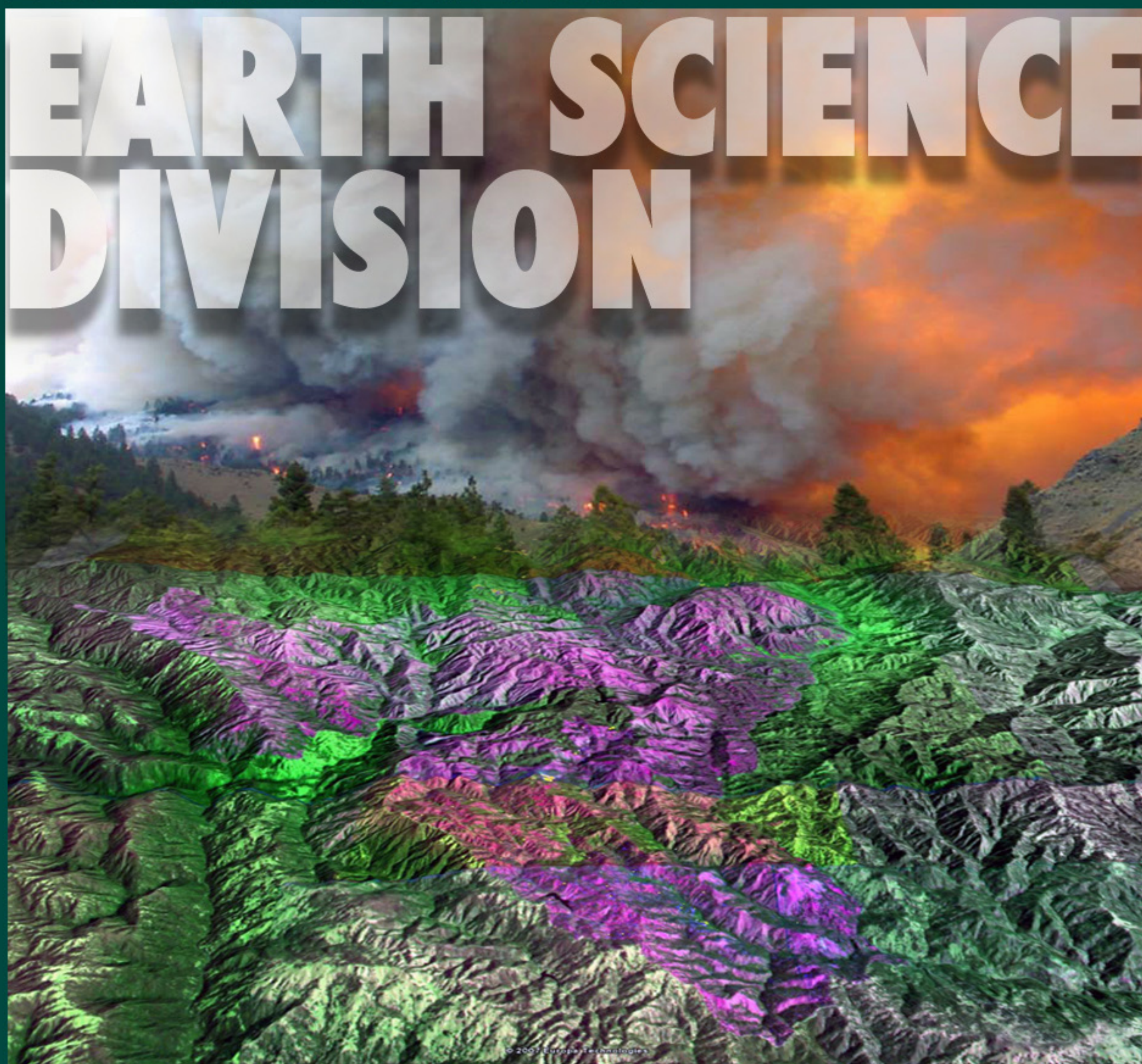
NASA AMES RESEARCH CENTER

2007 ANNUAL REPORT

EARTH SCIENCE DIVISION



National Aeronautics and Space Administration

NASA Ames Research Center

Earth Science Division

2007 Annual Report

http://www.earthscience.arc.nasa.gov

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Division Overview

R. Stephen Hipskind
Division Chief

Earth is a dynamic planet. During the last century we came to understand that the changes occurring on Earth result from natural processes affected by human activities. The new challenge in Earth Science is to better understand the physical and biological systems supporting life on Earth, how these systems change through natural variation and human impact, and how to use this understanding to mitigate change while planning for its consequences.

NASA's goal in Earth science, ".... to study the Earth from space to advance scientific understanding and meet social needs" determines how NASA employs its unique capabilities to address the fundamental challenges of Earth science.

The Earth Science Division in the Science Mission Directorate at NASA Headquarters is the organization assigned responsibility to meet the Agency's Earth science goals. The Division accomplishes its task through programs in research and applied science that develop and test new tools and techniques for observing the Earth from space; applying these observations to better understand fundamental Earth processes at global and regional scales; and using these observations and their research conclusions to benefit society by enhancing decision making in a world of rapid and unanticipated change.

Six focus areas comprise NASA's Earth science research program: climate change and variability, carbon cycle and ecosystems, Earth surface and interior, atmospheric composition, weather, and water and energy cycle. In support of these research areas, the Earth Science Division develops, launches and operates research instruments on spaceborne and airborne platforms; maintains data systems and archives to generate data products from the observations that are available to the research community and the public; and develops and applies models combining NASA observations with other data for greater insight on fundamental Earth processes and better prediction of future change.

The data from this robust Earth science research directly informs the Division's Applied Sciences Program. This program, in partnership with other federal agencies and user organizations, uses NASA's unique Earth science capabilities to enhance decision making processes related to agriculture, ecosystems, air quality, climate, disaster management, water resources, public health and weather.

The organizational structure for Earth science at NASA Headquarters is mirrored at Ames Research Center where the Ames Earth Science Division is part of the Center's Science Directorate. The Earth Science Division at Ames supports the Agency's Earth science goals and objectives through a vigorous program in atmospheric and biospheric studies, extending a long Ames heritage in Earth observations and analysis in research and applied science.

The Division's areas of expertise include the merging of airborne and satellite based observations, numerical modeling, laboratory studies related to the physics, chemistry and biology of remote sensing, and development of remote sensing instrumentation and information systems. This expertise is used in projects supported primarily through proposals awarded in competitive solicitations. Earth science research topics at Ames include 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 Earth and other bodies in the solar system. The Division applies the knowledge from Earth science research and supporting technology to applications used by partner organizations.

The Division is NASA's lead organization, through the Ames Earth Science Project Office, for managing Earth science field campaigns: multi-agency and multi-center efforts that often involve international partners at sites across the globe. Finally, Earth science at Ames is committed to educational outreach.

Motivated, talented and experienced professional staffs are the basis for the success of the NASA Earth science program. At Ames, Earth scientists and technical personnel design, develop and perform remote sensing and in situ experimental measurements, conduct computer simulations of atmospheric and ecosystem processes to understand exchanges between the biosphere and the atmosphere using data from airborne and satellite platforms, and conceive and develop advanced instrumentation to satisfy NASA Earth science measurement requirements. Project managers and project scientists provide science mission management and science leadership for major Earth science programs at NASA and partner agencies. Staff scientists enhance applications utilizing proven and new technology, and work within NASA programs and policies to transfer NASA Earth science capabilities to commercial enterprises, national and international government agencies and ministries, and educational institutions.

THE EARTH SCIENCE DIVISION AT AMES SUPPORTS THE AGENCY'S EARTH SCIENCE GOALS AND OBJECTIVES THROUGH A VIGOROUS PROGRAM IN ATMOSPHERIC AND BIOSPHERIC STUDIES THAT EXTEND A HERITAGE IN EARTH OBSERVATIONS AND ANALYSIS IN RESEARCH AND APPLIED SCIENCE.

NASA encourages a competitive environment in Earth science research to stimulate innovation in the NASA community and the broader research community. In response to this encouragement, the Earth Science Division in 2007 adopted an approach to Earth science research and applied science emphasizing three elements: maintaining broad involvement of Division staff in the research and applied science solicitations from NASA Headquarters, increasing emphasis on reimbursable projects at Ames (i.e., projects sponsored by other U.S. agencies and commercial interests), and collaborating with the Ames small satellite initiative to assure that Earth science has opportunities for new observations on such platforms. The Division believes these three elements will assure a healthy and competitive Earth science program at Ames, will contribute to the Agency's national and international goals, and will make federal capabilities available to beneficiaries at local and regional levels.

This report summarizes the accomplishments of the NASA Ames Research Center Earth Science Division during calendar year 2007. The Division achieved significant progress, with some projects making news at national and international levels. Included are the results of projects from all elements of the Division: the Atmospheric Science and Biospheric Science Branches, the Atmospheric Science and Technology Lab, and the Earth Science Project Office. Projects and tasks are described separately and linked to the elements of NASA's overall Earth science program. A point of contact is listed for each project or task. 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 (SGG) conducts research to advance the scientific knowledge and understanding of the processes that determine the behavior of the Earth's atmosphere. 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 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 of these had 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: CO, N_2O, and CH_4. Cadenza and its latest version Aero3X 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. Carbon monoxide By Attenuated Laser Transmission (COBALT) is an autonomous instrument based on off-axis integrated cavity output spectroscope to measure CO in the troposphere and tropopause. Branch member also collaborates 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.

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 for Science, Exploration Systems, and Aeronautics

THE ATMOSPHERIC SCIENCE BRANCH CONDUCTS RESEARCH TO ADVANCE THE SCIENTIFIC KNOWLEDGE AND UNDERSTANDING OF THE PROCESSES THAT DETERMINE THE BEHAVIOR OF THE EARTH'S ATMOSPHERE.

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.

- 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 Measurement 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, Space Bioscience Division, Small Spacecraft, and Exploration Technology), we have enjoyed collaborative programs worldwide.

Our NASA collaborators are NASA Headquarters, NASA Goddard Space Flight Center, NASA Langley Research Center, NASA Dryden Flight Research Center, NASA Johnson Space Center, NASA Glen Research Center, NASA Marshall Space Flight Center, 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, National Oceanic and Atmospheric Administration (NOAA), Pacific Northwest National Laboratory (PNNL) (Richland, WA), Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, DOE Sandia National Laboratories (Livermore, CA), Office of Naval Research, U.S. Environmental Protection Agency (EPA), and the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS).

Academic collaborators are University of Colorado, University of California Berkeley, University of California Davis, University of California Los Angeles, University of California San Diego, Scripps Institution of Oceanography, University of California Santa Cruz, Stanford University, Harvard University, University of Illinois, University of Denver, Colorado State University, Randolph-Macon University, Carleton College, University of Washington, Georgia Institute of Technology, San Jose State University, Pennsylvania State University, Santa Clara 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 (ORAU).

Lockheed Martin Palo Alto Advanced Research Center, Computational Physics Inc., Northrop Grumman Corp., Los Gatos Research, Inc., Novawave Technologies, Inc., SPEC 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, Germany's Forschungszentrum Julich, University of Cambridge, and Universite Pierre et Marie Curie, Paris.

Our researchers are recognized for their outstanding scientific contributions and expertise: Co-Project Scientist for the 2008 Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) campaign, NASA P-3B Platform Scientist for ARCTAS, WB-57 Co-Platform Scientist for the 2007 Tropical Composition, Cloud, and Climate Coupling (TC4) campaign, Executive Editor for the Journal of Atmospheric Environment, Editorial Board member of the International Journal of Global Warming, Editorial Board member of the Journal of Aerosol Science, and member of the Sunnyvale Green Ribbon Citizens Committee (Sunnyvale, CA) to provide recommendations to the Sunnyvale mayor and city council on how best to meet the provisions of the Mayor's Climate Protection Agreement to reduce greenhouse gas emissions to 7% below 1990 emission levels by 2012.

We are members of international science committees, national science teams, review panels, and planning communities: participant in the Intergovernmental Panel on Climate Change (IPCC), 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, Co-Chair of the 2007 Gordon Research Conference (GRC) on Radiation and Climate, Chair of a session on Biogenic Hydrocarbons and the Global Atmosphere at the 2007 Gordon Research Conference (GRC) on Biogenic Hydrocarbons and the Atmosphere, session organizers and Chairs for the 2007 AGU Fall Meeting, and session Co-Chairs for the 2007 MILAGRO/INTEX-B Science Conference in Mexico City.

We are also mentors to various educational and public outreach programs: NASA Postdoctoral Program (NPP); NASA DEVELOP Program intern science advisors; graduate student advisors; high school student intern mentors; presenter to K-12 students at the Stanbridge Academy, San Mateo, CA; presenter in the Tech Time for Girls program sponsored by the Girls Scouts of Santa Clara County; 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:

A Sample of Significant Scientific Results

- We have shown that the ice concentrations measured in the tropical tropopause layer (TTL) thin cirrus are far lower than nucleation theory predicts. This finding has important implications for TTL cirrus optical properties and their ability to dehydrate air entering the stratosphere.

- Analysis of measurements from the Solar Spectral Flux Radiometer (SSFR) and the 14-channel Ames Airborne Tracking Sunphotometer (AATS-14) show that the aerosol absorption can be approximated with an exponential power law with different aerosol materials having different ranges of exponents.

- A study of the reaction of methanol with nitric acid in aqueous solutions shows the exponential dependence of the reaction rate on the wt% of H_2SO_4 in solution, implicating NO_2+ as the nitrating agent and highlighting the strong dependence of methyl nitrate production on aerosol composition, and thus on the environmental temperature and relative humidity.

- We developed an algorithm to determine the frequency of mid- and high-latitude fire plumes penetrating the tropopause. This technique utilizes enhanced aerosol index (AI) from various satellites.

Missions and Experiments

- In 2007 the Earth Science Project Office (ESPO) successfully managed the NASA Tropical Composition, Cloud, and Climate Coupling (TC4) field campaign. This was a large, international experiment with participation from multiple research organizations. The mission focused on understanding the tropical tropopause transition layer (TTL): its composition and processes occurring in the region.

The Atmospheric Science Branch involvements listed below were multifaceted and important to the success of the experiments:

* Project management
* NASA WB-57F Co-Platform Scientist
* Chief Project Meteorological Forecaster
* Argus in-situ measurement system Principal Investigator
* Meteorological Measurement System (MMS) Principal Investigator
* Radiosonde observation (Ticosonde) Principal Investigator
* Solar Spectral Flux Radiometer (SSFR) Co-Principal Investigator
* Diode Laser Hygrometer (DLH) Co-Investigator

• The Argus instrument team successfully participated in the Department of Energy Atmospheric Radiation Measurement Program (ARM) Cloud and Land Surface Interaction Campaign (CLASIC) to advance the understanding of how land surface processes influence cumulus convection. Argus instrument provided continuous CO and CH_4 measurements.

• The Atmospheric Radiation Instrumentation Group supported the operation of the Shortwave Spectroradiometer (SWS) at the Atmospheric Radiation Measurement Climate Research Facility (ACRF) located in the Southern Great Plains (SGP) site in Oklahoma. The SWS is a moderate resolution sensor for the measurement of absolute visible to near infrared spectral radiance of the atmosphere directly above the instrument.

New Technologies

• Toward the development of an airborne Spectrometers for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR), the Sunphotometer-Satellite Group has been testing key technologies on a ground-based prototype. 4STAR will extend the capabilities of the NASA Ames Airborne Tracking Sunphotometer (AATS-14) while permitting its operation on a wider range of airborne platforms including unmanned aerial system (UAS).

• 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) Unmanned Aerial System (UAS). It is designed to carry experimental payloads up to 100 lbs. for testing, evaluation, and demonstration. The SIERRA UAS project achieved a major milestone in mid-October 2007 with its first radio-controlled flight.

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

ARGUS Airborne Laser Spectrometer

In situ measurements of the atmospheric tracers carbon monoxide (CO) and methane (CH4) in the troposphere and lower stratosphere

PI: Max Loewenstein

Supporting programs:
- *NASA Upper Atmosphere Research Program, Science Mission Directorate*
- *DOE Lawrence Berkeley National Lab*

Program Manager: Mike Kurylo

The mission of the Argus group at Ames is to provide key atmospheric composition information as a part of NASA airborne campaigns that study atmospheric chemistry, dynamics and cloud microphysics. During 2007 the group participated in the NASA TC4 and the DOE CLASIC missions discussed below. Argus measurements of CO and CH_4 provide critical chemical and dynamical data as a part of multi-instrument and multi-aircraft research missions.

