire sensor landed at Gray Butte, California, on Sunday morning, October 29, after flying for nearly 16.6 hours and delivering about 100 thermal image data sets and over twenty real-time derived fire-perimeter shape files developed by autonomous processes on the sensor system.

NASA welcomed the opportunity to support the Esperanza Fire Incident Management Team and the State of California, Office of Emergency Services by providing information that assists in managing these kinds of incidents.

NASA also extends its condolences to the wildland fire community, and the family, friends and coworkers of those who died fighting the Esperanza Fire.

Web site: http://geo.arc.nasa.gov/sge/WRAP/

IMPACT OF PIXEL SIZE ON MAPPING SURFACE WATER IN SUBSOLAR IMAGERY

Vern Vanderbilt, Project Principal Investigator

Program Support: NASA Ames, Director's Discretionary Fund

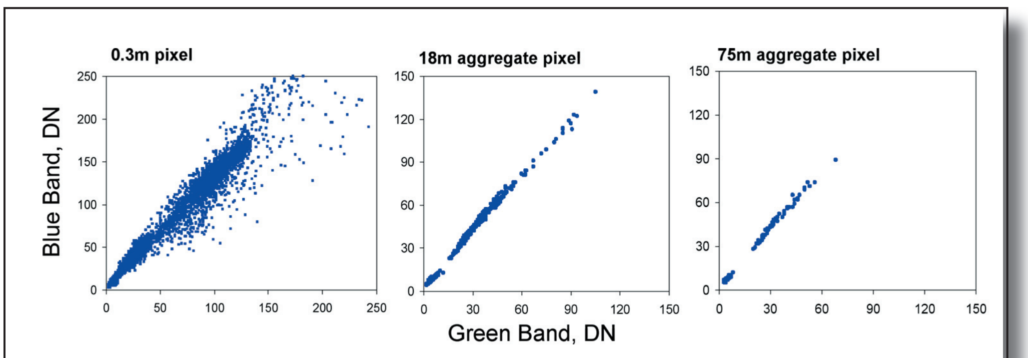
An accurate, satellite-based approach capable of monitoring the extent of inundated areas is needed to improve understanding of the hydrology of seasonal and inter-annual wetlands at the local to global scale. In earlier published research we described an analysis technique for discriminating open water, inundated vegetation and non-inundated cover types in wetlands. Our results showed that high radiance values measured near the direction of the sun glint (also termed the subsolar or specular direction) signaled the presence of either open water or inundated plant communities, in contrast to dry upland plant communities. While promising, these earlier results were constrained by the 150 m ground resolution of those image data, which are difficult to validate when compared to the meter-scale spatial resolution of many wetlands maps.

In this research we tested the hypothesis that as pixel footprint size increases the accuracy of remote sensing based estimates of surface water area tends to increase. We conducted two experiments looking at the accuracy of estimates of surface water area, one analyzing the effect of pixel size and the other looking at the effect of interactions between pixel size and class separation

We analyzed 56 images each collected looking obliquely at the sun glint reflected from surface water in the Suisun Marsh, Fairfield, CA. Shades of red indicate foliage; whites and grey tones indicate surface water.

distance. We showed the increase in accuracy is linked to the spectral separation between information classes that tends to increase with increasing pixel footprint size.

Our results suggest that regional to global scale wetlands issues that do not involve one meter resolution per se may be addressed with acceptable accuracy through analysis of low resolution imagery — such as the 1.2 km imagery simulated here — provided that imagery is collected in the subsolar direction where surface waters specularly redirect incident sunlight to an observing sensor. Our results argue for development of a small, very simple satellite sensor designed specifically for monitoring Earth's surface waters with the aid of the sun glint.

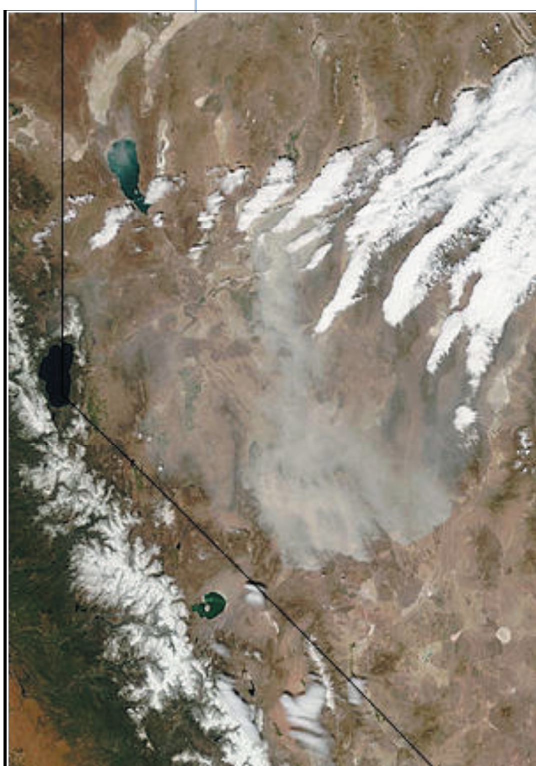


Scatter plots of the blue and green bands show that the separation between pure pixels of the two cover types (surface water and upland) increases with pixel size. Surface water DN values are generally greater than 15; upland DN, generally less than 15.

INVASIVE SPECIES MANAGEMENT ON WESTERN LANDS

David Bubenheim, Project Principal Investigator

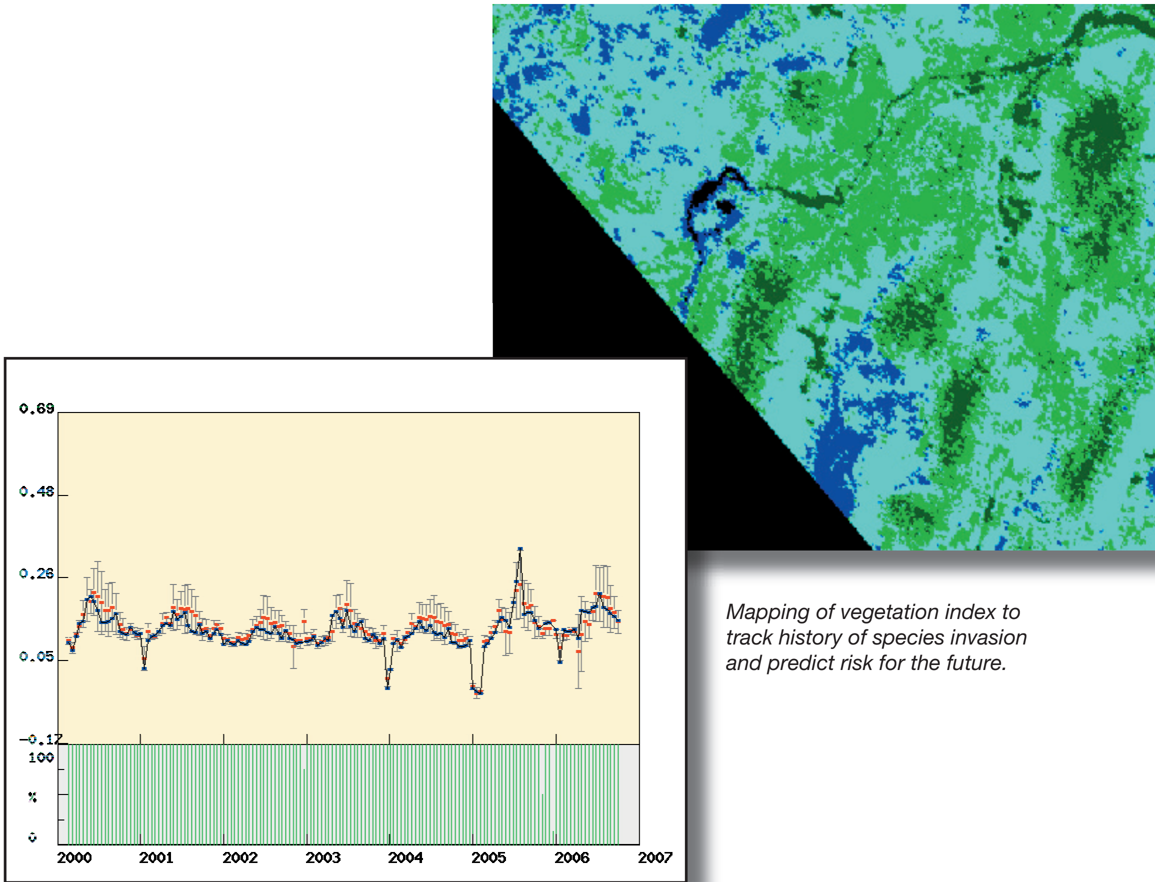
Program Support: NASA, Applied Sciences Program-Invasive Species, Ed Sheffner



Wild Fires in Nevada: Invasive species have modified the ecosystems of much of the West, resulting in increased occurrence of fire.