The Argus instrument, operational since 1996, is a unique Ames and NASA asset providing important data contributions to major atmospheric research missions. Argus is a 2-channel, infrared spectrometer employing wavelength modulated tunable diode lasers. Atmospheric data is acquired, in situ, in the second-harmonic mode at a 0.5 Hz rate and is subsequently analyzed using a Marquardt-Levenberg algorithm to fit the second harmonic spectra to theory and derive CO and CH_4 mixing ratio time series along the flight path. A current, central effort of the group is to improve the quality and precision of CO data returns, these data being then folded into analysis and interpretations of atmospheric processes under specific 'Mission' study.

Fig. 1: WB-57 in flight.

TC4 Research Campaign

The NASA Tropical Composition, Cloud and Climate Coupling (TC4) field campaign of July/August 2007 involved three research aircraft: DC-8, ER-2 and WB-57 (Fig. 1) to study the tropical atmosphere from a deployment base in San Jose, Costa Rica, 10 degrees North latitude. The main objectives of the field campaign were to: study the transition region between the tropical troposphere and lower stratosphere; elucidate the chemistry and dynamics of this region; and acquire data on the microphysics of large scale cirrus outflows from tropical convective cumulus towers. Three aircraft platforms, flying at different altitudes, sampled large convective systems with the ER 2 carrying radiation sensors at high altitude, the WB-57 carrying a complement of chemical and particle sensors at intermediate altitudes and the DC-8 carrying chemical, lidar and particle sensors at lower altitudes. Meteorologists, employing an advanced ground station, guided and managed overlays of the aircraft flight tracks with satellite weather images. Interpretation of the very large data set acquired in TC4 is ongoing with a major interpretive workshop planned for spring 2008.

The Argus CO airborne infrared spectrometer, measuring CO and CH_4, participated in the campaign on the WB-57 aircraft. CO measurements provide a tracer of air motions and a sensitive marker of the transition from the troposphere to the stratosphere. CO in the boundary layer source region is transported upward in rapidly evolving tropical cumulus towers. The CO is then distributed horizontally near the tropopause in cirrus anvils spreading from the tops of these towers and vertically by slow ascent into the lower stratosphere.

CO data taken during TC4 flights will be analyzed along with other measurements such as ozone, water vapor, ice water content in clouds, and carbon dioxide to provide interpretations about the details of air motions within the transition layer and vertically through the transition layer into the lower stratosphere.

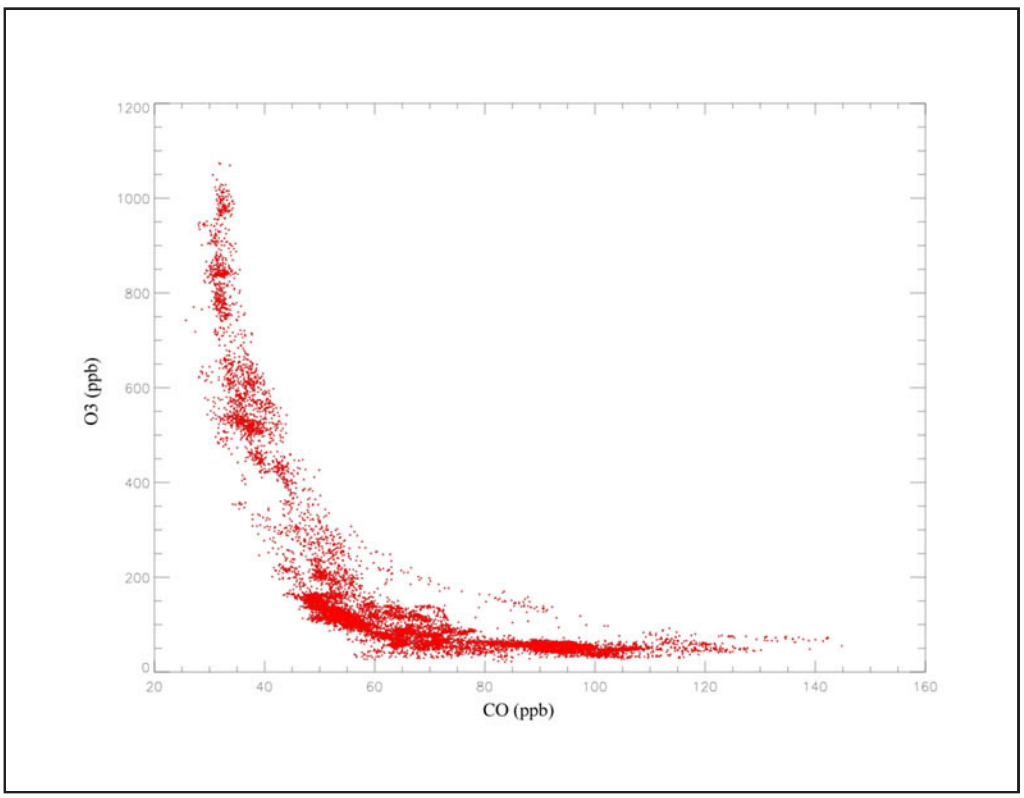


Fig. 2: Plot of CO:O3 from a previous airborne campaign that illustrates canonical correlation between the two species.

Fig 2 (page 11) shows a plot of CO:O_3 for one flight from a previous airborne campaign illustrating a 'canonical' correlation between these species. Deviations from this relationship can be used to identify processes occurring in the tropical transition layer and in cirrus anvils advecting from cumulus towers.

CLASIC Research Campaign

In June 2007, as part of the US Department Of Energy (DOE) Atmospheric Radiation Measurement (ARM) Program, the Cloud and Land Surface Interaction Campaign (CLASIC), took place in the Southern Great Plains (SGP) of the United States to estimate land-atmosphere exchanges of CO_2, water, and energy at 1 to 100 km scales. The primary goals of this campaign were to evaluate top-down and bottom-up regional fluxes and to understand the influence of moisture gradients, surface heterogeneity, and atmospheric transport on these flux estimates. In addition, CLASIC strived to advance the understanding of how land surface processes influence cumulus convection, an important component in the atmospheric radiation budget and hydrologic cycle of the SGP, particularly during the summertime growing season. Human induced changes in the land surface structure associated with plowing, crop rotation, and irrigation can induce changes in the surface latent heat flux, sensible heat flux, albedo, and carbon flux. Changes in surface energy balance and moisture transport to the boundary layer influence cloud processes, thus create a feedback loop.

In order to understand the carbon cycle during these processes, a Twin Otter aircraft (Fig. 3) carried precise CO_2, CO, and CH_4 continuous measurement systems, and 14C, radon, and NOAA 12-flask (carbon cycle gases and isotopes) packages. Flights were planned to constrain simple boundary layer budget models and to conduct Lagrangian air mass following experiments. The Argus instrument provided the continuous CO and CH_4 measurements on the Twin Otter aircraft.

Fig. 3: Twin Otter aircraft.

Plans for 2008 include:

- Participating in data interpretive workshops for TC4 and CLASIC,
- Proposing to NASA call to participate in TC4: Guam campaign in 2009, and
- Participating in NOVICE WB-57 new instrument campaign in Houston (NASA JSC).

CALIPSO

AND OTHER A-TRAIN AEROSOL OBSERVATIONS TO STUDY THE VERTICAL STRUCTURE OF AEROSOL RADIATIVE EFFECTS

PI: Jens Redemann

Supporting Program:
NASA Earth Science Research, Atmospheric Radiation Program
Program Manager: Hal Maring

The information obtained by combining lidar aerosol backscatter profiles with auxiliary aerosol data has been studied for more than a decade. In this project, we combine passive and active spaceborne aerosol observations for an estimation of the vertical structure of direct aerosol radiative effects using CALIPSO, MODIS and other A-Train satellite data.

Airborne data, collected in recent field experiments by a combination of an airborne UV-DIAL lidar system and an airborne sunphotometer, will serve as a test-bed for techniques to derive aerosol radiative properties. The combination of airborne lidar and sunphotometer data flying on separate aircraft will serve as a surrogate for the combination of CALIPSO and MODIS measurements within the A-Train. In a second step, we will transfer our knowledge of how to best combine the aerosol backscatter and optical depth (AOD) data to the space-borne sensors CALIPSO and MODIS. Finally, we intend to derive the vertical profile of shortwave, direct aerosol-induced radiative flux change.

NASA unique capabilities and assets employed in the project: NASA EOS observations by CALIPSO, MODIS & other A-Train satellite instruments; NASA Ames Airborne Tracking Sunphotometer, AATS-14; NASA Langley DIAL system.

Accomplishments in 2007

The CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) instrument aboard the CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) satellite has been acquiring data as part of the A-Train constellation of satellites since June of 2006.

A complete level 1B data set and a limited set of level 2 data products have been publicly available since December 2006. As of December 2007, the level 2 data products have been augmented to include aerosol optical depths and extinction profiles. In conjunction, the MODIS-Aqua level-2 data set, MYD04, is readily available for essentially all days in orbit since June of 2002 and provides column integrated aerosol observations at a spatial resolution of 10x10km at nadir.

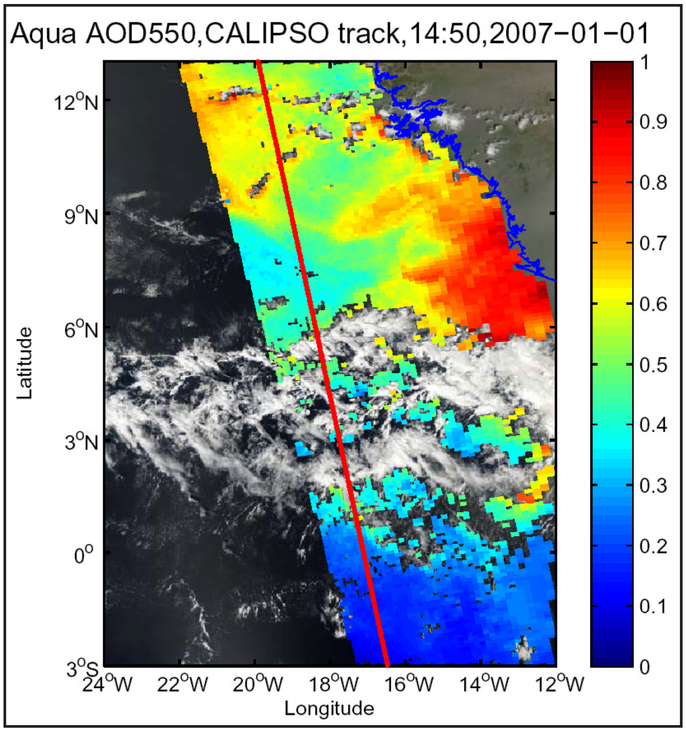


Fig. 4: MODIS RGB image acquired near the West coast of Central Africa on Jan. 1, 2007. MODIS retrievals of aerosol optical depth are overlaid where available (away from clouds), as is the CALIPSO satellite ground track.

Figure 4 shows a MODIS RGB image acquired near the West coast of Central Africa on Jan. 1, 2007. MODIS retrievals of midvisible aerosol optical depth (AOD) are overlaid where available (away from clouds), as is the CALIPSO satellite ground track. As a first step towards investigating the cloud masking techniques for the two different instruments, Figure 5 shows the standard MODIS cloud mask product, MOD35, for the same scene. From this figure it is apparent that only some of the areas with valid AOD retrievals are indicated as “confidently clear” by the standard MODIS cloud mask. Figure 3 shows a further comparison between MOD35, the spatial variability-based cloud mask used in the MODIS AOD retrieval algorithm (here indicated as std3x3) and the cloud layer product derived from CALIPSO backscatter data at three different vertical resolutions (red: 0.33km; magenta: 1km, black: 5km).

Objectives in 2008

After further cloud screening comparisons similar to those in Figure 6, we will examine the agreement between MODIS and CALIPSO derived aerosol optical depth (AOD) to investigate whether cloud screening techniques have a major impact on AOD retrievals.

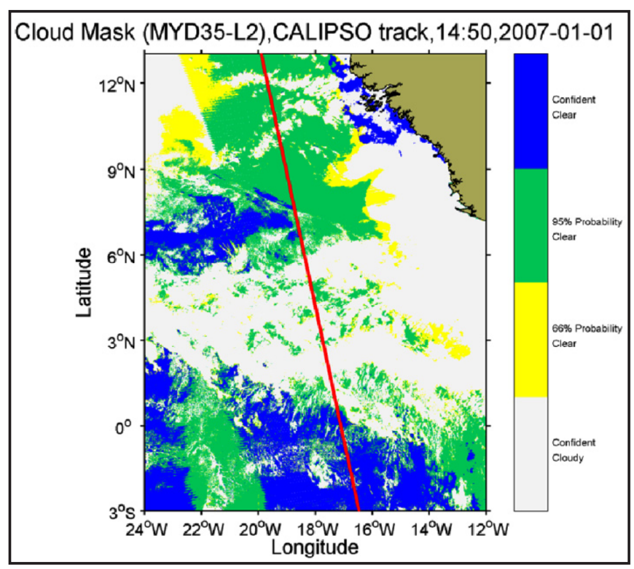


Fig. 5: Standard MODIS cloud mask (MOD35) for the scene shown in Figure 4.

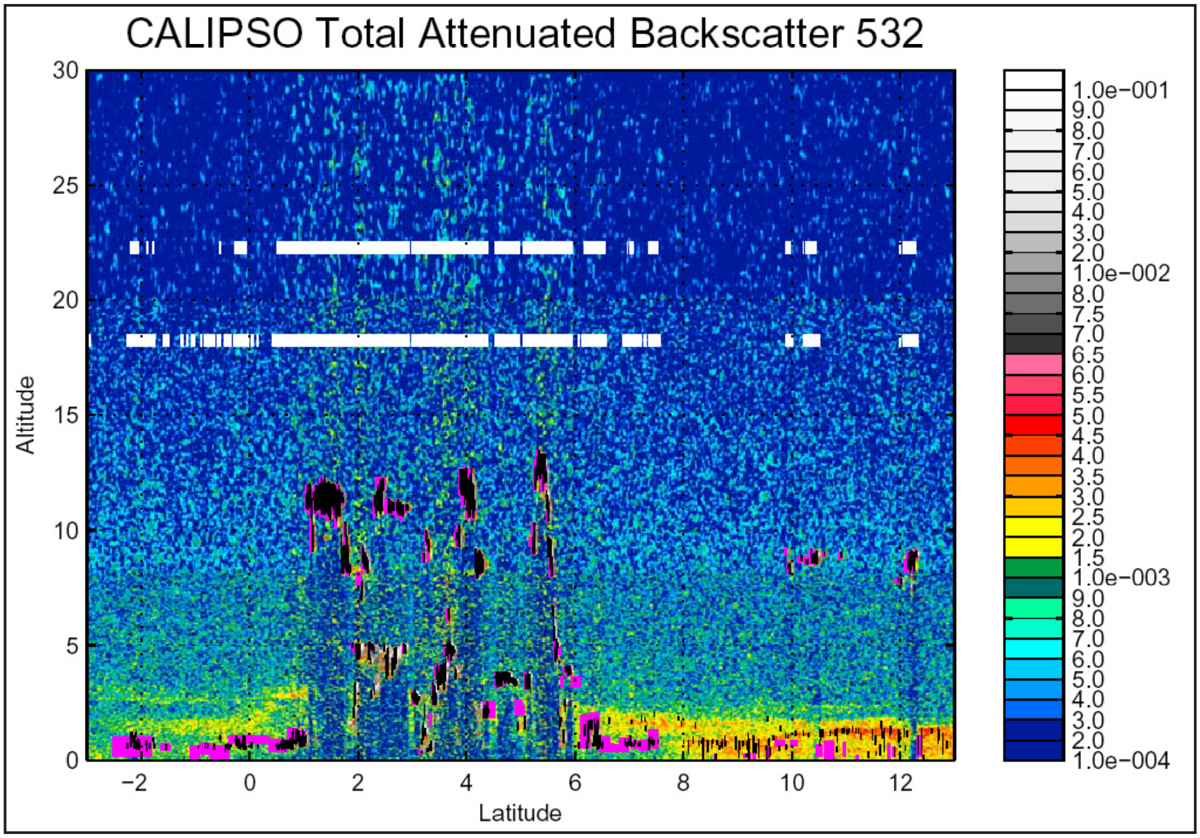


Fig. 6: Curtain plot of CALIPSO-derived total attenuated backscatter (at 532 nm) along the CALIPSO ground-track shown in red in Figures 1 and 2, with indications of MODIS and CALIPSO cloud screening results overlaid (see text).

Convection and Circulation
During the TC4 Experiment

Co-PIs: Leonhard Pfister
Henry Selkirk

Supporting Programs:
NASA Upper Atmosphere Research Program
Program Manager: Ken Jucks

The Tropical Clouds Chemistry Climate Coupling Experiment (TC4), conducted in summer 2007 in Costa Rica with three NASA aircraft, was designed to answer the following basic science questions:

(1) What are the properties of cirrus clouds and cirrus anvils in the tropics, how do they evolve with time, and what are their effects on climate and the stratosphere?; and

(2) How does convection redistribute chemical constituents within the troposphere and the tropical tropopause layer?