Invasive weed species adversely impact managed and non-managed areas, including agricultural fields, rangelands, urban areas, and rivers and wetlands, in California and throughout the western United States. Yellow starthistle, (*Centaurea solstitialis*), saltcedar (*Tamarix spp.*), knapweed (*Acroptilion repens*), tall whitetop (*Lepidium latifolium*), cheatgrass (*Bromus tectorum*), red bromegrass (*Bromus rubens*), and waterprimrose (*Ludwigia hexapetala*), are invasive weeds that rapidly invade areas and ultimately alter diverse ecosystems into pure stands of the invasive plant. Waterprimrose, whitetop and saltcedar are potential threats to riparian water resources, causing intensified sedimentation, flooding, and bank displacement. In a similar fashion, the competitive advantage of plants like yellow starthistle, knapweed, cheatgrass and red brome enables them to consume limited resources, particularly summer surface and ground water, and alter the ecosystem composition by altering the water available to other species. Resulting changes in the plant communities often increase the incidence and intensity of wildfire and further cause reductions in wildlife forage value. Invasive plant species cost local land managers millions of dollars annually in attempts to control infestation levels and spread rates, yet the problem persists and is expanding.

Our project is focused on leveraging the unique abilities, tools and knowledge of NASA and USDA, enabling USDA to exploit NASA science measurements, models and knowledge. A systems approach to assessment and management of sustainable agricultural, urban and natural area land use is needed to improve and maintain effective human and natural systems in the Pacific Western States. A combination of remote sensing and locally obtained data on watershed health, including vegetation cover and utilization;



Mapping of vegetation index to track history of species invasion and predict risk for the future.

range hydrology and downstream water utilization; and soil stability and nutrient management; and wastewater control need to be assessed and linked through integrated use strategies that optimizes overall resource sustainability. Currently, many natural resources systems are overloaded and showing symptoms of this stress in the form of increased pest invasions (such as those focused on here), surface water pollution (nutrient loading, microbial contamination, excessive sedimentation, etc.) affecting drinking and irrigation waters, and a myriad of other linked factors. The specific work focused on quantifying the impact of invasive plant species on ecosystems to provide a basis for decision making on a much broader scale. For example, developing the tools to assess the competitiveness and expansion of invasive species in rangeland provides a segregated biomass estimate that can be used to support many aspects of range management, including fire risk, grazing capacity and ecosystem stability.

LIFE IN EXTREME ENVIRONMENTS: UV RADIATION IN NATURE

Lynn J. Rothschild, Project Co-Principal Investigator

Program Support: NASA, Astrobiology Institute, SETI, Carl Pilcher

Dana Rogoff (SETI Institute and Research Associate for the Rothschild lab), performs UV readings in the Bolivian Altiplano. Laguna Verde is seen in the background.

The first step in predicting the location and extent of life on early Earth and elsewhere in the universe is understanding the environmental limits of life on earth. We focus on microbial life as microbes are the most likely organisms to live in extreme environments and be found elsewhere. During the last decade, our work has focused on several parameters, most notably the range of natural solar radiation environments and the effect they have on DNA damage (base modification and breakage). Beginning with measurements at NASA Ames, and extending to the hot springs of Yellowstone to the Rift Valley of Kenya, to the radioactive springs of the Flinders Ranges in Australia to the Bolivian Altiplano, UV measurements are being made and correlated with Earth Probe TOMS data sets, DNA damage and community composition. These studies have revealed a remarkable range of inhabited environments on earth living under surprisingly high radiation regimes.

Lynn Rothschild measuring temperature at Chocolate Pots hot spring, Yellowstone National Park. The dark patches are the cyanobacteriun Oscillatoria (inset) which are protected from UV radiation by the chocolate-colored iron-rich deposits. Analysis of this ecosytem is being done in collaboration with Dr. Janice Bishop, SETI Institute, and funded by the NAI SETI team grant.

NASA OBSERVATIONS AND MODELS TO ESTIMATE AND PREDICT POTENTIAL CARBON SEQUESTRATION

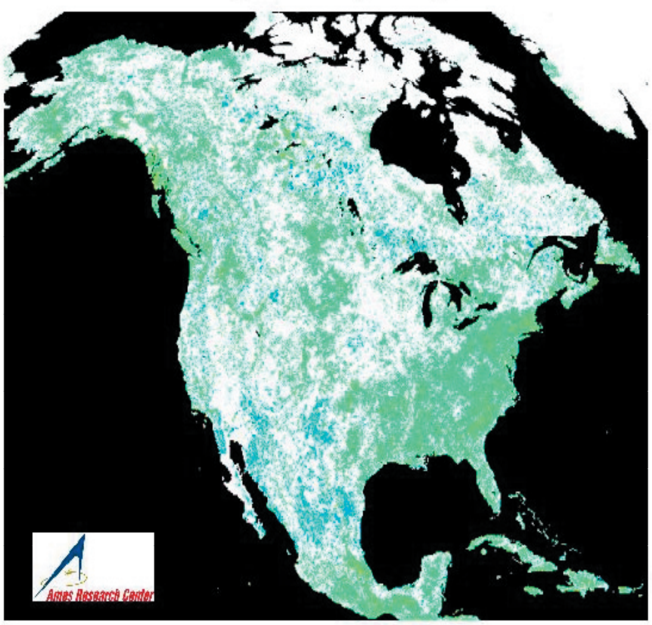
Christopher S. Potter, Project Principal Investigator

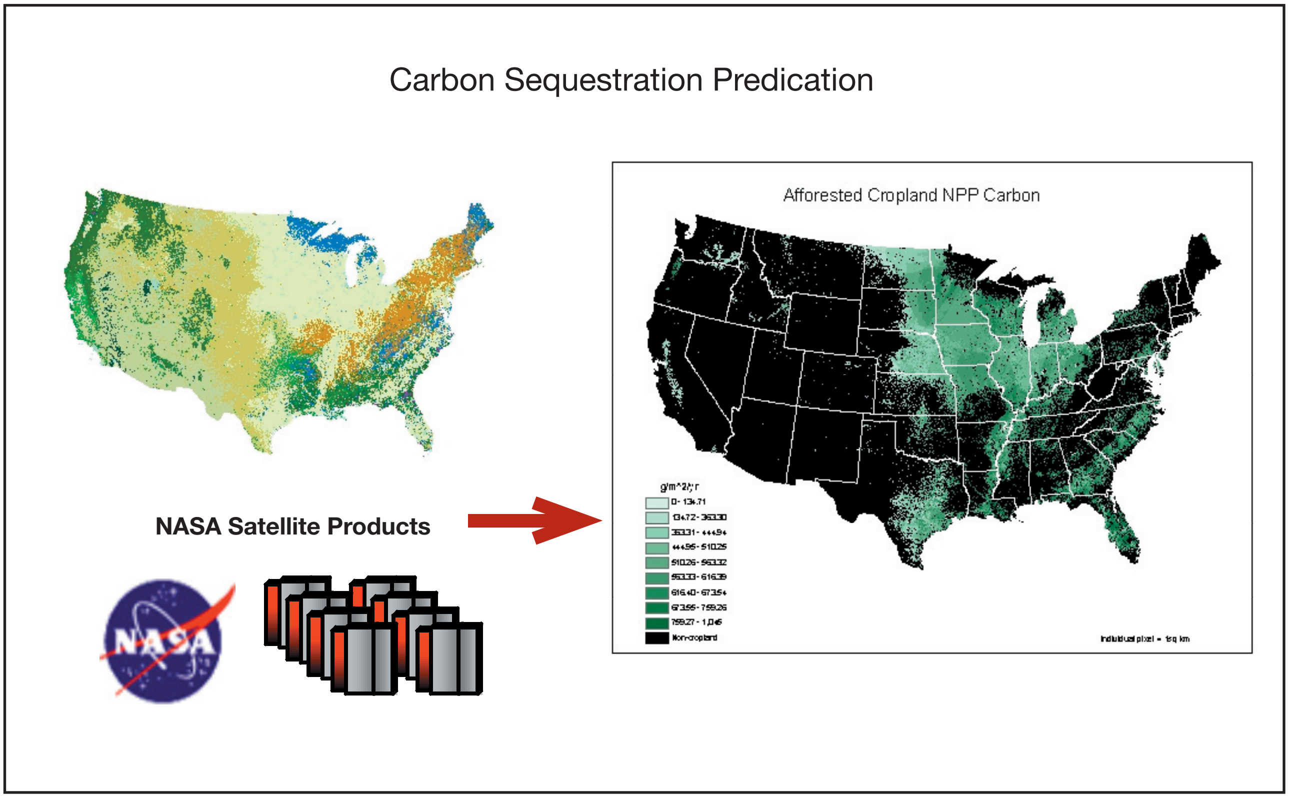
Program Support:
- *NASA, Carbon Cycle and Ecosystems, Diane Wickland*
- *NASA, Applied Sciences Program-Carbon Management, Ed Sheffner*

Carbon sequestration in ecosystems involves the net uptake of CO_2 from the atmosphere for persistent storage in sinks of terrestrial vegetation or soil pools. Land areas that consistently sequester carbon by growth in net ecosystem production are potentially important as future sinks for CO_2 emissions. Conversely, land areas that do not consistently sequester carbon over time may be adding to already increasing atmospheric CO_2 from fossil fuel–burning sources.

Investigators at NASA Ames have demonstrated that several large regions in the United States, Mexico, and Canada have been adversely affected over the past 20 years by rapid shifts in weather patterns. Satellites can measure a "greenness" index of plant health and productivity over time. Areas particularly hard hit by climate variations during the 1980s and 1990s were detected along the northern tundra zones of Canada and Alaska, the western Great Lakes, the Great Plains of the central U.S., the Mountain West, and the arid zones of the southern U.S. and Mexico. The most

Trends in plant health and productivity during the 1980s and 1990s
(Blue = negative, Green/yellow = positive)



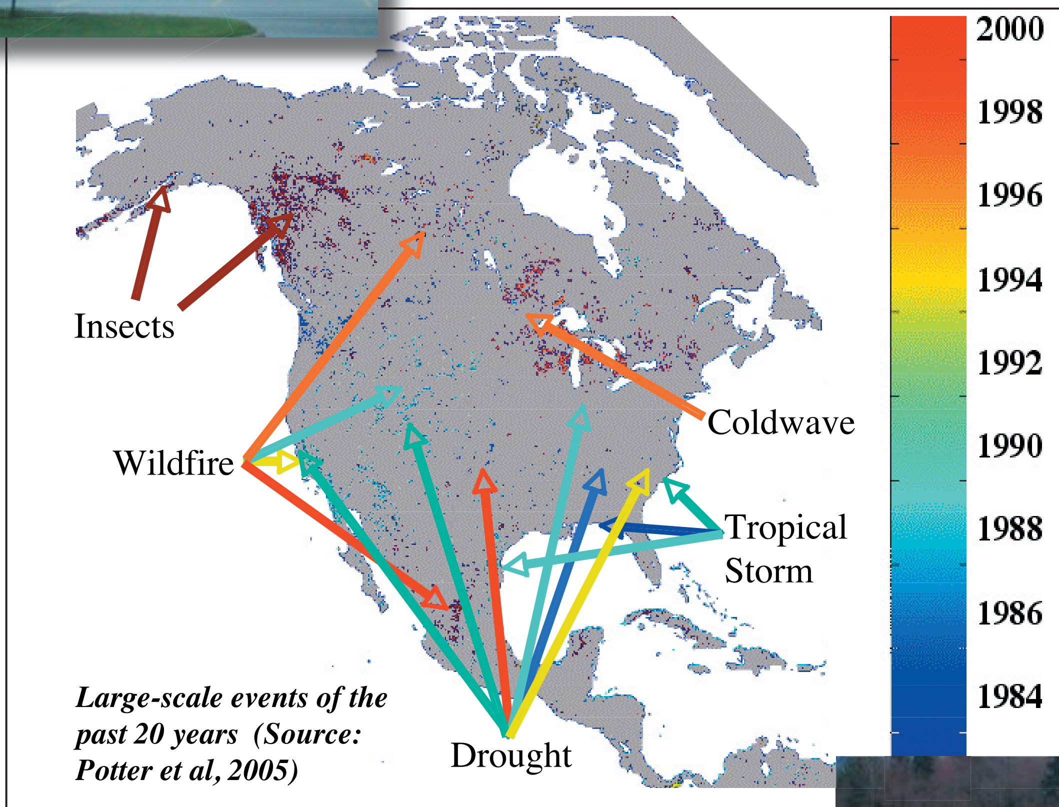


Potential afforestation carbon gains in relatively low-production crop areas mapped to show predicted gross carbon sink flux per year at 1-km resolution.

frequent cause of these large-scale declines in plant health was drought. Periods of unusually low rainfall, combined with warming trends, make ecosystems of the Mountain West and the south-western U.S. particularly vulnerable to major wildfires and damaging insect outbreaks.

The NASA CQUEST (Carbon Query and Evaluation Support Tools) application is building new and unique partnerships with Federal and State agencies and their collaborators to demonstrate integration of research efforts toward verifiable reductions in greenhouse gas (GHG) emissions. Important gaps in our national database of carbon sequestration can be addressed by combining NASA remote sensing technology, ecosystem process modeling, and field-based measurements to characterize land management impacts on the carbon cycle.

Fires, floods, hurricanes, droughts are events that can alter the landscape for years to come, and change the lives of people in sudden and often severe ways. Investigators at NASA Ames have evaluated patterns in an 18-year record of global satellite observations of vegetation phenology from the Advanced Very High Resolution Radiometer (AVHRR) as a means to characterize major ecosystem disturbance events and regimes. The fraction absorbed of photosynthetically active



The effects of droughts, wildfires, insect damage, cold waves, and hurricanes are detectable in the satellite data as a large-scale North American ecosystem disturbance record.

radiation (FPAR) by vegetation canopies worldwide has been computed at a monthly time interval from 1982 to 2000.

Potential disturbance events were identified in the FPAR time series by locating anomalously low values (FPAR-LO) that lasted longer than 12 consecutive months. Results suggest that nearly 400 Mha of the global land surface could be identified with at least one major FPAR-LO event over the 18-year time series. The majority of these potential disturbance events occurred in shrub lands or in evergreen forest ecosystems (see figure above).