Answers to both of these questions have important implications for global climate change and for the ozone layer.

An important part of the experiment is providing meteorological guidance, both during and after the mission. A small, international team of meteorologists, led by the Co-PIs, guided the mission. The team included professional meteorologists from the Costa Rican Meteorological Service, a modeling group from the University of Costa Rica, and scientists from Colorado University and NOAA. The task was to evaluate possible meteorological hazards to the aircraft and to identify suitable targets for scientific investigation by the aircraft. This included forecasting the location of convection that might generate cirrus clouds, as well as other aspects of the circulation that would affect the distribution of chemical constituents.

The post-mission task is to understand the overall tropical circulation that provides a context for the chemical measurements, the distribution of convection and its effects, and the role of small and mesoscale motions in cloud formation. The work is ongoing, but several results have already emerged. Figures

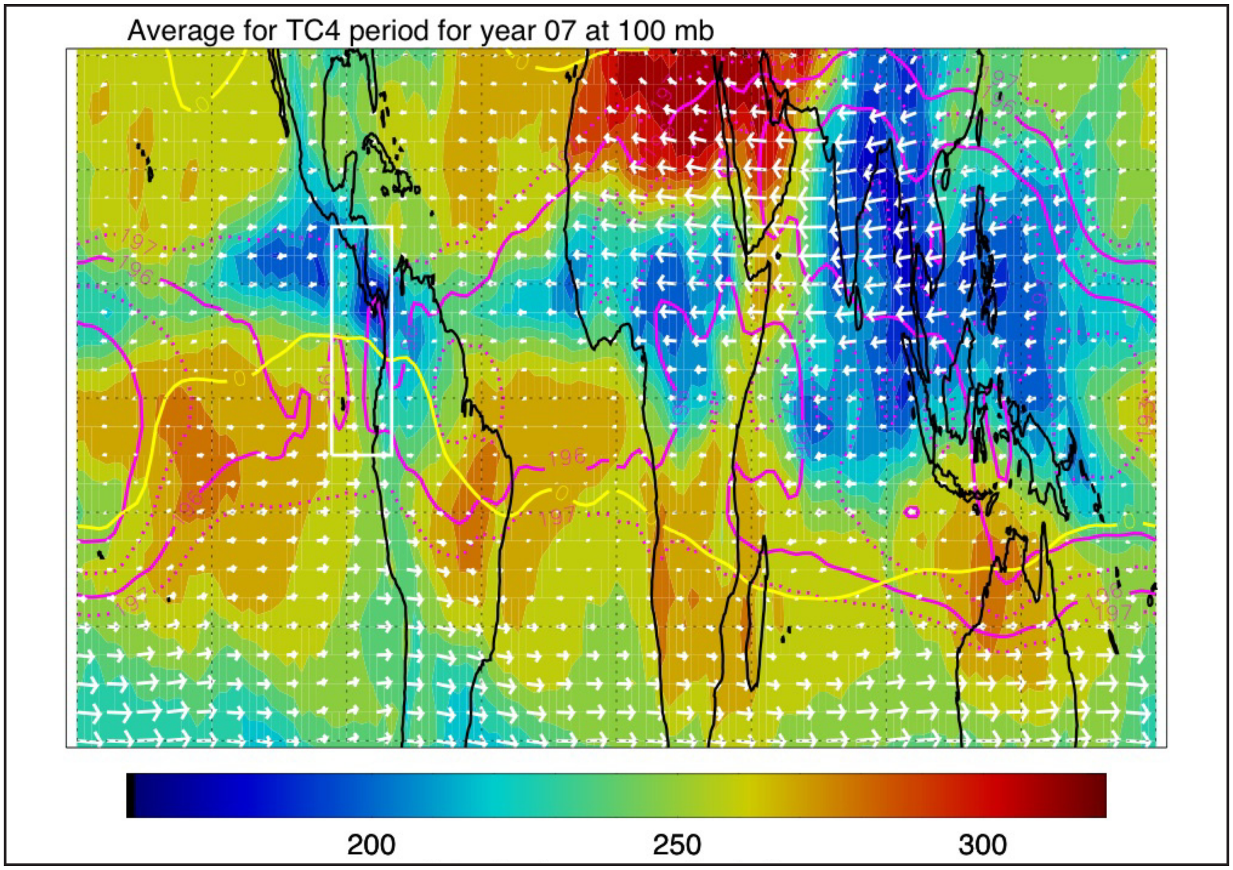


Fig. 7: Global circulation during the TC4 period in 2007 at the cloud top level. The shading shows the incidence of cold and high cloud tops, with blue regions indicating a high incidence of clouds and thunderstorms. Magenta contours are temperature, showing the coldest regions over southeast Asia. White wind vectors show air traveling from these cold regions toward the experimental region near Costa Rica (white rectangle). The yellow line is the boundary between winds from the west and winds from the east.

7 and 8 show the global circulation near the tops of tropical clouds, both for the period during the mission, and for the same period during other years. The figures show clearly that Costa Rica is in a convectively active region that is downstream of a much larger and colder convectively active region over south and southeast Asia.

The post-mission task is to understand the overall tropical circulation that provides a context for the chemical measurements, the distribution of convection and its effects, and the role of small and mesoscale motions in cloud formation. The work is ongoing, but several results have already emerged. Figures 7 and 8 show the global circulation near the tops of tropical clouds, both for the period during the mission, and for the same period during other years. The figures show clearly that Costa Rica is in a convectively active region downstream from a much larger and colder convectively active region over south and southeast Asia.

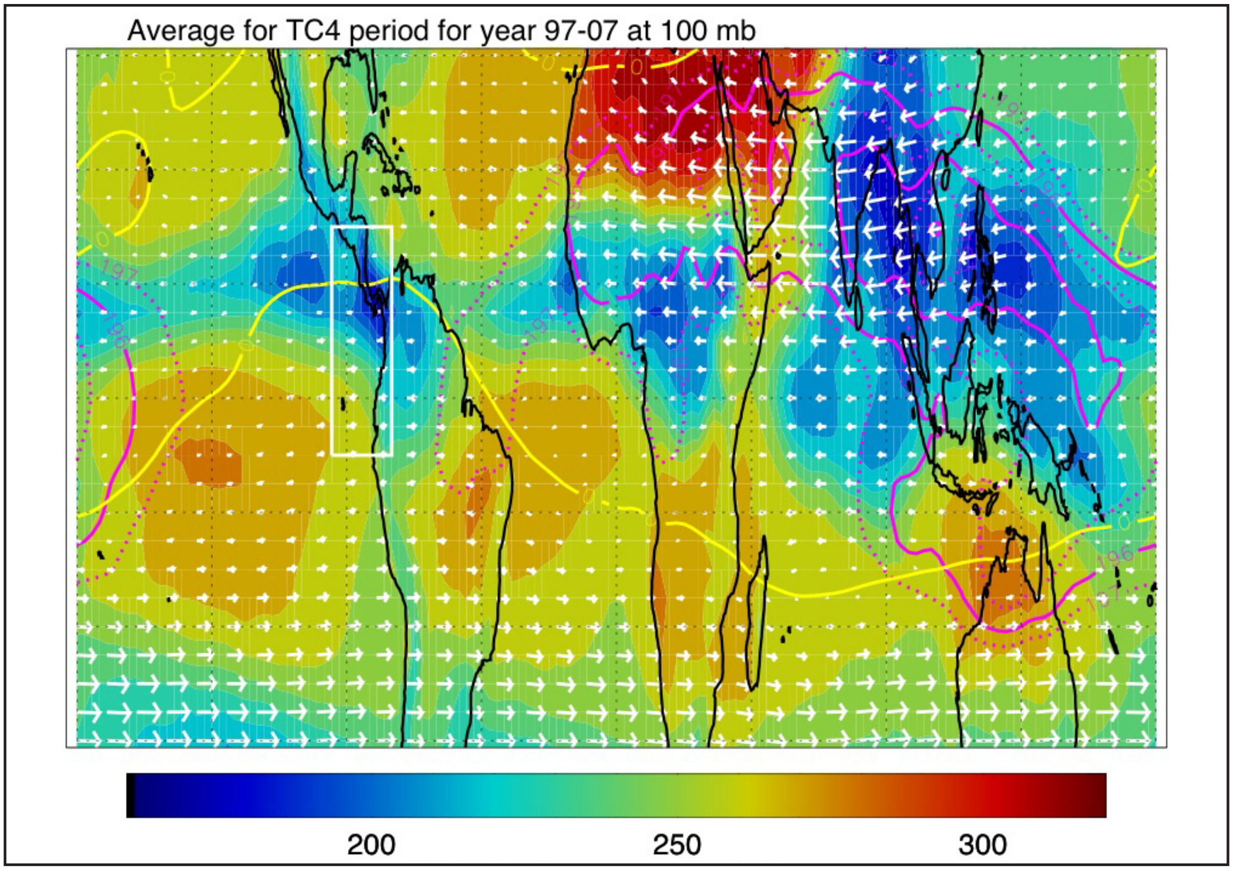


Fig. 8: As in Figure 7, except for a multiyear average. The situation is similar as for 2007, except that temperatures in the Costa Rica region are warmer, and winds are more from the west than during 2007.

Above the convective cloud tops, the Costa Rica region is warmer than regions upstream. The implication is that we might expect relatively few clouds above the convective cloud tops because moisture has been "wrung out" upstream. The comparison with other years shows that summer 2007 was colder than normal, with a stronger westward flow towards Costa Rica than usual. Another finding is that convection in the Costa Rica region was somewhat weaker than in a typical year, probably due to cold sea surface temperatures in the eastern Pacific (La Nina conditions).

Figure 9 (page 20) shows the locations of convection that influence the air in a particular region (the outlined black square) during the TC4 period. This, along with the time since convection, is important in understanding both the chemical composition and the water vapor distribution at the bottom of the ozone layer. The figure shows that, as altitude increases, remote convection becomes increasingly important in affecting the air over the Panama Bight south of Costa Rica. The steady westward circulation shown in Figures 7 and 8 allows convection in Africa and South Asia to influence the air we observe over Panama.

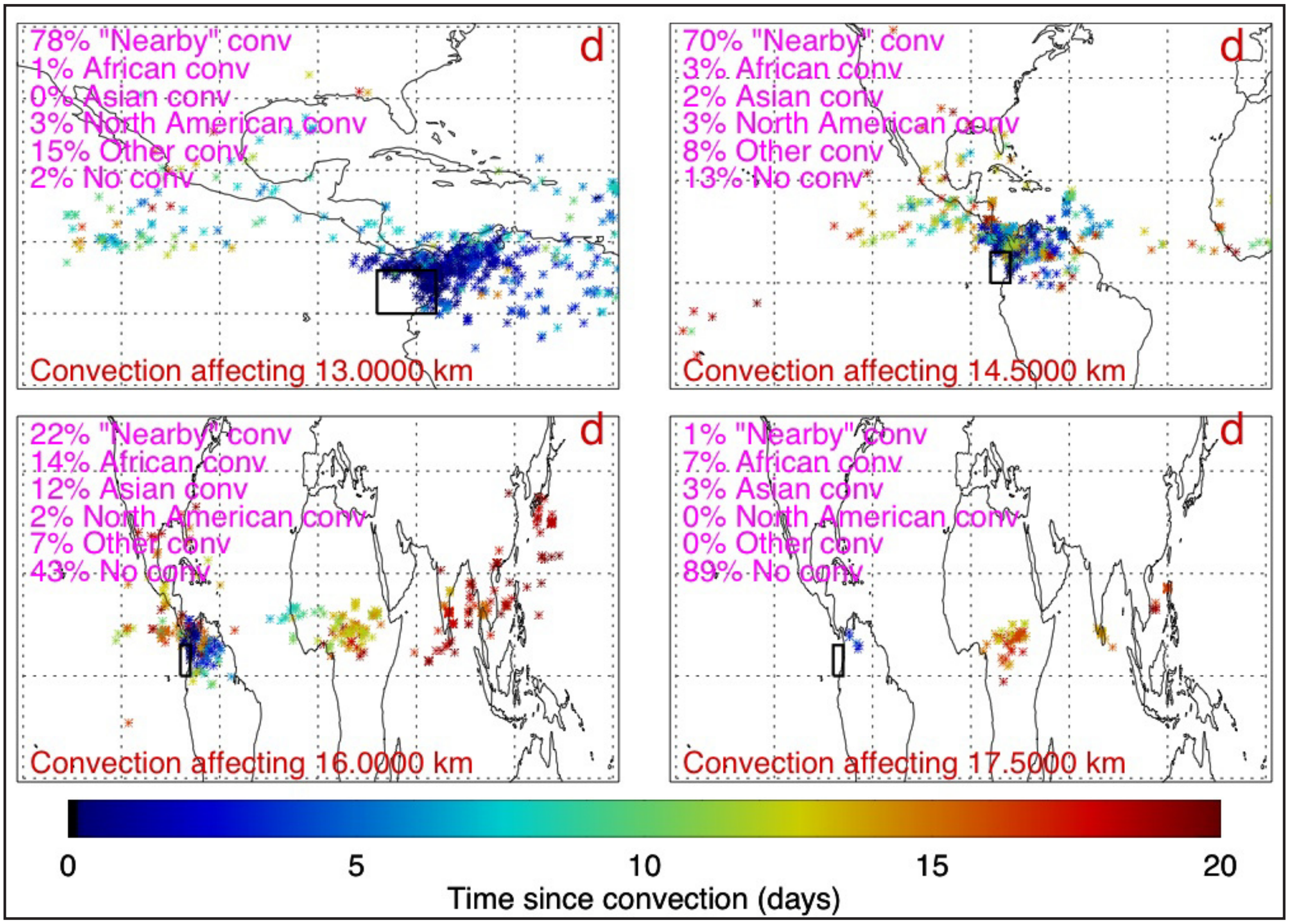


Fig. 9: Locations of convection whose outflow affects the Panama Bight region south of Costa Rica (black square) during TC4 as a function of altitude. Asterisks indicate the location of the convection, and their colors indicate the transit time between the convection and the arrival of the air in Central America.

Tropospheric Remote Sensing and Air Pollution

PIs: Robert Chatfield
Vance Fong
EPA Region 9

Supporting Program:
Environmental Protection Agency, Air Chemistry Modeling and Analysis Program
EPA Program Managers (Custodial): Rangasayi Halthore and Earnest Hislenrath

This line of investigation sought to identify the most useful NASA technology to inform air pollution agencies about smog-layer ozone. The best current technology describes the larger-scale aspects, such as lower tropospheric ozone that influences smog ozone via upwind boundary conditions. However, nose-level ozone remains elusive.

We evaluated various techniques using NASA's Ozone Monitoring Instrument and the Microwave Limb Sounder, both of which are instruments on the EOS-Aura satellite. Extensive comparisons with balloon-borne ozone soundings suggested that a computer-model assimilation technique made good use of the satellite information to define lower tropospheric layers. Another technique that produced a whole tropospheric column rather than a layer-by-layer structure proved surprisingly useful for boundary-condition ozone in the lower troposphere, but of little value for hour-by-hour near-surface ozone concentrations. Why the statistics of the whole-tropospheric-column ozone are so useful remains to be fully explored. The ozone products used were developed at NASA GSFC and have recently been described in the *Journal of Geophysical Research* (I. Stajner, M. Schoberl, et al.). Earlier research on the long-distance movement of tropospheric ozone, that combined ozone sondes and remote sensing, was published in 2007, and another publication has been submitted.

Tropospheric Remote Sensing

We are investigating a technology that is fully sensitive to smog-layer ozone that lies in the micro-windows of the infrared spectrum and between the major absorbers. Radiation in the 3.58 and 3.27 micron regions of the infrared, just short of the major thermal-radiation regions, has unit sensitivity to every ozone molecule, no matter what altitude in the atmosphere. The traditional ultraviolet wavelength (0.31 micron) measurements (used for the Total Ozone Mapping Spectrometer and the Ozone Monitoring Instrument, mounted on satellites) are quite insensitive to the smog layer. Nevertheless, the combination of the ~3-micron and the ~0.3 micron technologies can describe smog-layer ozone by differentiating between measurements. The challenge has been to raise the precision of the ~3 micron measurement to approach the precision of the well-studied ~0.3 micron technique. We are working with Lockheed-Martin's Advanced Technology Center (John Kumer and Aidan Roche) on this methodology and on an instrument incubator program. Two working field prototype instruments tested by Lockheed Martin are passing all sensitivity and resolution checks in a timely manner.

This technology was advocated in a letter to the National Research Council and was published as part of their Decadal Survey of space technology for remote sensing for the Earth Sciences. In 2007, Chatfield presented the ideas at the NOAA Global Monitoring Division (Boulder), Harvard University, and the Goddard Space Flight Center, leading to a presentation at NASA Headquarters.

Heterogeneous Chemistry of Upper Troposphere/Lower Stratosphere Organics

The effect of Cloud Cycling on Aerosol Properties

PI: Laura Iraci

Supporting Programs:
NASA Earth Science Research, Atmospheric Composition
Program Managers: Ken Jucks, Michael Kurylo, James Crawford, Hal Maring

This laboratory project studies the composition of aerosol particles in the upper troposphere and lower stratosphere (UT/LS), evaluates cloud processing as a source of variability in aerosol chemistry and behavior, and provides information about potential chemical feedbacks in the cloud formation process. By examining the uptake of soluble organics and their fate within particles, our results will reduce uncertainty regarding the cloud nucleation behavior of mixed aerosols. This, in turn, will reduce one aspect of the uncertainty which currently limits the prediction of the indirect climate effects of aerosol particles.

The long-term goals of our research program are to understand the organic trace composition of UT/LS particles and to explore how the chemistry of sulfate/organic aerosols and atmospheric chemical processes influence the climate system. In this study we examine the uptake, reaction, and photolysis of oxygenated organic compounds in aqueous solutions with compositions ranging from that of strongly acidic stratospheric sulfate aerosols to very dilute cloud droplets. A variety of laboratory techniques are employed, including infrared and UV-vis spectroscopy and mass spectrometry.

A new experimental apparatus has been designed and assembled, allowing us to irradiate solutions representative of a wide variety of atmospheric particles.

Many organic compounds that have been either observed or proposed to exist in atmospheric aerosols have significant UV-visible absorption cross-sections in the atmospheric window. Thus, photo-initiated reactions of these compounds may be important sinks for particle-phase reactants as well as sources of new organic products in both the particle and gas phases. Currently, relatively little is known about the chemical fate of most organic compounds that absorb UV-visible radiation in the condensed phase, especially under the highly acidic conditions typical of sulfate aerosols in the upper troposphere and lower stratosphere. In 2007, our group designed and built a new apparatus to examine the solution-phase photolysis of organic materials representative of atmospheric aerosols. Preliminary results identified several chemical changes upon irradiation of various organic compounds in aqueous and sulfuric acid/water solutions relevant for atmospheric aerosol particles and cloud drops.

As shown in Figure 10, exposure to UV-vis radiation has opposite effects on aqueous and sulfuric acid solutions of methylglyoxal. Upon irradiation with a Xe solar simulator lamp, water solutions show a decrease in the 275nm absorption peak, indicating a loss of the monohydrate and/or polymers. In contrast, irradiation of a 50 wt% H2SO4 solution leads to increased UV-vis absorption, potentially indicating an increase in the monohydrate and/or polymer forms. (This work was presented at the Fall 2007 AGU meeting, poster A11A-0042.)

A related long-term study is in progress to explore the formation of surface films on aqueous, acidic solutions containing aldehydes. We observed very reproducible formation of self-assembled films on the surface of acidic solutions containing aldehydes such as propanal. These resilient films were highly colored, and their formation has definite temperature and acidity dependences. Thus, formation of such a surface film may depend critically on the temperature history of UT aerosols, and aerosols exposed to different temperature and relative humidity conditions may demonstrate differing behavior. Furthermore, these films appear to be degraded by exposure to simulated solar radiation, suggesting that their composition, and potentially their stability, can be affected by sunlight. (Spring 2007 AGU meeting, poster A41C-05)

Because ambient aerosols contain a wide variety of trace organic compounds, many of which participate in well-known reactions in acidic solution at room temperature, we have performed a set of survey experiments to determine which functional groups are most important for forming low volatility products under atmospheric conditions. We found that ethanol and formaldehyde each enhances the uptake of acetaldehyde into 40 wt% H2SO4, likely due to the formation of acetal reaction products. In 71 wt% H2SO4, however, ethanol enhances the solubility of acetaldehyde by ~100x, but no reaction is observed; addition of acetone increases the solubility of acetaldehyde by ~10x. When acetone is present in H2SO4/H2O solution, ethanol reacts upon uptake. The standard "resistor model" mathematical treatment for first-order kinetics does not describe our data well, and future work will study the underlying causes of this discrepancy. (Fall 2007 AGU meeting, poster A21E-0799)

This year, we completed a study of the reaction of methanol with nitric acid in aqueous solutions that is summarized in the *Journal of Atmospheric Chem*istry (58: 253-266). The main finding of this work is the exponential dependence of the reaction rate on the wt% of H_2SO_4 in solution, implicating NO_2^+ as the nitrating agent and highlighting the strong dependence of methyl nitrate production on aerosol composition, and thus on the environmental temperature and relative humidity.

In the coming year we will complete our study of the solar irradiation of solutions of methylglyoxal and will evaluate similar processes for other organic solutes. In parallel, we will explore the effect of dilution on the chemical state and reactivity of oxygenated organics, as an aerosol particle takes up water and grows into a cloud drop.

Given the growing understanding of the fate of CFC replacement compounds, we will also study the role of fluorinated, oxygenated organic compounds in aerosol chemistry. In particular, we will examine the solubility and reactivity of trifluoroacetic acid and compare and contrast it with the behavior of acetic acid.

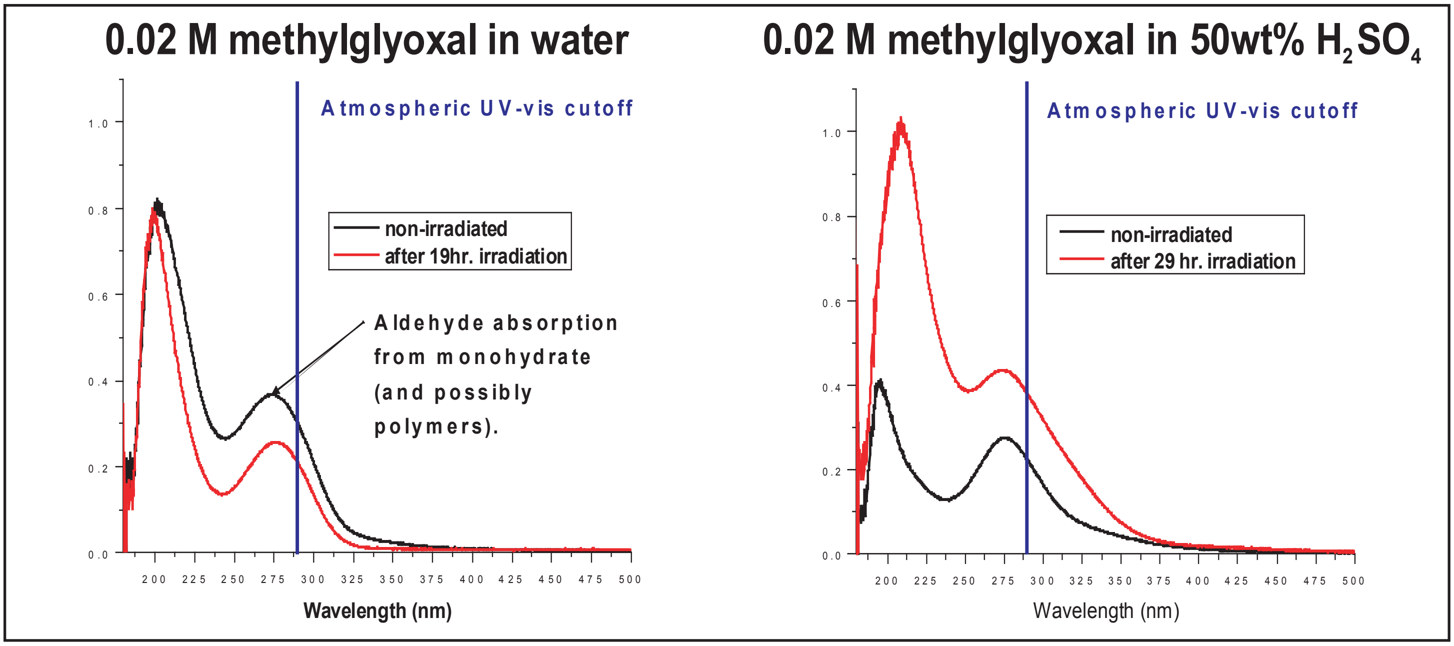


Fig. 10: UV-visible absorption spectra for solutions of methylglyoxal in water (left) and in an aqueous sulfuric acid solution (50:50 by weight). Black spectra taken at the start of each experiment; red spectra taken after the solutions were irradiated with a solar simulator for 19 and 29 hours, respectively.

Measurement of Solar Spectral Irradiance

in support of the 2007 Tropical Composition, Cloud, and Climate Coupling (TC4) Experiment

Co-PI: Warren Gore

Supporting Programs:
NASA Radiation Science Program
Program Manager: Hal Maring

During the 2007 Tropical Composition, Cloud, and Climate Coupling (TC4) experiment in Costa Rica the Solar Spectral Flux Radiometer (SSFR) team from NASA Ames Research Center and the University of Colorado measured the upwelling and downwelling solar (visible and near-infrared) spectral irradiance above and below cirrus cloud systems using the SSFR on both the NASA ER-2 and DC-8 platforms. We use these data to quantify the tropical radiative energy budget, to relate cloud radiation to ice crystal size and shape, to derive cloud thermodynamic phase, optical thickness, effective particle size, and ice water path, and to assist in the validation of satellite sensors, specifically the Moderate Resolution Imaging Spectrometer (MODIS) and its airborne counterpart, the MODIS Airborne Sensor (MAS). Our long term goal is to advance our understanding of how tropical convective cloud systems alter the deposition and transport of solar radiation in the atmosphere.

The SSFR is a moderate resolution flux (irradiance) spectrometer.

- Wavelength range: 380 nm to 2200 nm
- Spectral resolution: ~8-12 nm
- Simultaneous zenith and nadir viewing
- Hemispheric 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

From July 17, 2007 to August 8, 2007, the NASA ER-2 and DC-8 each flew eleven science flights out of Costa Rica. Many of these flights were coordinated among the two aircraft as well as with satellites. The SSFR acquired valuable data in every flight.

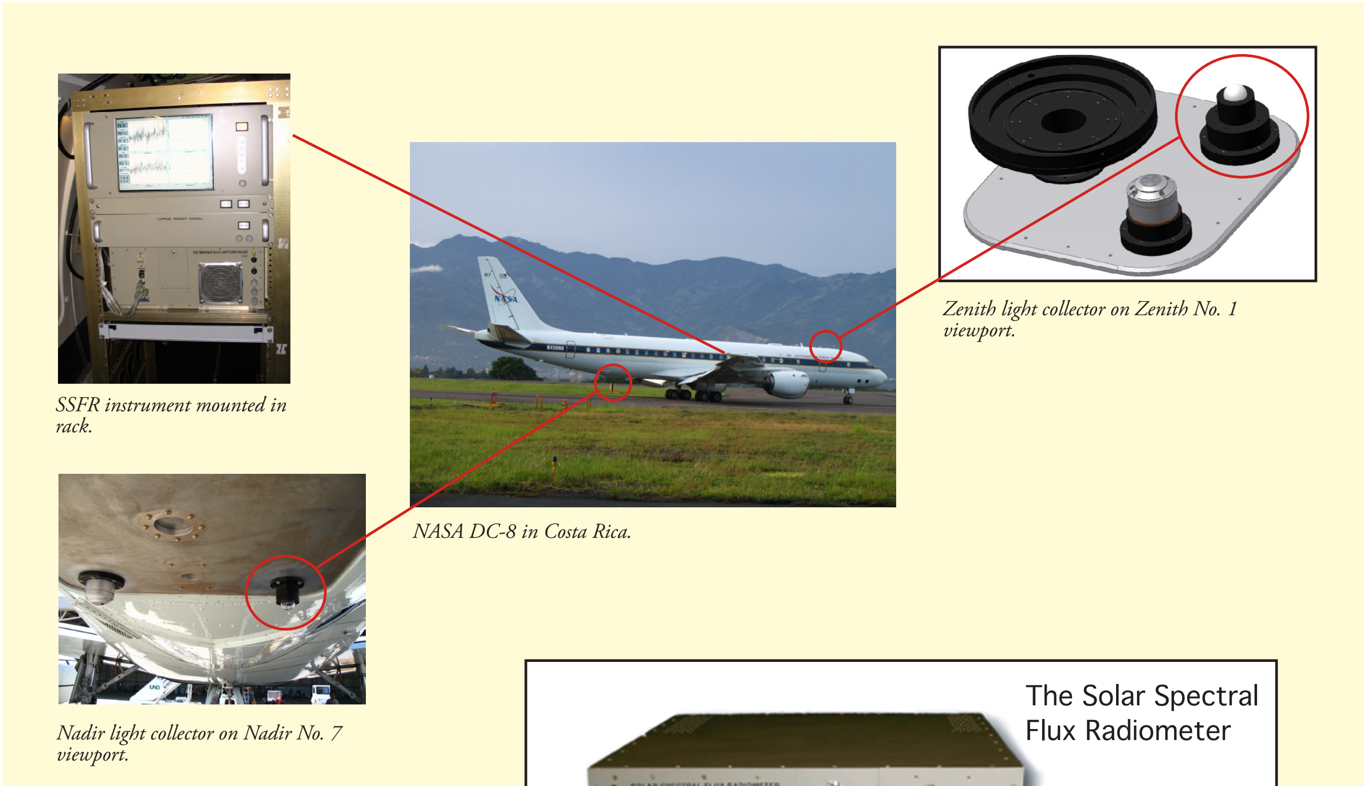
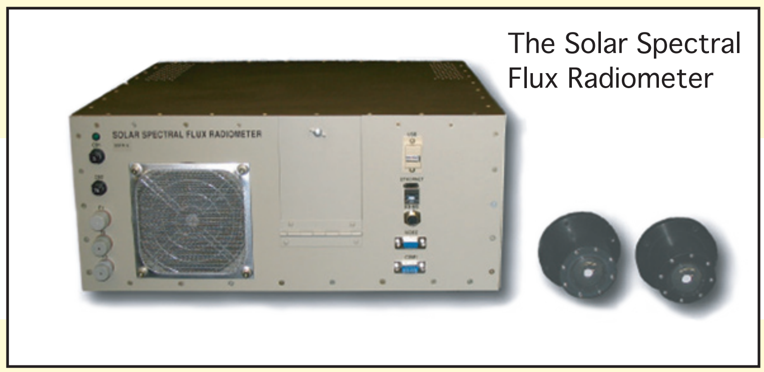


Fig. 11: SSFR as part of payload on NASA DC-8 during TC4.



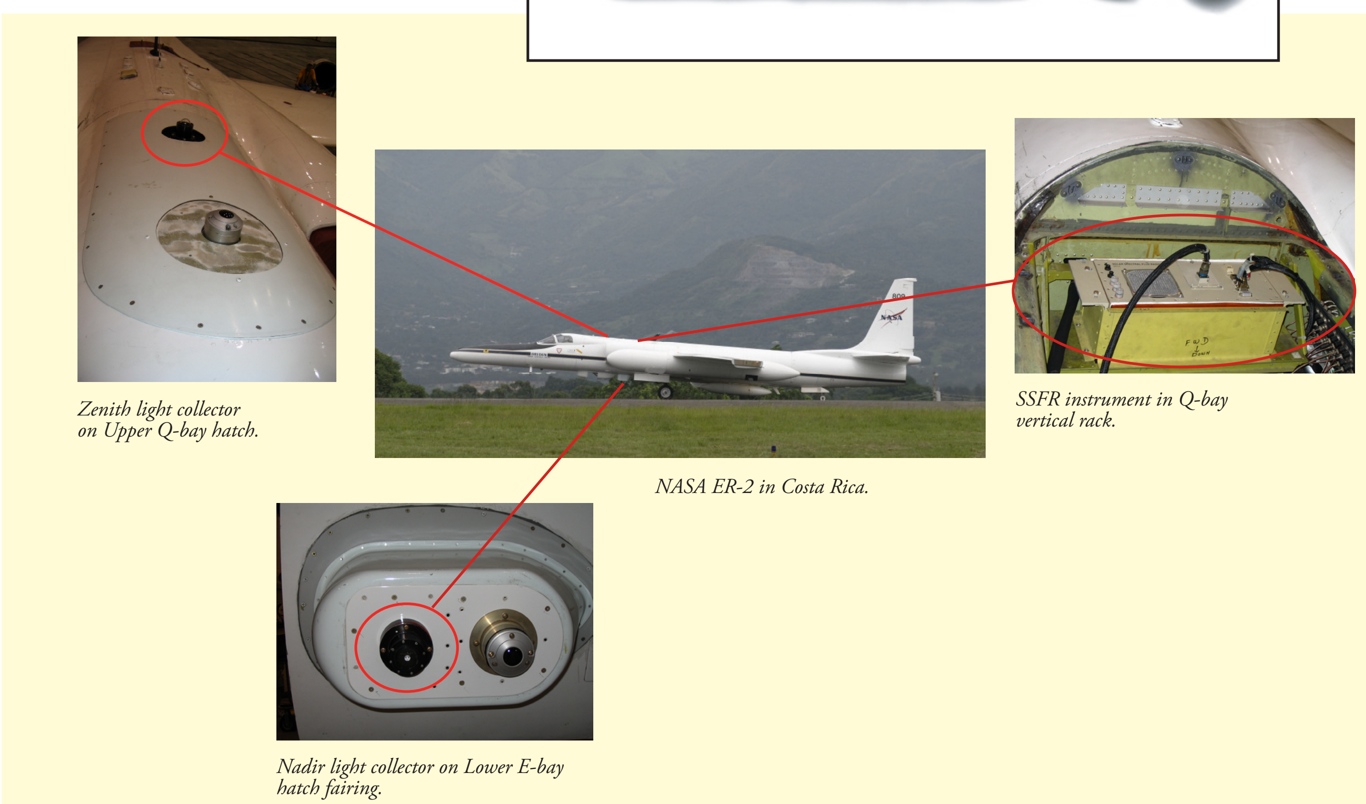


Fig. 12: SSFR as part of payload on NASA ER-2 during TC4.