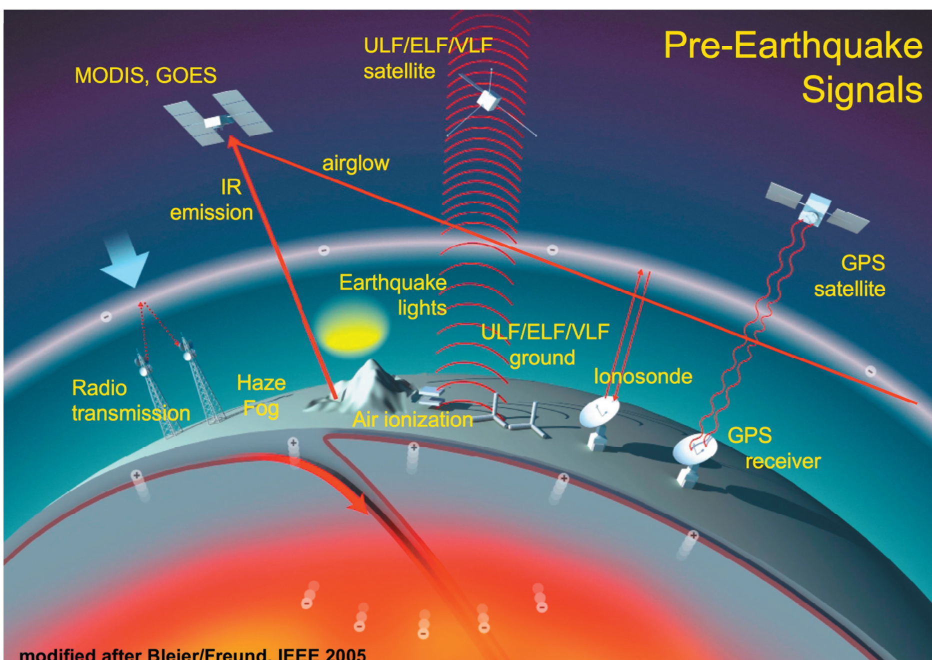
SATELLITE-BASED GLOBAL EARTHQUAKE EARLY WARNING SYSTEM

Friedemann Freund, Project Principal Investigator

Program Support: NASA, Astrobiology Institute, SETI, Carl Pilcher

Of all natural disasters, earthquakes are the most feared. They seem to strike without forewarning. The ultimate goal of earthquake research is to predict – within limits as narrow as possible – time, place and magnitude of major events. This goal may never be achieved to the satisfaction of some, but it should be possible to predict much better in the future than today. Today's earthquake risk assessments are made on the basis of probability models built almost exclusively with input from seismology. Other data that could provide valuable information about impending seismic activity are not included. Non-seismic precursory data can be obtained from:

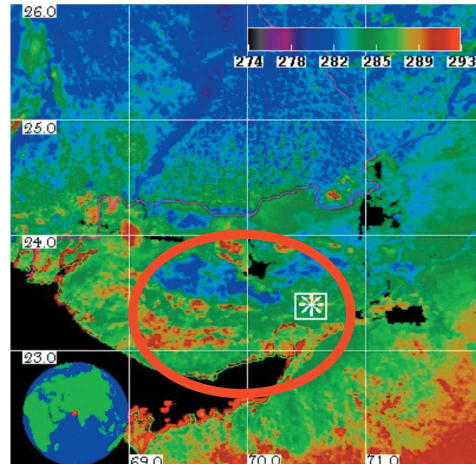
- Ionospheric perturbations
- Low frequency electromagnetic (EM) emissions
- Enhanced infrared emission from the ground



Schematic representation of the multitude of pre-earthquake signals that can be monitored from satellites and ground-based stations.

- Ultralow frequency magnetic field variations
- Changes in the lower atmosphere
- Earthquake lights
- Strange animal behavior etc.

Current earthquake risk analysis excludes a wide range of potential early warning signs. The often-quoted rationale for the rejection of non-seismic premonitory signals is that (i) they are not always reliably observed, and (ii) there are no known physical processes to explain how these signals might be generated. This situation has changed. We have now deciphered the basic physical processes that underlie the generation of a wide range of non-seismic pre-earthquake signals. Key is the discovery of a previously unknown type of electronic charge carriers in common rocks. These charge carriers are defect electrons in the oxygen anion sublattice, also known as positive holes or pholes for short. The pholes are responsible for the "battery effect", i.e. the observation that, when rocks are subjected to stress, they turn into batteries from where electric currents can flow out.



Night-time MODIS image, Jan. 18, 2001, of Gujurat province, NW India, where a M=7.6 earthquake struck eight days later at a depth of 29 km. Increasing stresses on the buried faults are imaged through stimulated, short-lived IR emission. (The star marks the epicenter.)

Normally the pholes lie dormant in the rocks, inconspicuous and electrically inactive. However, once activated by stress, they are capable of spreading from the stressed rock volume into the surrounding unstressed rock.
The pholes can travel fast and far, over distances on the order of tens of kilometers. Forming positive charges at the surface of the Earth, they are thought to alter the regional ground potentials and, hence, the ionosphere. They can generate electric fields high enough to cause ionization of air molecules, formation of airborne positive ions, and – under certain conditions – luminous glow discharges.

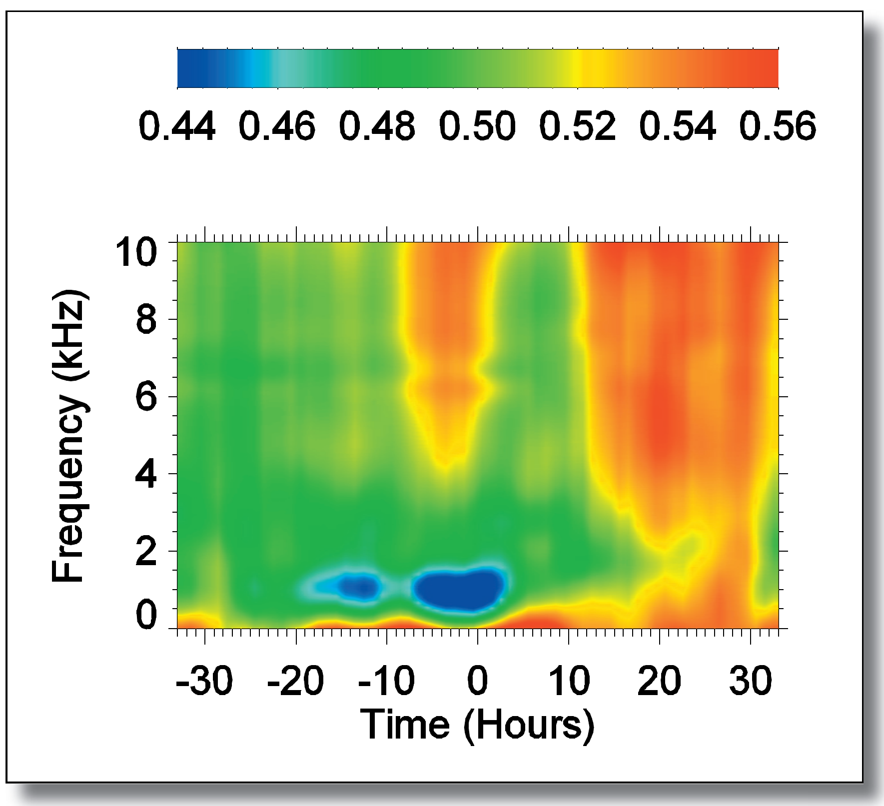
Once we started to more fully understand the pholes, their activation in Earth's crust, their spreading through the rocks and how they can give rise to a host of secondary processes, we were able to explain most, if not all reported non-seismic pre-earthquake signals. All those signals appear to be driven in some ways by those electronic charge carriers, the pholes.

The new insight allows us to see – for the first time ever – that the different pre-earthquake signals are expressions of the same fundamental physical process: the stress-activation of pholes deep in the Earth's crust. The different signals appear at different stages of the build-up of stresses in the Earth's crust that eventually lead to earthquakes. This allows us to look at these signals as valid indicators of impending earthquake activity.

Though the research goes back more than two decades, progress during the past 18 months has been crucial. We think we have solved the long-standing enigma of many different types of non-seismic pre-earthquake signals that have been reported from all seismically active regions of the world. Now comes the second important phase of this work:

- Broaden the scope of the laboratory studies,
- Initiate theoretical work to understand the physics of pholes,
- Validate observational data available from different sources,
- Cross-correlate the data from satellites and ground stations,
- Establish criteria for pre-earthquake signals.

We can begin develop IT programs with pattern recognition features and multi-level decision trees capable of weaving together multiple large data streams from very diverse satellite and ground-based sources.



Superposition of the characteristic low-kHz EM emission recorded by the French DEMETERsatellite while passing over 3561 earthquakes of M>4.8 during the first 18 months. Note the onset of the EM signal 3-9 hrs before the events.

SCALABLE AND AFFORDABLE UNPILOTED AIRCRAFT SYSTEMS TO ENABLE EARTH SCIENCE MISSIONS

Stephen Dunagan, Project Principal Investigator

Program Support: NASA, Suborbital Science Program, Cheryl Yuhas

NASA's Earth Observing System must be complemented by a sensor web providing corroborating and ground truth data at a full range of spatial and temporal scales. Unpiloted Aerial System (UAS) technology comprising vehicle, sensor, data processing, communications, and automation elements has progressed significantly in recent years and may be key to executing a number of important missions not previously feasible. Aircraft have long been the vehicle of choice for missions requiring fine scale remote sensing, access to a localized spatial domain for long duration, or to support the simulator instruments that provide the basis for developing and testing the retrieval algorithms that make NASA's orbital instrument assets productive. UAS technology is particularly attractive for missions considered too hazardous for manned aircraft, such as hurricane tracking, pre-eruptive volcano monitoring, fire plume analysis, and long duration polar flights. These high risk missions are only enabled by UAS technology that is affordable and expendable at the budgetary scale of the mission.

The SIERRA in the lab at NASA Ames.

The Systems Integration Evaluation Remote Research Aircraft (SIERRA) Project is developing a sophisticated UAS to serve NASA's SMD Suborbital Science community as well as partnering government organizations. The aircraft is in the 350 lb gross weight class, with a wingspan of 20 ft, duration of 10 hrs, altitude ceiling of 10,000 ft, and payload capacity of 100 lbs. The aircraft is fitted with a scalable payload bay which can support a broad range of imaging and in situ sensors, including navigational and metrological instruments capable of measuring the wind field at high accuracy. On board data processing has been developed and implemented in collaborating projects, with a specific focus on reducing multispectral imaging data to a 3-band format that is geo-rectified against digital elevation model data and delivered via both line-of-sight and satellite communications links in near real time to ground-based customers in the field.

Communications links include a primary line-of-sight (LOS) radio/modem system operating at 421.5 MHz and up to 25 Watts, providing 128 Kbits/sec throughput at up to 30 miles range. A secondary radio modem transmits in the 900-920 MHz frequency range at up to 1 watt power, with mode hopping capability and up to 128 Kbits/sec throughput at up to 5 miles range. A tertiary comm link is implemented through the Iridium SatCom constellation and provides over-the-horizon communications at up to 2.4 kbits/sec bandwidth.

Onboard automation elements for this UAS will also leverage other projects within the Ames Information Science and Robotics community, and will include cooperating sensor and aircraft planning modules which will optimize the productivity of the system against a pre-defined mission merit function. The UAS autopilot avionics have been selected to support such advanced automation capabilities as formation flying of up to 10 constellation aircraft, with control centralized in a single ground station. This capability is attractive for several mission profiles, particularly when the time evolution of distributed phenomena must be sampled concurrently (e.g. convective eddy transport in the lower troposphere). Considerable testing and risk mitigation will be required to realize the benefits of high levels of onboard automation, particularly for tasking the aircraft flight profile. However, this automation toolset will be directly applicable to several exploration missions where optimized collaboration of instruments and vehicles will be essential to mission success.

The SIERRA UAS was initially designed at the Naval Research Laboratories (NRL). The graphite composite and plywood airframe was constructed under contract to RnR Products. Ames' Earth Science Division has taken ownership of the aircraft from NRL and assumed responsibility to complete the detail design of electrical, avionics, hydraulics, power, propulsion, and ground station elements. Aircraft subsystems have been integrated and ground tested in preparation for flight certification by the Ames Air Flight Safety Review Board. Initial flight testing will focus on tuning the autopilot avionics to ensure stable flight, followed by incremental envelope expansion flights to determine the performance limits of the aircraft as required to define the mission capability.

Concurrent with initial flight testing, a number of payloads will be developed and integrated into interchangeable, scalable nose-mounted payload sections. These will include a metrological measurement system (MMS) for precise measurement of troposphere winds and thermodynamic properties, a cavity ringdown system for in-situ measurements of specific atmospheric constituents, and a variety of imaging systems including a high resolution color-IR camera, a prismatic narrow-band camera, a thermal IR camera, and a pushbroom hyperspectral instrument with spectral coverage in the visible and near IR.

Following successful flight testing the UAS will become a catalog asset supporting NASA's Suborbital Science Program. It will also be available to support the NRL missions of original intent, along with a number of potential missions that have been identified with collaborating government agencies including the Forest Service (USFS), National Oceanic and Atmospheric Administration (NOAA), and the Department of Homeland Security (DHS). A second ship will be certified to support concurrent and formation flight missions.

SMALL UASs FOR WILDFIRE MONITORING

Randall Berthold, Mission Manager
Vincent G. Ambrosia, Project Principal Investigator

Program Support: NASA, Applied Sciences Program - Disaster Management, Steve Ambrose

NASA-Ames Research Center and the US Forest Service have a long-term research and applications project focused on the maturation, demonstration and integration of technologies to improve the real-time assessment of wildfire conditions. Those technologies include advanced small unmanned aircraft platforms, imaging systems, data communications capabilities, and rapid data integration and information exchange processes. A major focus of the technology evaluations is demonstrating capabilities in "real-world" field demonstrations.

Major Field Demonstration

In June of 2006, a demonstration to evaluate the use of advanced unmanned aircraft systems (UAS) technologies for wildfire imaging and mapping capabilities was performed. The demonstrations occurred over prescribed fires at the Fort Hunter Liggett Garrison near King City, California. The demonstration exhibited platform and thermal imaging technologies, communications, and innovative data visualization capabilities.

Wildfire burning near Mt. Hamilton, California.

Platforms and Imaging Capabilities

Four small UASs participated in the demonstration flights: AeroVironment PUMA, IntelliTech Microsystems' Vector-P, The InSitu Group's ScanEagle, and NASA-Ames UAV Collaborative APV-3. Each UAS platform demonstrated effective flight and data gathering, mobility, imaging, and real-time air-to-ground data communication. Three

Demo participants (clockwise from upper right): hand-launching the Aero-Vironment PUMA; (lower right) IntelliTech Vector-P with operational crew; (bottom left) Evergreen's ScanEagle and catapult.

different launch and recovery options were showcased with the UASs: hand-launch / rough-field-landing, catapult launch / sling-recovery, hard-surface runway launch / recovery.

To enable UAS data collection over fires, controlled burns were ignited at the demonstration. The UASs then demonstrated operational capabilities during day and night flights. The fires were ignited over five miles from the UAS launch site, further demonstrating UAS capabilities for operations beyond Line-of-Sight (LOS) control.

"Repeater-in-the-Sky" Demonstration

NASA-Ames demonstrated a 'repeater-in-the-sky' capability. Traditionally, remote radio communications between fire camps and field personnel are hindered by terrain. The "Repeater-in-the-Sky" concept embeds a repeaters on a small UAS, circling above a strategic point, allowing emergency communication with a 'remote' field team with fewer communications drop-outs. This demonstrated the maintenance of constant communications in emergency situations in rugged terrain where locating repeater stations on high terrain is not feasible.

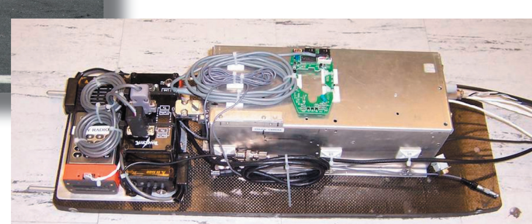
Thermal image acquired by ScanEagle UAS over controlled burn.