Multi-Instrument Study of Effects of Boreal Forest Fires

On The Global Upper Troposphere and Lower Stratosphere

PI: Jimena Lopez

Supporting Program:
NASA Earth Science Research, Atmospheric Composition
Program Managers: Ramesh Kakar, Ernest Hilsenrath

Increases in the extent and severity of biomass burning activity and severity have been observed since the 1950s. Further increases, driven by climate change, are expected. Recent remote sensing and *in situ* observations show that highly polluted, smoke-laden air from these fires can be injected into the upper troposphere and even the stratosphere, where it can remain for weeks. These plumes contain aerosols and greenhouse gases that have the potential to affect the radiative balance of the atmosphere and the formation of ozone. Due to atmospheric transport mechanisms, these effects can extend beyond the local to regional, and even trans-continental, scales. The global significance of this transport has not previously been assessed.

Biomass burning, the burning of forests and other vegetation initiated by natural or manmade events, results in the release of large quantities of combustion products including particulate matter and greenhouse gases. Through convection and atmospheric transport, biomass burning plumes travel across the globe, affecting air quality and altering the atmospheric composition far from the original source. While biomass burning occurs on a relatively small spatial scale, the combined emissions from fires worldwide have the potential to alter the chemical and radiative balance of the atmosphere affecting the global climate.

We currently lack quantitative data on the total mass of aerosols and gases deposited to the upper troposphere/lower stratosphere (UTLS) from biomass burning. This project will develop tools to recognize and measure incidences of biomass burning transport, with the future goal of using these techniques to quantify the amount and chemical composition of biomass burning emissions. Ideally we hope to develop an algorithm that will identify biomass burning signatures and their effects automatically, without doing case studies. The case studies are currently being used to develop that algorithm.

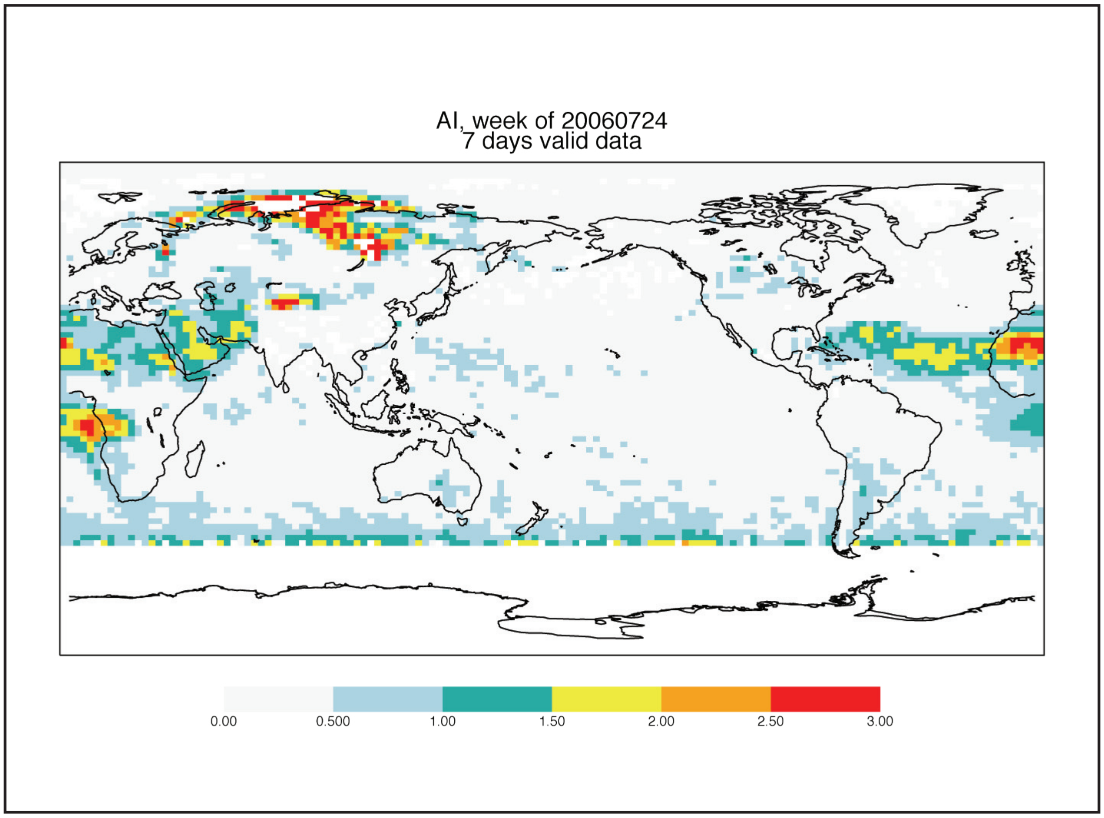


Fig. 13: OMI aerosol index values for the week of July 24, 2006. Areas in red indicate elevated AI in Siberia.

Currently we pursue case studies of boreal forest fires using available satellite data. First, we look at OMI or TOMS aerosol index data to find potential biomass burning plumes. We identify plumes that result in high aerosol index (AI) values (at or above 5). Next we look at MODIS fire products for the time period that a plume is first observable to verify that there was fire activity in that region. If there are no fires in the region at the time, it may be that the aerosol plume is not due to biomass burning, but industrial pollution or a volcano. It may also be high AI transported from a fire elsewhere. For some fires, ground observations and news reports are available to link an aerosol plume to a fire and provide further insight into a plume's geographical origin.

Once we are fairly certain we are looking at a biomass burning plume, we need to get an estimate of the vertical extent of the plume. We use CALIPSO data for this purpose, when available. The altitude of an aged plume may be higher or lower than the initial altitude over the fire, so we run back trajectories, when necessary, to determine the initial injected height while verifying that the aged plume originated from the suspected region. By comparing the estimated maximum altitude to a skew-T diagram from the region and time where the maximum occurred, we can determine if the plume reached the upper troposphere, the lower stratosphere, or neither, a some point in its trajectory. To assess transport and it effects, we may look at other pieces of information such as carbon monoxide and ozone measurements.

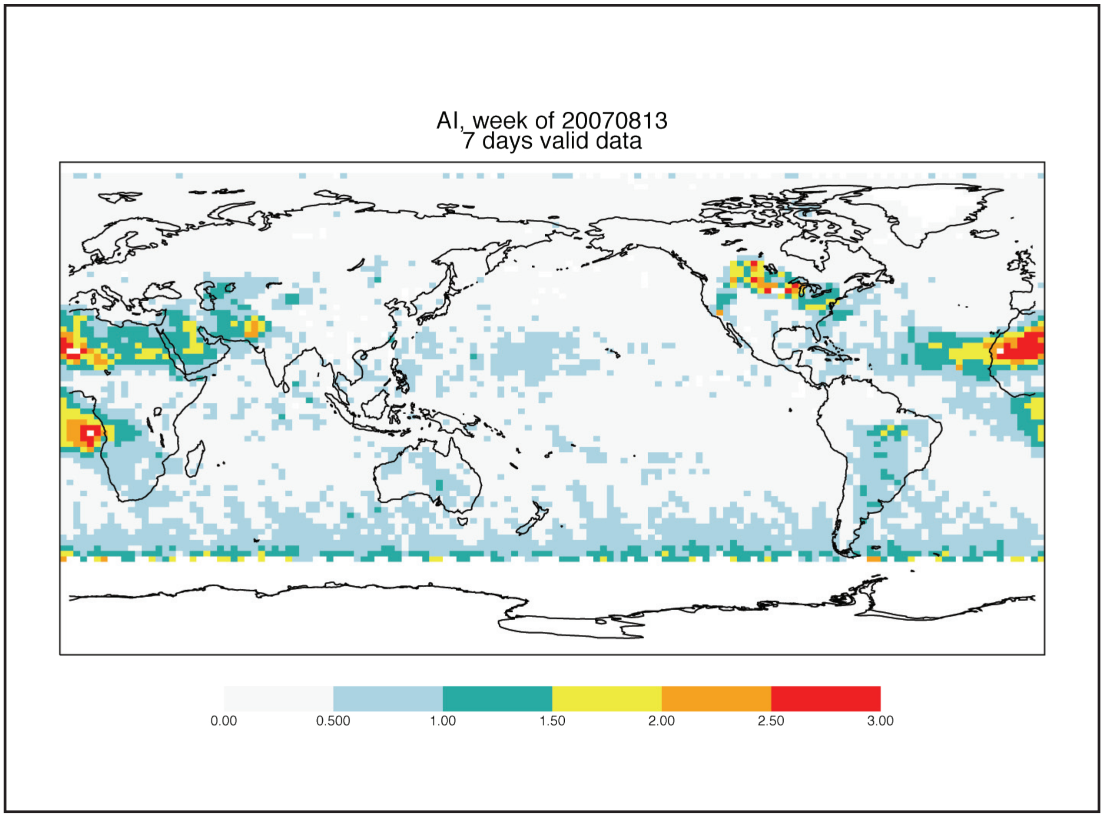


Fig. 14: OMI aerosol index values for the week of August 13, 2007. Areas in red indicate elevated AI over western Africa.

Unique NASA capabilities and assets employed in the project include the satellite instruments TOMS, TES, MLS, CALIPSO, MISR, MODIS, MOPITT, and AIRS.

Progress and accomplishments in 2007:

- We determined how often mid- and high latitude fire plumes penetrate the tropopause, using enhanced AI from various satellites.
- We investigated multiple past events and developed an historical climatology of these injections of biomass burning effluent to the upper troposphere/lower stratosphere See Figures 13 and 14 for weekly averaged AI on 2 different years and weeks.
- We calculated a running average of the frequency of high AI to elucidate any long term trends in AI.

Objectives in FY08:

- Cross-compare aerosol products, to identify most valuable signatures. This includes cloud-top temperatures and pressures to determine how deep into the stratosphere these fire injections have reached.
- Study the composition of the large plume injections (including chemistry).
- Devise screening procedure for smaller injections using diluted signatures identified from the large fires
- Continue investigation of AI on new fires

NASA AMES RESEARCH CENTER's

METEOROLOGICAL MEASUREMENT SYSTEM

PI: *T. Paul Bui*

Co-PIs: *Stuart W. Bowen*
Cecilia Chang
Jonathan Dean-Day
Leonhard Pfister

Supporting Programs and Managers:

- *NASA Upper Atmosphere Research Program*
  Program Manager: Michael J. Kurylo
- *NASA Radiation Sciences Program*
  Program Manager: Hal Maring
- *NASA Atmospheric Dynamics Program*
  Program Manager: Ramesh Kakar

An accurate characterization of turbulence phenomenon is important to understand dynamic processes in the atmosphere such as the behavior of buoyant plumes within cirrus clouds, diffusion 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.

The Meteorological Measurement System (MMS) instrument is specifically designed and developed to make science quality measurements of the state variables on atmospheric research platforms. The long-range goal is to further the understanding of atmospheric chemistry and dynamics through the advancement of the measurement technology.

The MMS provides high-resolution and accurate meteorological parameters (pressure, temperature, turbulence index, and the 3-dimensional wind vector). The MMS consists of three major systems: (1) an air motion sensing system to measure the air velocity with respect to the aircraft, (2) an aircraft motion sensing system to measure the aircraft velocity with respect to the earth, and (3) a data acquisition system to sample, process and record the measured quantities.

The MMS is uniquely qualified to investigate atmospheric mesoscale (gravity and mountain lee waves) and microscale (turbulence) phenomena. 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. The MMS has operated successfully on the NASA DC-8, ER-2, and WB-57F.

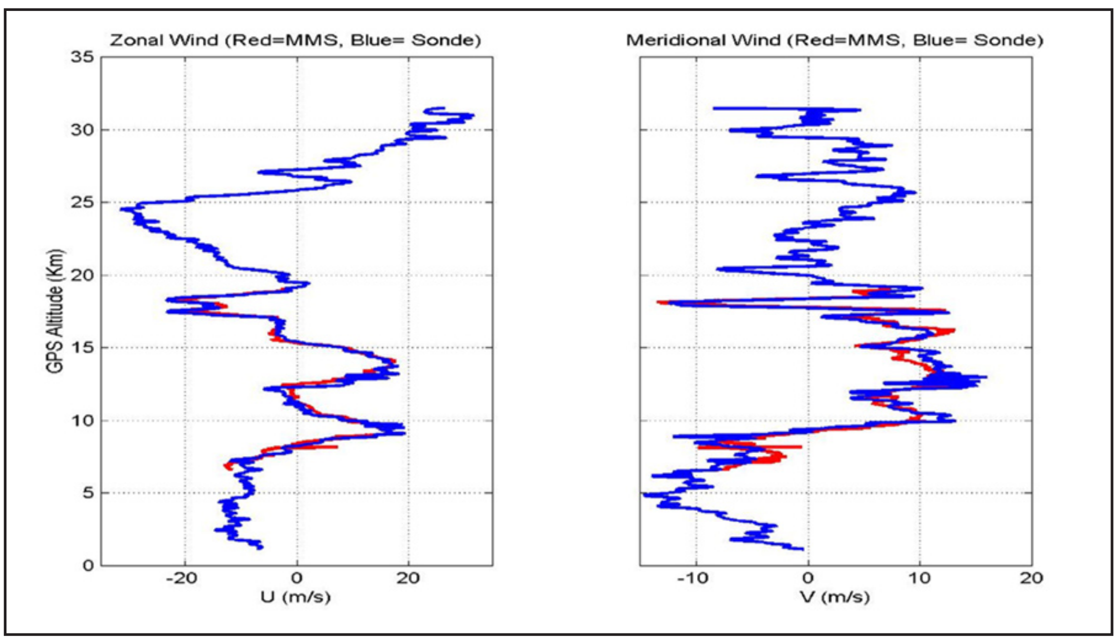
The MMS has successfully participated in major NASA field missions: STEP in 1987, AAOE in 1987, AASE I in 1989, AASE II in 1991-1992, SPADE in 1992-1993, ASHOE/MAESA in 1994, SUCCESS in 1996, STRAT in 1995-1996, SONEX in 1997, POLARIS in 1997, SOLVE in 2000, CAMEX-4 in 2001, CRYSTAL-FACE in 2002, MidCix in 2004, AURA Validation Experiment in 2005 & 2006, NAMMA in 2006, and TC4 in 2007.

During FY2007, MMS accomplished the following milestones:

- Re-processed and archived calibrated MMS data from NASA African Monsoon Multidisciplinary Activities (NAMMA) in Cape Verde.
- MMS participated with both the WB-57F and DC-8 platforms in the Tropical Composition, Cloud, and Climate Coupling Experiment (TC4) in Costa Rica, summer 2007
- Generated and submitted preliminary field data during TC4.

Objectives in FY2008:

- Re-process and archive calibrated MMS data from the TC4.
- Develop the MMS for the Global Hawk and SIERRA UAVs



Figs. 15 (top) and 16 (opposite): Comparisons with sonde data from (H. Voemel) University of Colorado during CRAVE.

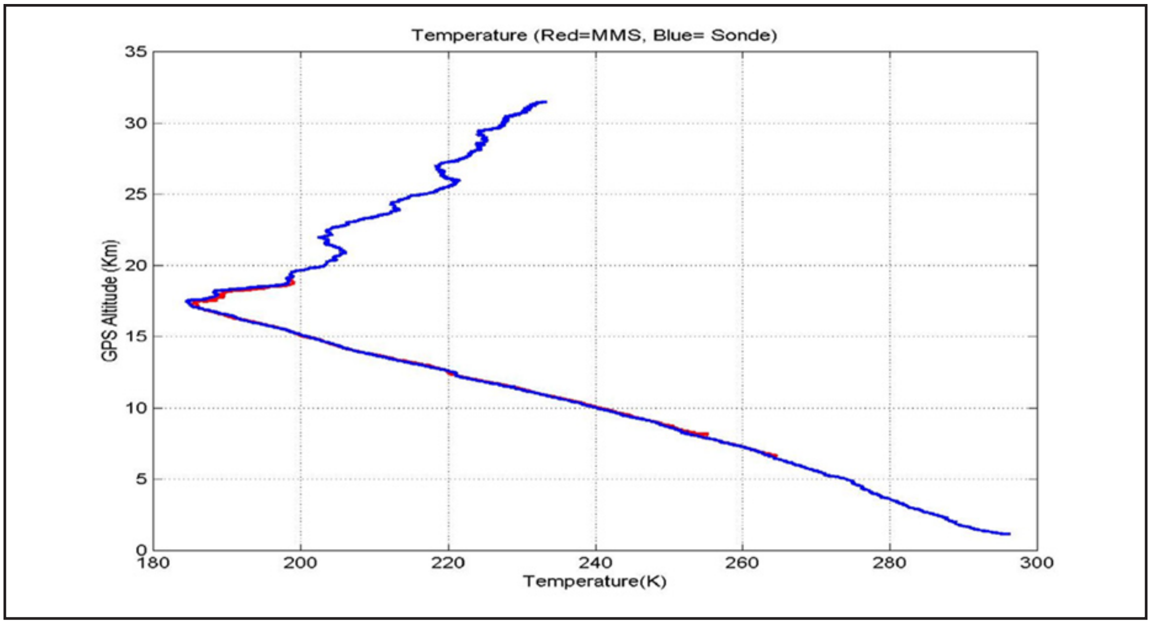


Fig. 16: Temperature comparisons.

Smog Ozone Processes and Production

PI: Robert Chatfield

Supporting Programs:

- *NASA Earth Science Applications, Rapid Prototype Capability*
  Program Manager: Lucien Cox
- *NASA Global Tropospheric Program*
  Program Manager: James Crawford

This study of lower tropospheric ozone, especially pollutant or smog ozone, is conducted via three areas of interest. The first is an extended analyses of NASA's aircraft missions that collect images of Earth from high altitudes that detect urban smog ozone production, thereby identifying the best satellite observations for this purpose. The second involves a collaboration with the Environmental Protection Agency to identify current NASA remote-sensing products that define lower tropopsheric ozone. The third is determining new remote sensing windows and technologies that will allow an unprecedented view of the most difficult task of remotely sensing pollution-layer ozone near the Earth's surface.

Smog Ozone Production Deduced from Moderate-Technology Instrumentation.

One goal is to devise simple empirical estimators of pollution ozone production rate that are useful for controlling ozone at the local level. In 2007, we conducted a mathematical analysis approximating the basic chemical theory behind a statistical summary that quantifies the basics of photochemical smog: the rate of oxidizing radicals production, the role of the critical catalytic species, nitric oxide, in converting these oxidizing compounds to ozone, and the role of ultraviolet radiation. It was not clear how far this simple analysis could be extended towards important urban source regions with their multiple, differing pollutant sources. Research has shown that rural relationships do carry over: the chemical production rate of ozone (typically considered to require extensive chemical simulation and a good knowledge of ozone precursor species) is proportional to a simple mathematical expression (jHCHO [HCHO] [NO])0.4 derivable from modest-technology instrumentation like chemiluminescent nitric oxide sensor, a tunable diode laser formaldehyde instrument, and a suitable adaptatoion of common measurement of ultraviolet readiation. The measurements indicate UV photolysis (jHCHO), formaldehyde concentration, [HCHO], and nitric oxide concentration [NO].

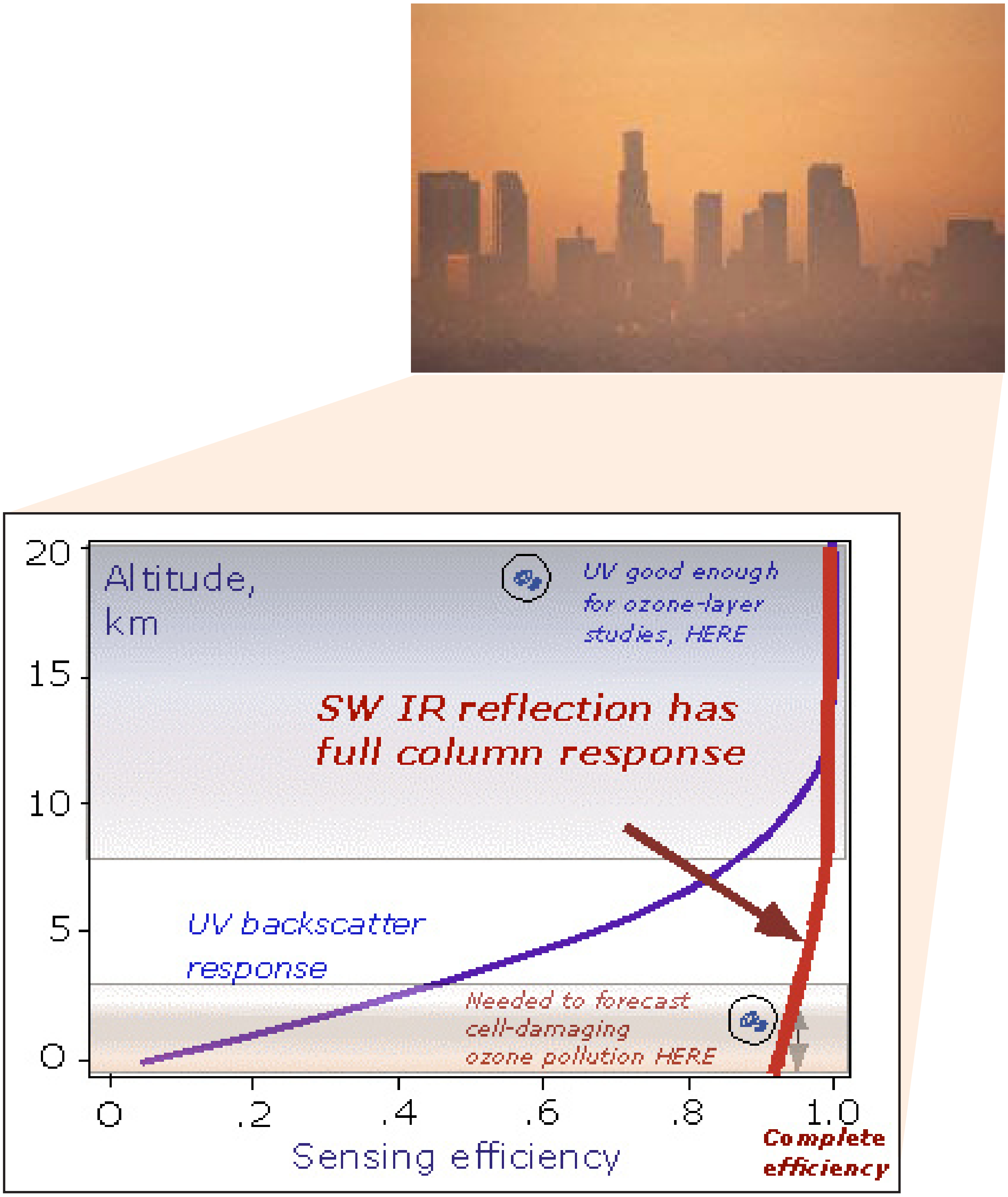


Figure 17: Short-wave Infrared Radiation (SW IR) technologies reveal smog ozone in the lowermost layers of the atmosphere. The violet curve depicts the "total column ozone" measurement of UV (~0.3 micron) remote sensing instruments. Low sensitivity to the lowest kilometers is apparent. The red line depicts new SW IR (3-micron) measurement obtained by Tropospheric Infrared Mapping Spectrometry (TIMS) instrumentation. Two field-tested TIMS instruments have been developed under NASA Instrument Incubator Program support to Lockheed Martin, and we propose altering these instruments to prove ozone sensing capabilities from airborne platforms.

Spatial variability of atmospheric data products derived from MODIS and MISR

PI: Jens Redemann

Supporting Program:
NASA Earth Science Research, Atmospheric Radiation Program
Program Manager: Hal Maring

The work under this grant combines analysis of observations from airborne platforms and EOS instruments of aerosol optical depth and columnar water vapor collected during recent field experiments to assess the feasibility of using MODIS native resolution radiance measurements for retrieving aerosol properties in the immediate vicinity of clouds.

NASA unique capabilities and assets employed in the project include NASA EOS observations by the MODIS instruments aboard Terra and Aqua, NASA Ames Airborne Tracking Sunphotometer, and the AATS-14.

The major accomplishments through 2007 include the completion of the analysis of the EVE (Extended-MODIS-λ Validation Experiment) data set, the publication of a GRL-manuscript dealing with MODIS near-IR aerosol products and their spatial variability (Redemann et al. [2006]), the implementation of a MODIS–like aerosol retrieval algorithm applicable to 500m-resolution MODIS reflectance spectra, and the study of the spatial variability of aerosol properties in the vicinity of clouds based on collocated MODIS and sunphotometer observations during the EVE campaign. Figure 18 shows a MODIS true color image for a scene on April 30, 2004. Figure 19 shows a map of the standard deviation of groups of 3-by-3 MODIS L1B reflectance at 553nm.

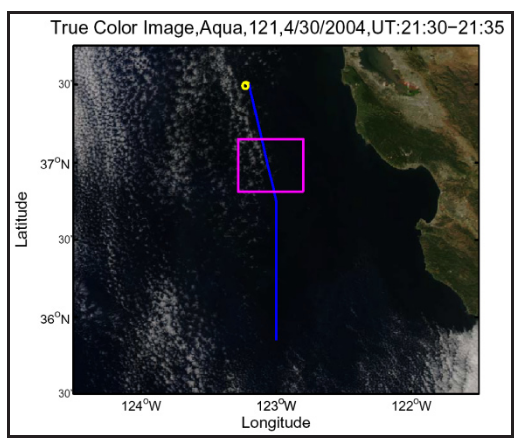


Fig.18: Flight track of EVE flight CIR06 (red), April 30, 2004, superimposed on MODIS-Aqua true color image.

The question arises whether the variability in the vicinity of clouds could be due to 3-D radiative effects or even the variability in aerosol properties rather than actual cloud contamination. To begin addressing this question, we adapted the operational MODIS aerosol retrieval algorithm, normally applied to 10km-averaged reflectance spectra, and applied it to 500m-resolution MODIS reflectance spectra. As case studies we selected MODIS observations in the vicinity of clouds for the scene indicated by the magenta box in Figure 18, where airborne sunphotometer observations consistently indicated significant increases in aerosol optical depth (AOD) at distances of 0-2km from clouds.

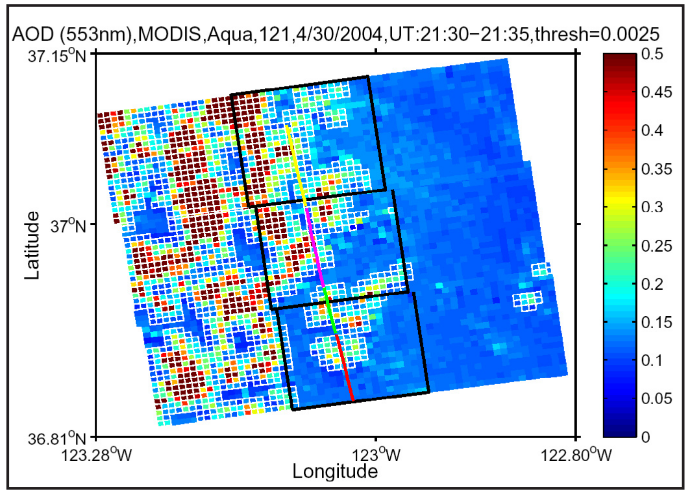


Fig. 20: Example of 500m-resolution MODIS-like aerosol retrieval for a set of measurements collocated with airborne sunphotometer measurements in EVE.

Figure 20 shows an example of the 500m-resolution aerosol retrievals thus obtained. To investigate if the clear sky pixels next to clouds yield realistic aerosol retrievals, we compared the AOD in these pixels to the coincident sunphotometer observations. Figure 19 shows the comparisons of midvisible AOD from MODIS and the airborne sunphotometer, respectively, as a function of their distance from the nearest cloud edge. Figure 19 indicates that the MODIS-like AOD retrievals differ from the airborne sunphotometer observation by 0.04 to 0.05. However, when plotted as a relative change in AOD, the MODIS and airborne sunphotometer AOD data show similar increases in AOD towards clouds. However, at wavelengths in the SWIR, the MODIS AOD retrievals show increases near clouds that exceed the sunphotometer observations considerably. The cause of this discrepancy is currently under investigation and a GRL paper summarizing these findings is currently being prepared.

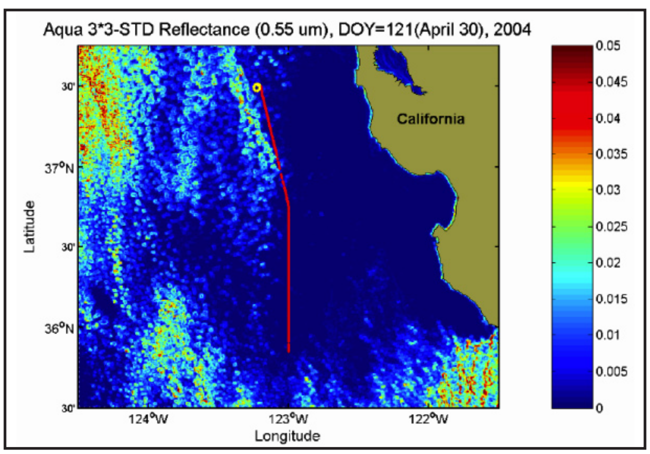


Fig. 19: Standard deviation of groups of 3-by-3 MODIS L1B reflectance at 553nm.

Objectives in 2008: Bring to conclusion the GRL paper on aerosol variability in the vicinity of clouds. Begin incorporating aerosol observations from the CALIPSO lidar to investigate similar case studies.

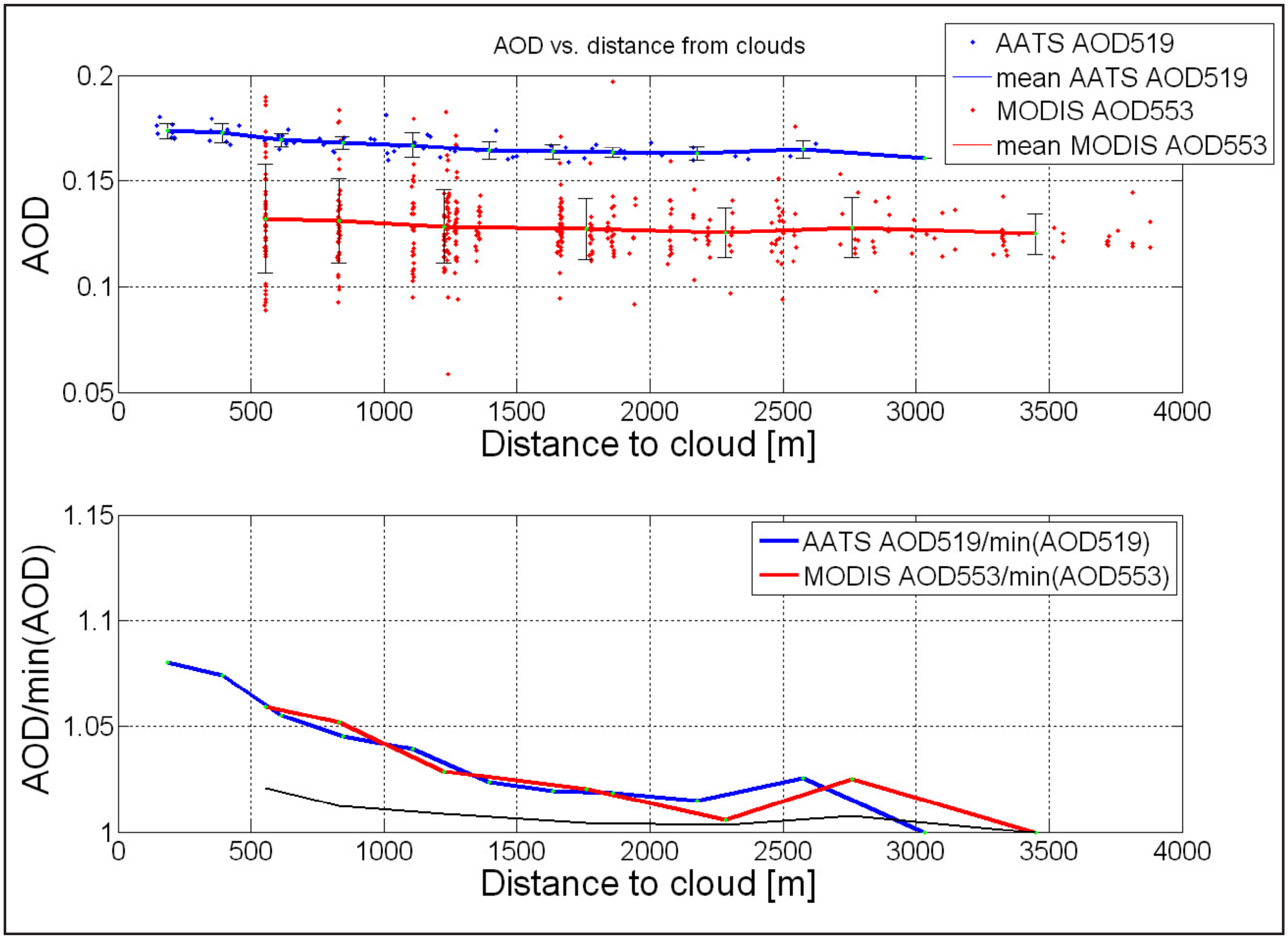


Fig. 21: Comparison of MODIS-like retrievals of midvisible AOD to airborne sunphotometer observations as a function of distance to the nearest cloud edge

Spectrometers for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR)

PIs: Phillip B. Russell
Beat Schmid
(Batelle Pacific NW Division)

Supporting Programs:
NASA Earth Science Research, Atmospheric Radiation Program
Program Manager: Hal Maring

Current questions in Earth science require advanced instruments to validate and extend spaceborne measurements of aerosol particles and gases. In this project we design and test methods that extend airborne sunphotometry in two ways: by enabling measurements of sky brightness distribution and by adding spectroscopy.