Platform Awareness and Flight Safety Demonstration

The UAV Collaborative of the NASA Research Park at Moffett Field demonstrated a Sense-and-Avoid Display System (SAVDS). The SAVDS is a ground portable radar system that provides situational awareness capabilities for low-altitude, long-endurance UAS. The system displays topographic base map overlaid with aircraft identification and positional information of all air traffic in the vicinity of the radar, as well as the UAS. The radar information and display, allows the UAS pilot to de-conflict with any other aircraft in close proximity to the operations. SAVDS enables UAS pilots to be fully aware of the local air traffic environment to ensure safe operations, a critical necessity in the complex airspace found on major wildfire events.

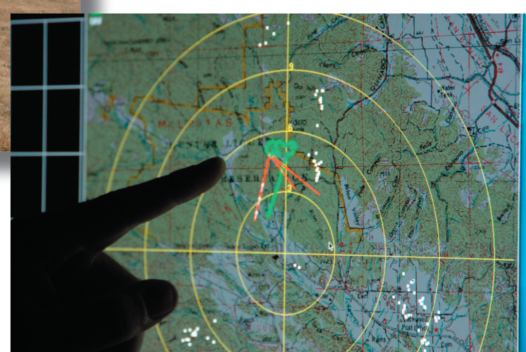
Successful Results

These demonstrations were successfully implemented and attended by over 100 participants and observers from various wildfire management agencies. The participants represented federal, state and local agencies, international observers, academia and commercial ventures. The capabilities demonstrated in June 2006, will lead to a more rapid understanding of the niche roles of UASs in supporting disaster monitoring and will assist in streamlining a path towards implementation of UASs into day-to-day operations on wildfires in the US.



APV-3 with radio repeater communications equipment payload.

A 360^{O} group photo of UAS Small Demo participants and team. (Photo courtesy of Fran Stetina.)



SAVDS Radar and Display of UAS and other aircraft.

WATER UTILIZATION MONITORING WITH REMOTE SENSING

Lee Johnson, Project Principal Investigator

Program Support: • State of California Dept. of Water Resources, Baryohay Davidoff
• NASA, Applied Sciences Program-Agriculture Efficiency, Ed Sheffner

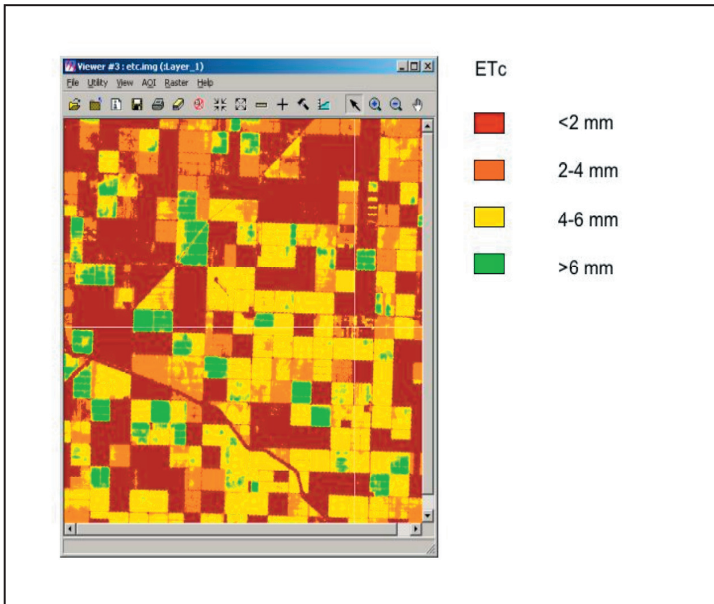
As competition for water in the West increases, irrigated horticultural producers seek to optimize water use to sustain or maximize income from limited water supplies. Proper irrigation timing and amounts on high value crops are important to avoid adverse impact on yields and quality. Efficient application of water can benefit from precise irrigation scheduling. Water loss, or evapotranspiration (ET), from horticultural crops is difficult to generalize due to varietal differences, climatic variation, and cultural practice. Crop canopy light interception has been shown to be related to ET for several crops, and may be the best alternative to derive ET coefficients for horticultural crops.

In collaboration with the USDA-Agricultural Research Service, satellite remote sensing was used to map percent cover and crop ET in the San Joaquin Valley. Percent cover was measured for several western fields by ground-based methods. Calibrated Landsat data were normalized to top-of-atmosphere reflectance and converted to normalized difference vegetation index (NDVI). The NDVI was strongly related to percent cover across several major crop types, including grapes, almonds, pistachio, cotton, melon, tomato, beans, and onion. Nearby reference ET measurements (California Dept. Water Resources) were used to convert crop cover to crop ET, which was then mapped for a 400 sq km portion of Fresno County.

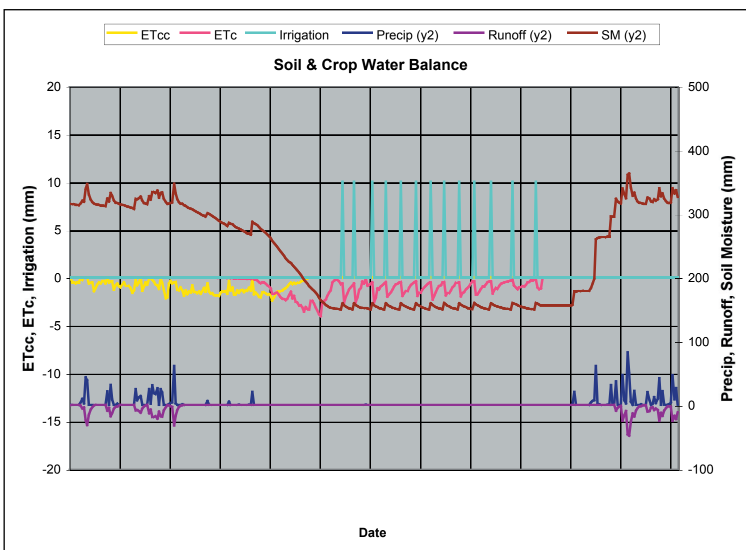
A crop water balance model, VSIM, has been developed and tested as a

(Continued on page 116)

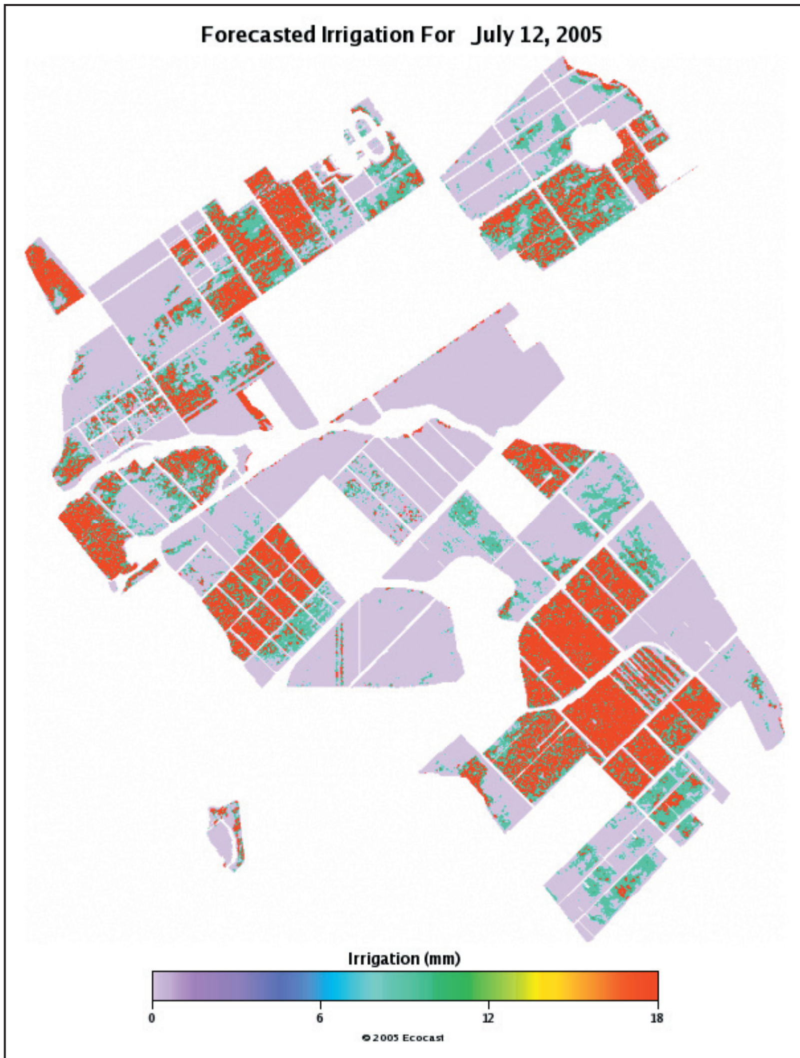
Measurement of canopy cover in San Joaquin Valley using digital camera.