Our aims for the envisioned instruments are extending the capabilities of the NASA Ames Airborne Tracking Sunphotometers (AATS-6 and -14), while reducing instrument size, weight, and power, and increasing instrument autonomy to permit operation on a wider range of aircraft, including unmanned aerial vehicles (UAVs). We seek to extend AATS capabilities in two ways:

- Sky scanning: By adding the capability to measure the angular distribution of sky brightness, the new instrument will enable retrievals of aerosol type (via complex refractive index and shape) and aerosol size distribution including sizes larger than attainable by direct-beam sunphotometry. These capabilities, currently provided on the ground by NASA's AERONET network, would be extremely valuable in an airborne instrument.

- Wavelength resolution: By using a spectrometer in place of the discrete photodiodes and filters of AATS, the new instruments will improve accuracy of water vapor and ozone measurements, enable measurements of other gases (e.g., NO_2, SO_2) and improve accuracy of aerosol measurements via better aerosol-gas separation.

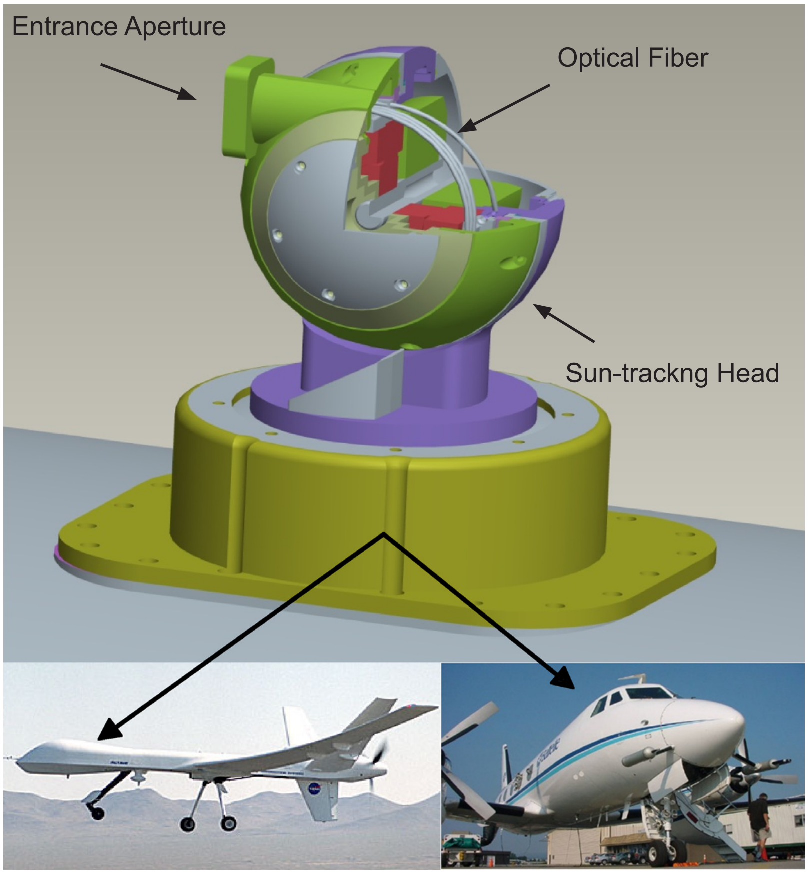


Fig. 22: A concept for a sun-sky spectrometer smaller than AATS-14 and usable on manned and unmanned aircraft, both small and large.

To investigate the feasibility of these objectives, we explore advanced instrument concepts and test key technologies. The advanced concepts, called Spectrometers for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR) are smaller than AATS-14 but extend AATS capabilities in the above ways.

The project uses a unique ground-based prototype, 4STAR-Ground, as well as AATS-14. 4STAR-Ground enables us to test key technologies such as fiber optics, spectroscopy, and collecting optics. AATS-14 provides a standard of comparison for key metrics like radiometric stability and tracking accuracy.

Progress and accomplishments in 2007. Adding a diffuser and improving concentricity at the fiber optic entrance port greatly improved short-term signal stability and produced field-of-view scans with quality exceeding that of AATS-14. Measurement comparisons between 4STAR-Ground and an AERONET Cimel photometer showed similar ability to measure skylight angular

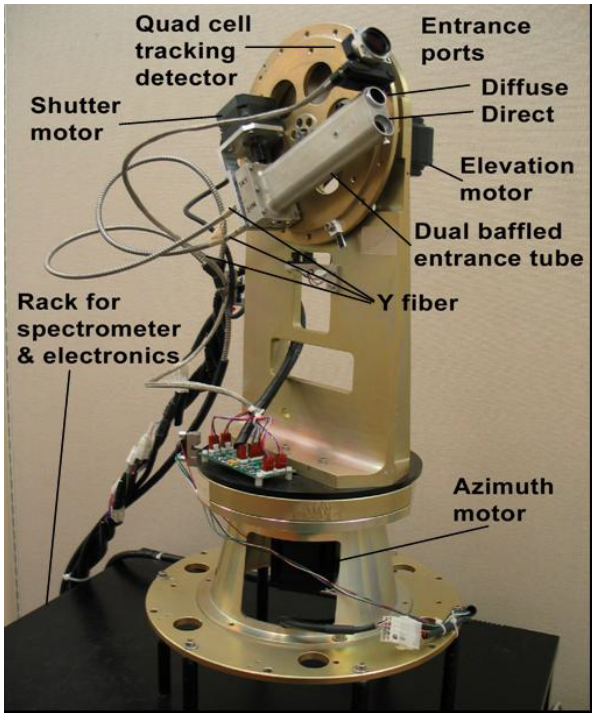


Fig. 23: Photo of the ground prototype Spectrometer for Sky-Scanning, Sun Tracking Atmospheric Research (4STAR-Ground).

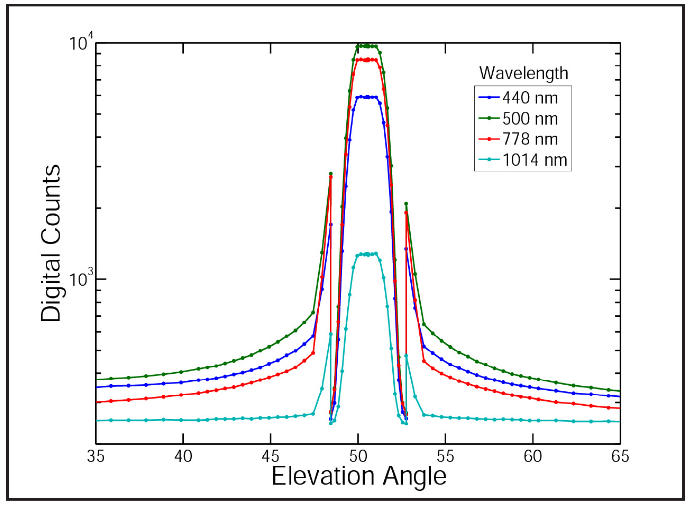


Fig. 24: Plans for 2008. Build and test the new collector. Develop design for an airborne prototype (4STAR-Air) and propose it to NASA HQ.

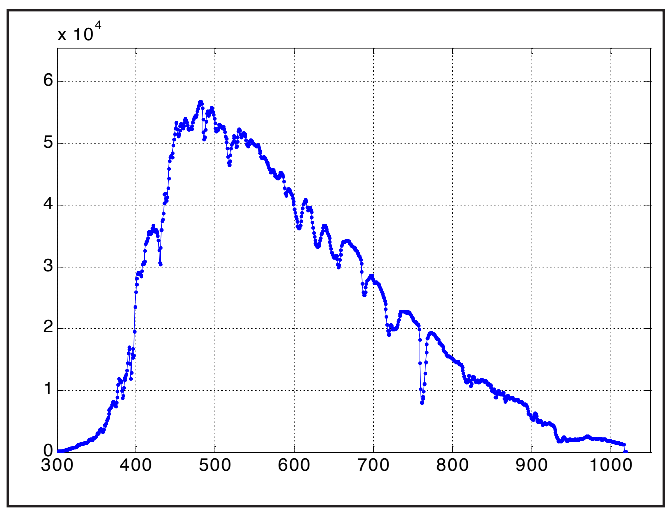


Fig. 25: Data from 4STAR-Ground. (a) Output counts for four wavelengths during an elevation scan that combines data from diffuse (sky) and direct (sun) channels (b) Direct-sun spectrum.

distribution except at the longest wavelengths near the darkest part of the sky. This led to the design of an improved collector for 4STAR-Ground. Size distribution retrievals from the Cimel and 4STAR-Ground produced similar results. We procured a fiber optic rotating joint (FORJ), and demonstrated that its transmission is reproducible to ~0.25% through a 360° rotation. Results are described in a December 2007 AGU presentation (http://geo.arc.nasa.gov/sgg/NID/presentations.html)

Ticosonde/TC4:

Balloonsonde Measurements of the Deep Convective Atmosphere Over Central America, June-August 2007

PI: Henry Selkirk

Co-PIs: Leonhard Pfister

Jimena Lopez

Supporting Program:

NASA Earth Science Research, Atmospheric Radiation Program

Program Manager: Hal Maring

Since 2004, the Earth Science Division at NASA Ames Research Center has collaborated with the University of Colorado, the Costa Rican National Meteorological Institute (IMN), the University of Costa Rica (UCR), the National University (UNA) and the Costa Rican National Center for High Technology (CeNAT) in the long-term atmospheric sounding project called Ticosonde. Ticosonde explores the time variability and vertical structure of the deep tropical atmosphere using high-frequency, high-resolution radiosonde measurements launched from the IMN site at Alajuela, Costa Rica [10.0°N, 84.2°W].

The NASA TC4 mission in the summer of 2007 was the occasion for the fourth consecutive Ticosonde summer campaign, and fifth overall, with 15 days of twice-daily soundings at 00 and 12 UT beginning June 16, and four-times daily soundings (at 00, 06, 12 and 18 UT) from July 1 through August 13. All radiosonde launches during the TC4 campaign were made with the Vaisala RS92SGP radiosonde by a team composed of personnel from the IMN and students from the School of Physics at UCR supervised by Profs. Walter Fernández, Jorge Amador and Jorge Andrés Diaz and Mr. Werner Stolz of IMN. Fig. 26 shows a sonde launch during January 2006.

(Continued on page 45)

Fig. 26: Marcial Garbanzo of the UCR team launching one of the Vaisala sondes during the Ticsonde/CR-AVE campaign in January and February of 2006..

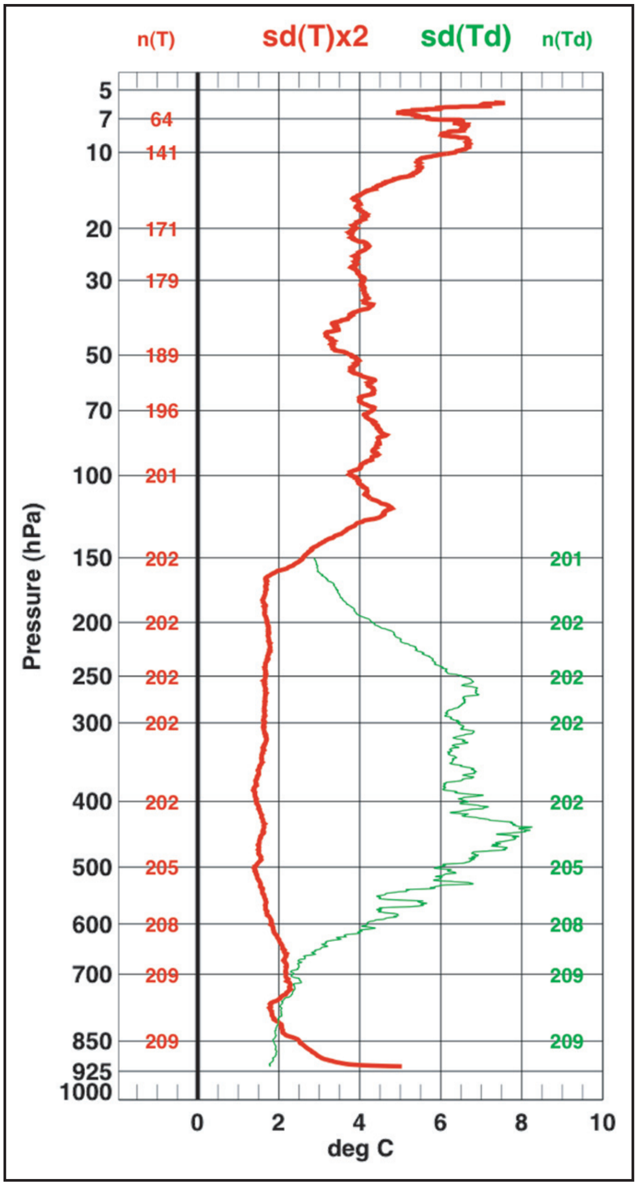


Fig. 27

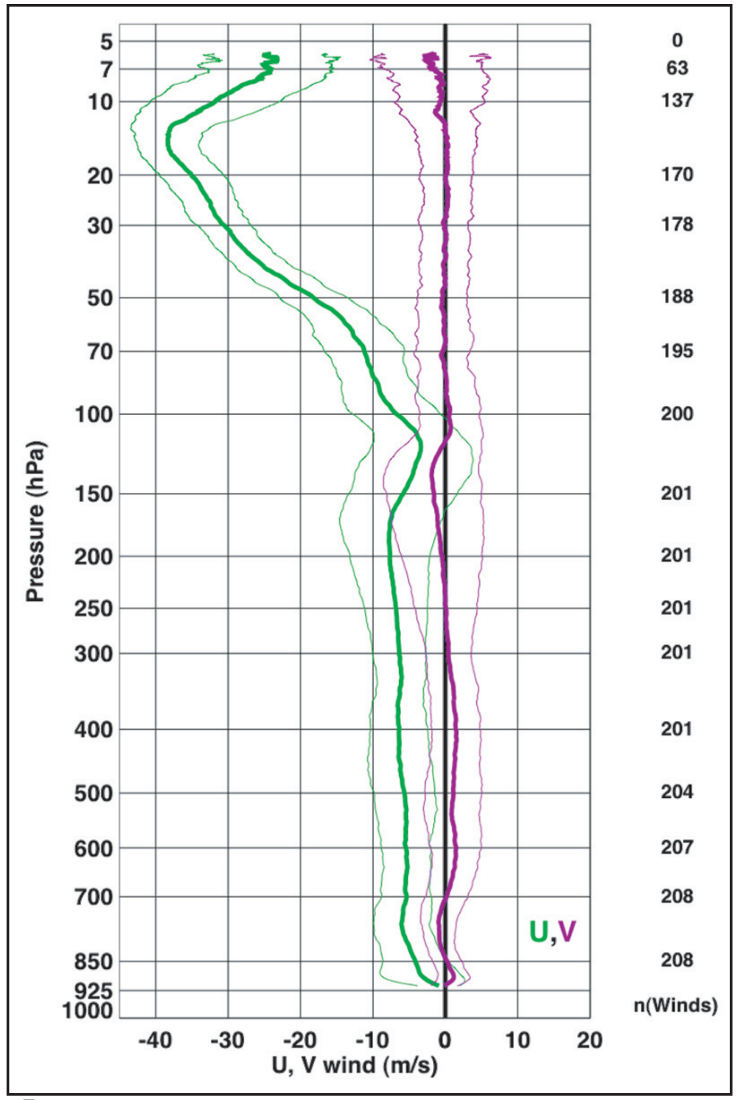


Fig. 28

Figures 27-29: Time mean and standard deviation profiles for Ticosonde launches, June 16 – August 13, 2007 at Alajuela, Costa Rica, in increments of 10 m. Fig. 27 (left), depicts standard deviations of temperature (x2) in red and dewpoint in green. Fig. 28 (right), shows standard deviations of u (green) and v (violet). Fig. 29 (page 44) depicts temperature in red and dew point in blue, individual cold points marked with black +, and wind barbs in knots