Satellite-based map of crop evapotranspiration for San Joaquin Valley study area, 20 x 20 km



The VSIM crop water balance model allows the user to explore relationships among irrigation, rainfall, runoff, soil moisture and crop evapotranspiration.



Remotely sensed imagery enables VSIM to perform 2-dimensional (landscape) simulations. Here, irrigation demand is predicted, based on a National Weather Service 7-day forecast, for a 400 ha vineyard in Napa Valley.

tool for agricultural water resource management. The model simulates how variations in climate, soils, and canopy density influence crop water use and plant water stress. These environmental elements are important factors in determining crop quality and yield. VSIM assists the water resource manager in forecasting irrigation demand, developing deficit irrigation regimes, and in optimizing agricultural water use.

VSIM has been integrated with NASA's Terrestrial Observation & Prediction System (TOPS), which uses Earth-viewing satellite imagery to generate data fields related to hydrology, meteorology and ecosystem function. The prototype system incorporated high-resolution satellite imager, meteorological data, and soil texture information to generate daily maps of crop evapotranspiration, soil moisture, and leaf water potential (a measure of water stress) throughout a 400 ha Napa Valley vineyard. As the capability is further refined and linked with an increasingly rich and accessible body of earth observational data and weather forecasts, it will support tactical (grower) and strategic (resource agency) water management decision systems on a local-to-regional basis.

AIRBORNE SCIENCE OFFICE

Matthew Fladeland
ASO Manager

The NASA Ames Airborne Science Office within the Earth Science Division (ESD) supports the Suborbital Science Program (SSP) at NASA Headquarters through requirements analysis, flight request management, and communications with the science community and program stakeholders. The following efforts provide information that guides the content of the SSP aircraft catalog and guides investments in new technologies for improving observations of the earth.

5-year Plan

The SSP 5-yr plan provides an annual update on the near to mid-term requirements for the SSP from the agency's science disciplines and flight projects. The plan is developed through inputs from Science Focus Area Program Managers at NASA HQ, scientists, and space mission managers. The plan consists of major campaigns in each discipline, sensor developing and testing (i.e.. Earth Science Technology Office IIP test flights), interagency science campaigns, and future calibration and validation needs for upcoming space mission. The 5-yr planning meeting is held each year and is followed by interviews and a comment period before being published at the beginning of each fiscal year. This assessment provides important information on the need to sustain certain assets while potentially retiring others, and provides input to schedules for the aircraft program offices.

Systematic Requirements Analysis for Suborbital Science

Requirements from the NASA ESD science focus areas, flight missions, and technology development programs drive the composition of the suborbital program aircraft catalogue and the performance of sensors and sub-systems. For the science focus areas, conferences, publications, workshops, and interviews provide inputs to science requirements documents. These summaries and analyses are reviewed and approved by the Program Managers and SMD executives and are updated on bi-annual basis. Analyses of requirements for telemetry, data recorders, multidisciplinary sensors, and science-support systems are also conducted on an as-needed basis, usually requested by the SSP manager or science managers. Once science requirements are gathered and reviewed, they provide a critical input to technology development efforts, and ultimately, drive changes to the composition of the aircraft catalogue.

Unmanned Airborne Systems Roadmap

The Unmanned Aerial Systems (UAS) Roadmap is a joint effort between the Science and New Technology program elements to assess the requirements for unmanned systems within the Earth Science community, determine technology solutions, and provide guidance on the priorities for future development and deployment of unmanned systems. This project will follow-on from the Civil UAS assessment activity, by refining promising mission concepts, analyzing requirements suited to unmanned systems, and working with the Science Program leads to prioritize future technology development and procurements. Information to support this effort is gathered at conferences, workshops, scientific literature, and interviews.

The NASA Altair Unmanned Aerial System is an example of an emerging technology that may lead to new observations of the earth system; the airborne science office is developing a roadmap to guide development of such capabilities

Stakeholder and Customer Feedback

Interaction with Project and Mission scientists, and principal investigators provides a critical pathway for understanding current and future operations requirements and to gauge user satisfaction. Beyond personal interactions at meetings and during missions, feedback is gathered through the flight request process, from comments received through the program website, and through interviews and lessons learned activities.

Communications

This office is responsible for maintaining an open line of communication with the science community. This is accomplished through development and maintenance of the suborbital science internet portal, through the annual call letter for flight requests, and through the generation of educational materials that are displayed at conferences and workshops.

Conferences and focused workshops are important venues for hearing from the community and better understanding future requirements for airborne science.

AIRBORNE SCIENCE & TECHNOLOGY LAB

Jeffrey Myers, ASTL Manager

Program Support:
- *NASA, Suborbital Science Program, Cheryl Yuhas*
- *NASA, EOS Project Science Office, Michael King*
- *NASA, Earth Science & Interior Program, John LeBrecque*
- *NASA, Applied Sciences Program - Disaster Management, Steve Ambrose*

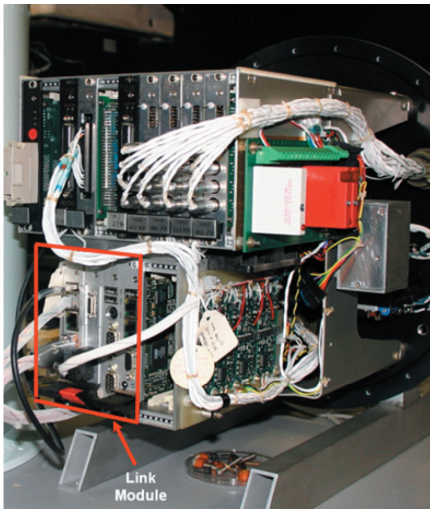
The Earth Science Division ASTL is part of the Ames University-Affiliated Research Center (UARC), and is staffed by the University of California at Santa Cruz. The lab has been supporting airborne measurements for the NASA science community for over 20 years, and specializes in infrared imaging devices and Earth remote sensing. It conducts a range of airborne science support activities, including instrument design, fabrication, and calibration; and sensor operations, flight planning, and data processing.

It is also tasked with maintaining and operating the MODIS and ASTER Airborne Simulators (MAS and MASTER) for the NASA EOS Program.

The AMS sensor components installed on the lower tray of the new Common Sensor Pod, later flown on the Altair UAS for the Western States Fire missions.

Technology Development

Autonomous Modular Sensor. The new AMS system was developed in FY06 for use on the Altair/Predator-B and Global Hawk UAS platforms, and was initially deployed for and the Western State Fire demonstration missions. This system was designed for extended autonomous operation on a UAS, in a fully-networked environment. The AMS features include re-configurable spectral bands to support multiple science requirements, extensive onboard



The UAS Telemetry Link Module, shown here in the lower rack of the AMS data system enclosure.

data processing capabilities, and full connectivity to high-bandwidth satellite communications systems for real-time applications. After initial testing on the Cessna Caravan, it was installed into the new UAS Common Sensor Pod and successfully completed a series of fire mapping missions on the Altair UAS.

Telemetry Interface Module. An outgrowth of the AMS project was a generic telemetry interface module, which can manage high bandwidth data (up to 40 Mbs) from multiple sensors across the sat-com links on Altair, Ikhana, or Global Hawk, to web servers on the ground. Developed jointly with the SGE Biospherics Branch, it provides standard interfaces to client sensors on board the UAS, and is designed to be both platform-independent, and transparent to the data users on the ground. It includes programmable processors dedicated to the science payload, which can be used for real-time data reduction, and is intended as a test-bed for future sensor web concepts. During the UAS fire missions it was configured to generate Level-1B and Level-2 data products onboard the aircraft, which were then transmitted to the ground via a 3 Mb/sec Ku-Band sat-com link.

Science support

The engineering staff facilitated the integration of the MILAGRO payload onto the J-31 aircraft, which involved major modifications to this FAA-certified contract platform. The new installations included a special rotating nose-mount for the Cloud Absorption Radiometer, the AATS-14 Tracking Sun Photometer, the Solar-Spectral Flux Radiometers, and an Applanix NAV-Met system.

ASTL personnel also provided flight planning support and mission logistics for various remote sensing missions on the ER-2, B-200, Caravan, and Twin Otter. Valuable operational

The CAR instrument installation in the nose of the J-31 aircraft. The entire forward section of the nose rotates to scan from the zenith to nadir directions.

experience was also gained with the Altair during the 2006 UAS missions, and several trained engineers are now available to assist with the integration of science payloads on this class of UAS platform.

Sensor Operations

The ASTL operates the MODIS and ASTER Airborne Simulators (MAS and MASTER) in conjunction with the EOS Project Science Office and JPL. These two systems were flown on a total of 56

Cirrus digital camera image of Puerto Rico.

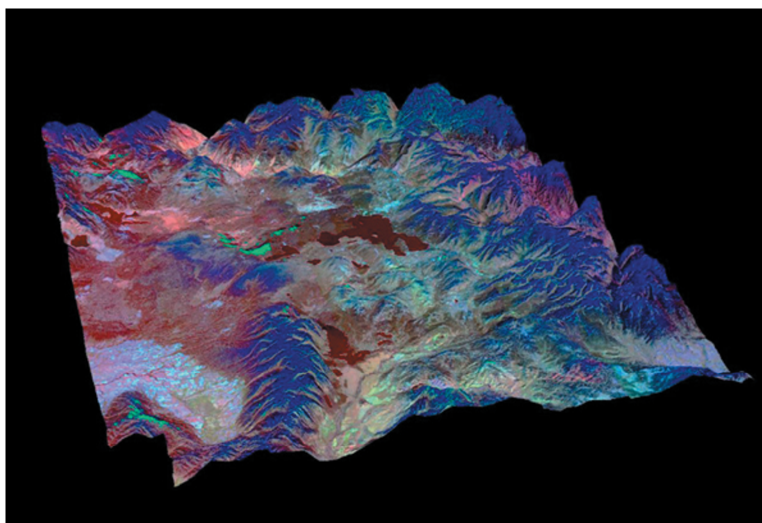
science missions, including the CC-VEx experiment, and various multi-disciplinary process studies onboard the ER-2, B-200, and Caravan. (These instruments are made available to the NASA science community through the Flight Request process.)

The ASTL also operates a suite of facility assets for the Suborbital Program, including stand-alone precision navigation systems (Applanix POV-AV IMU/DGPS units), the DCS digital tracking cameras, and environmental housings for instrument packaging. The two DCS cameras were flown

37 times in FY06, in support of SMD research, which included an AVIRIS deployment to Puerto Rico. The POS-AV units flew 48 times, supporting missions on the Altair, J-31, B200, and Cessna Caravan. This utility hardware is available for community use via the Flight Request process.

Instrument Calibration

The ASTL Calibration Laboratory is a community resource that is co-funded by the Suborbital Science and EOS programs. It performs NIST-traceable spectral and radiometric characterizations of remote sensing instruments. Recent additions to the lab include a precision transfer radiometer for calibrating radiometric sources, and a high-temperature cavity blackbody. The lab also provides portable radiance sources (integrating hemispheres) and a portable ASD spectrometer to support field experiments. Instruments utilizing the lab this year included the AATS-14 and SSFR radiometers, MAS, MASTER, AMS, and the NASA/UND Space Station AgCam, and AeroCam systems.



MASTER data acquired on 25 September, 2006 over Yellowstone National Park. This a mosaic of twelve parallel geo-referenced flight lines, draped over a USGS Digital Elevation Model, and is a statistical representation of five spectral bands ranging from 11.0um to 0.55um.

EARTH SCIENCE PROJECTS OFFICE

Michael Craig, ESPO Director

Program Support: NASA, Suborbital Science Program, Cheryl Yuhas

Project Management

The NASA Earth Science Project Office (ESPO) provides project management services and support for large, complex, national and international research missions.

ESPO is supported by the NASA Science Mission Directorate (SMD) Research Programs. The team has provided exceptional science mission planning, project implementation and post mission support for scientific field campaigns internationally for over 20 years.

In order to ensure the best overall success, each mission is tailored to the specific needs of the research program. From the development of the mission's concept, to the publication of the results, ESPO provides unique cost-effective campaign support unequaled by other project management organizations. ESPO assists the Program Manager in managing all the project activities while it provides all the necessary communications and infrastructure support to complete any mission objectives.

NASA DC-8 on Sal Island, Cape Verde. USAF C-17 arrives in the background with NAMMA project equipment.

In recent years the Earth Science Project Office has been in very high demand. Research missions are becoming more and more complex as agencies and universities combine resources and assets to answer more complex questions about the Earth's system. In 2006 alone, ESPO managed six different highly successful missions in over a dozen different locations worldwide. These included the Costa Rica Aura Validation Experiment (CR-AVE), the Megacity

Forecast/Flight planning meeting to discuss the science objectives before a DC-8 flight.

Initiative: Local and Global Research Observations (MILAGRO), the second Intercontinental Chemical Transport Experiment (INTEX-B), the Intercontinental and Mega-city Pollution Experiment (IMPEX), the CALIPSO-CloudSat Validation Experiment (CC-VEX) and the NASA African Monsoon Multidisciplinary Analyses (NAMMA) missions.

Currently, the ESPO group is in the detailed planning stages for two large upcoming international NASA missions including the Tropical Composition, Cloud and Climate Coupling (TC4) mission in Central America and the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) mission.

Program Support

Although ESPO mission management support is available to all of the NASA Science Mission Directorate Focus Areas, current customers include:

- The Upper Atmospheric Research Program (UARP)
- The Atmospheric Chemistry Modeling and Analysis Program (ACMAP)
- The Atmospheric Dynamics and Remote Sensing Program (ADRSP)
- The Radiation Sciences Program (RSP)
- The Tropospheric Chemistry Program (TCP)
- The Suborbital Sciences Program (SSP), and
- The Earth Observing System Program (EOS)

Other federal agencies ESPO has supported include Department of Energy (DOE), Environmental Protection Agency (EPA), National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS), National Center for Atmospheric Research (NCAR), National Scientific Balloon Facility (NSBF), and the Naval Research Laboratory (NRL). ESPO has worked with over seventy universities and has a vast experience working with the U.S. State Department, the Federal Aviation Administration, the U.S. Air Force, the U.S. Navy, and hundreds of commercial companies world-wide.

To ensure that NASA's Suborbital Science Program (SSP) mission has the best overall outcome, ESPO plays a vital role in the direction of the program through the Airborne Science Office at Ames. The team helps collect the science requirements for the program through their field experience and the management of the Suborbital Flight Request System. ESPO oversees any transitions of aircraft and instruments without loss of capabilities and plays a critical role in the development of new uses of Uninhabited Aerial Systems (UAS) and sensor web technologies.

The goal of ESPO is to provide the necessary support to meet all program, project and investigator requirements with the most efficient use of resources and to share the exciting results of our missions with the general public through direct interactions, press coverage and educational outreach.

Web site: http://www.espo.nasa.gov

NASA WB-57 takes off from San Jose, Costa Rica during an Aura Satellite Validation mission.

APPENDIX A:
2006 DIVISION PUBLICATIONS

Journal Articles

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