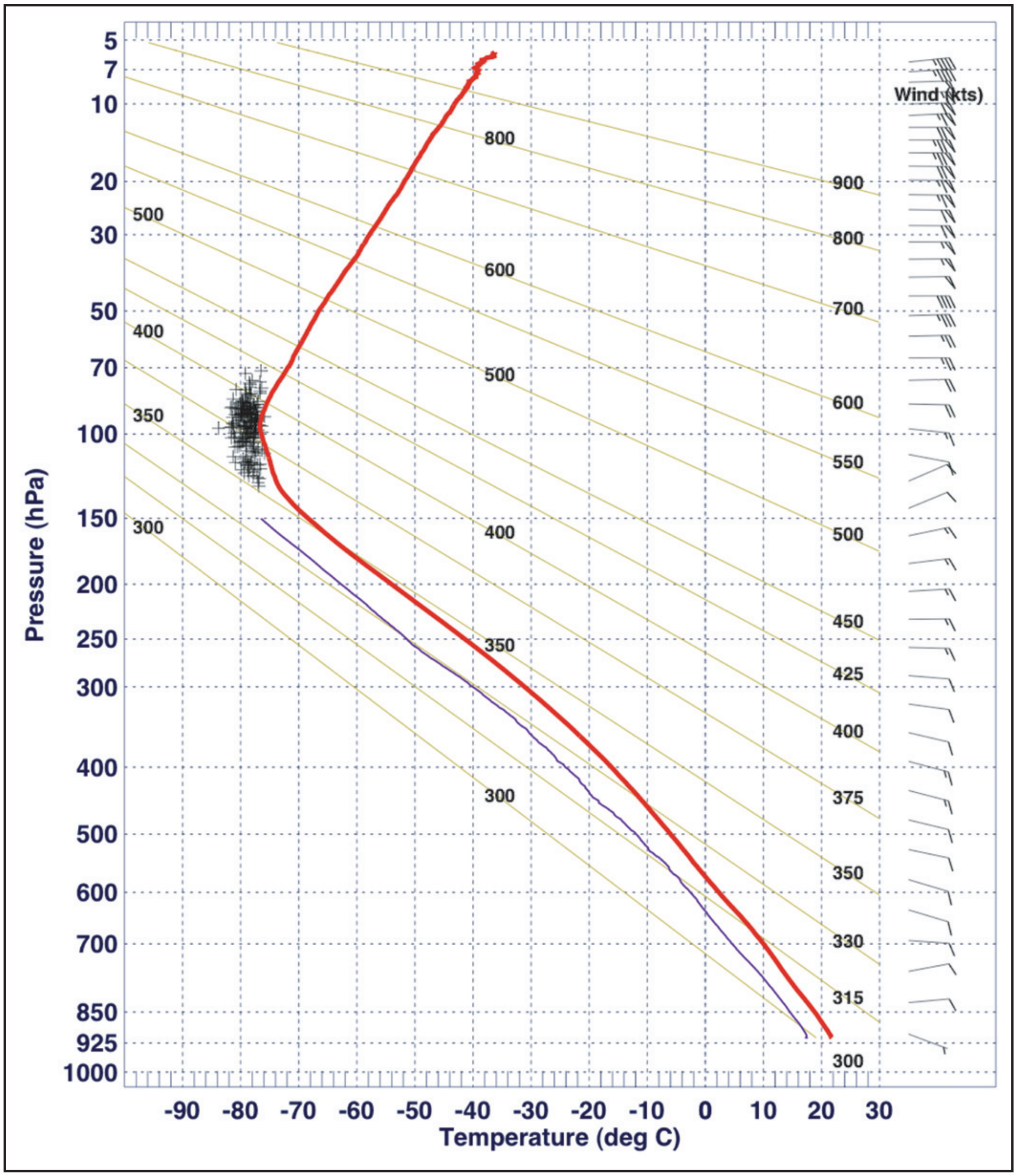

Pressure (hPa)
Temperature (deg C)
Wind (kts)
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Fig. 29

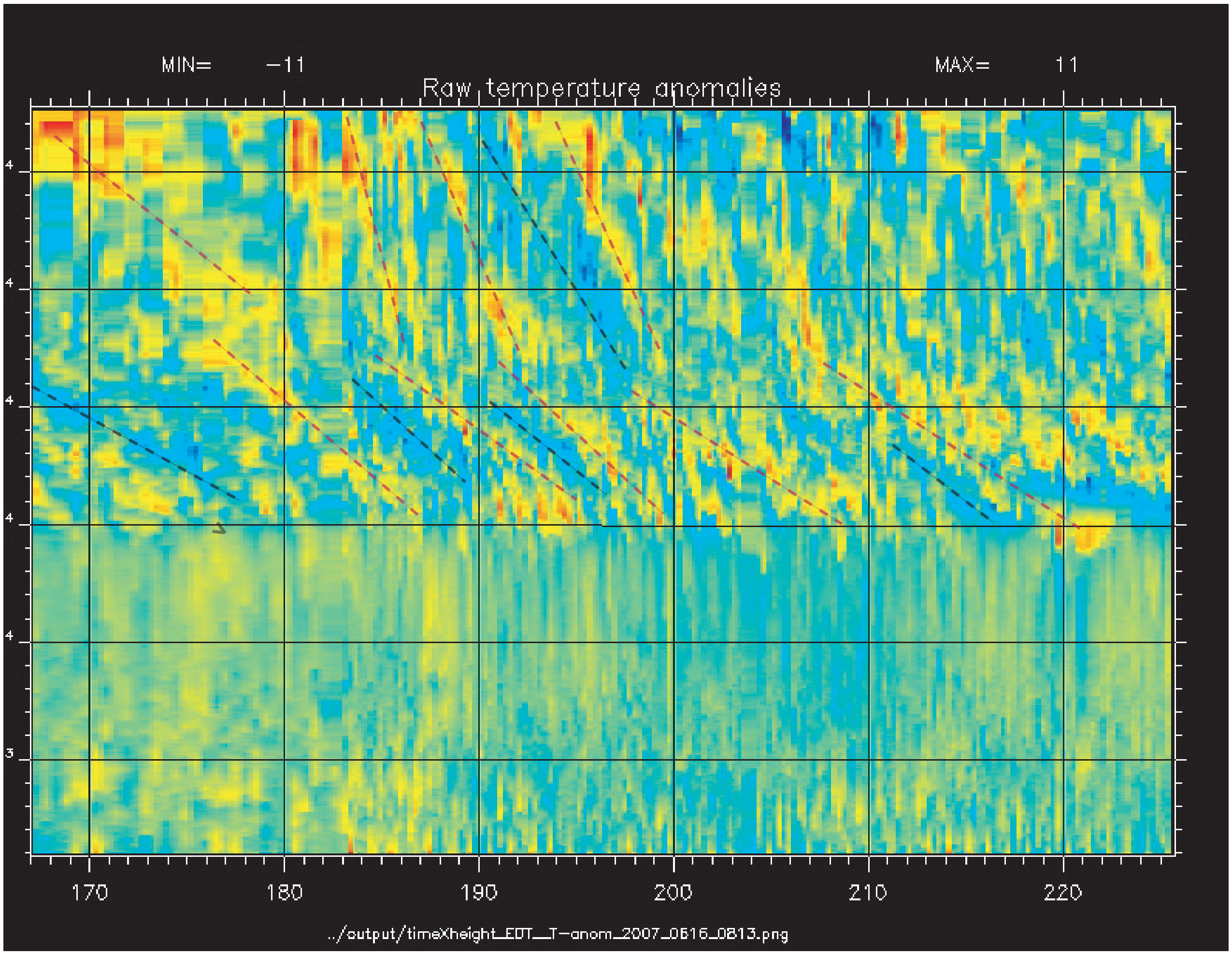


Figure 30: Time-height cross-section, June 16 through August 13, 2007 and 900 to 32.5 km, of unfiltered temperature anomalies as deviations from the time mean temperature profile in Figs. 24-26. Max anomaly amplitudes (red or violet) 11 K. Dashed lines indicate downward phase propagation of long timescale waves. Grid lines every 10 days and every 5 km.

Ticosonde campaigns since 2005 have also included frequent balloonsonde launches by a team of UNA students and IMN personnel led by Dr. Holger Vömel of the of CU and Dra. Jessica Valverde of the UNA. Their payload includes the CU cryogenic frost point hygrometer (CFH) and an ECC ozonesonde. The CFH data in particular have become a critical *in situ* database for validation of both Aura satellite and airborne measurements of water vapor in the tropical upper troposphere and lower stratosphere, while the radiosonde measurements have been key in validation of temperature and relative humidity measurements on Aura and as well as the AIRS instrument on the Aqua satellite.

The Ticosonde databases of temperature and wind measurements from the five campaigns since 2004 provide important insights into both the dynamical and trace constituent structure of the tropical tropopause layer. Figs. 27-29 (pages 43-44) depict the time-mean profiles of temperature, dew point and winds for the TC4 campaign period to the middle stratosphere. Of note is the rapid increase of temperature standard deviation beginning at ~14 km or 150 which we argue defines the base of the 'dynamical' tropical tropopause layer (TTL). Within the TTL and especially above 16 km or the tropopause, individual radiosonde temperature profiles exhibited kilometer-scale variations of temperature with amplitudes as high as 5 K near the tropopause. These temperature excursions and associated wind anomalies are reflective of organized quasi-horizontal motions within the TTL and the overlying stratosphere, and in particular instances, distinct laminae in water vapor and ozone were observed. The time-height cross-section of temperature anomalies in Fig. 28 and the frequency-height cross-section of the meridional wind anomalies in Fig. 31 reveal a predominance of equatorial wave modes at sub-inertial time scales and inertio-gravity modes in the TTL and above. The frequent occurrence of thin sub visible cirrus layers in the TTL is a direct consequence of the quasi-horizontal and laminar character of the motions associated with these inertio-gravity and equatorial wave modes that remain as the energy of higher-frequency wave modes is rapidly dispersed.

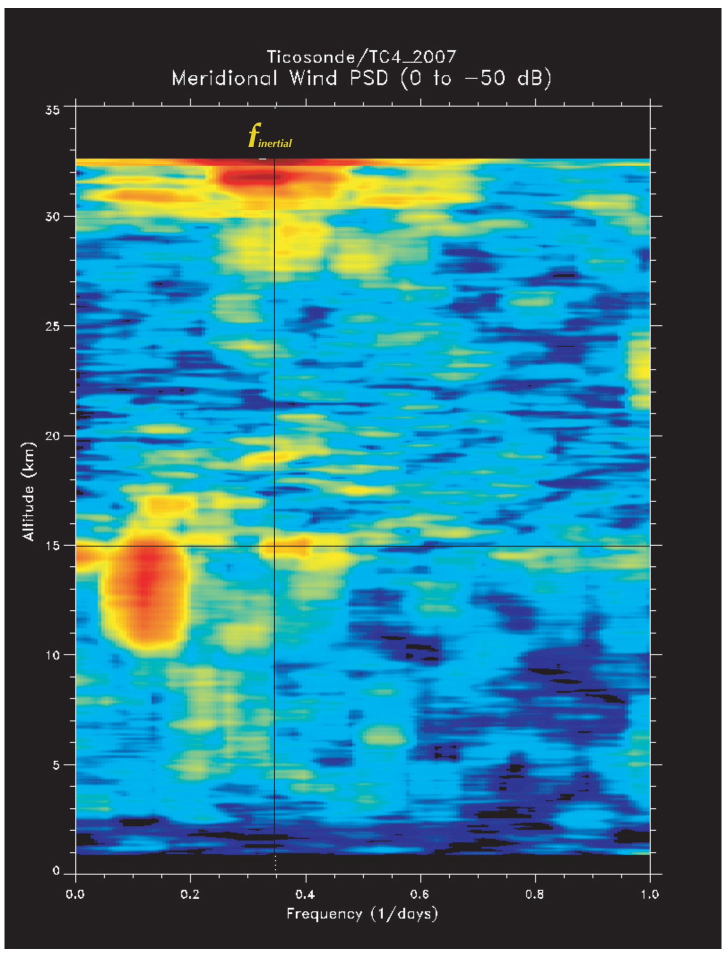


Figure 31: Frequency-height cross-section of power spectral density of meridional winds, June 16–August 13, 2007 at Alajuela, Costa Rica. Inertial period of 2.88 days at this 10°N location indicated by thin vertical line. Thin horizontal line marks the 15-km level.

NASA Tropical Composition, Cloud and Climate Coupling (TC4) Mission

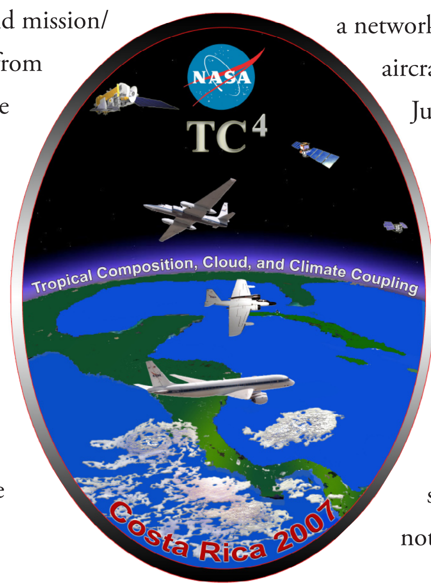
Project Manager: Marilyn Vasquez

Supporting Programs:

- *NASA Atmospheric Composition Focus Area, Upper Atmosphere Research Program*
  Program Manager: Michael J. Kurylo
- *NASA Radiation Sciences Program*
  Program Manager: Hal Maring

The NASA Tropical Composition, Cloud and Climate Coupling (TC4) mission was a major 2007 field campaign based in Costa Rica and Panama. TC4 was a comprehensive study to identify and quantify the atmospheric processes in the upper troposphere and tropopause transition layer. Understanding these processes is essential to the study of climate change, stratospheric ozone depletion, and global tropospheric chemistry.

TC4 brought over 300 scientists, engineers, and mission/support personnel to Costa Rica and Panama from mid-July through mid-August, 2007. This large international experiment united researchers from 8 NASA centers, over 14 U.S. and international universities, and more than 20 U.S. and international agencies. Support from the U.S. Air Force for airlifts and supplies was essential to the success of the mission.



The TC4 mission involved 3 of NASA's unique aircraft, 2 ground radars, a research trailer and a network of balloon launches. The three NASA aircraft (DC-8, WB-57 and ER-2) flew from the Juan Santamaria International Airport in Costa Rica and carried over 60 highly specialized instruments that collected both *in-situ* and remote-sensing data.

NASA's "A-train" satellite observations provide crucial information on the spatial and temporal variations in the atmosphere. The TC4 aircraft observations validated the satellite data and provided critical observations not available from the satellites. High altitude

Figure 32: ER-2 Group photo during the TC4 experiment.

aircraft collected tropopause data while the medium altitude aircraft provided profiles and measurements of the structure of the tropical upper troposphere and lower stratosphere. This complex multi-aircraft mission made some of the first measurements of particle properties and water vapor in the region's sub-visible cirrus clouds and obtained data that should clarify the amount of water in the tropical upper atmosphere.

The Earth Science Project Office at Ames Research Center managed the TC4 mission and made all the international agreements and arrangements for the aircraft and personnel in both Costa Rica and Panama. Scientists from the Earth Science Division at NASA Ames also filled many important roles, including platform scientist, weather forecasters, and instrument scientists, that provided tracer measurements, meteorological measurements, solar flux measurements, hyperspectral and video imagery, and management and support for all the sonde launches.

TC4 generated a tremendous amount of publicity. An open house generated international coverage from over 9 television networks, 14 newspapers, and many radio stations. The President of Costa Rica and the U.S. Ambassador visited the mission and deemed it of national importance for Costa Rica. The visits from many local school children were also a huge hit both in Costa Rica and Panama.

The TC4 mission was sponsored by the NASA Headquarters Atmospheric Composition Focus Area including the Upper Atmospheric Research Program, the Radiation Science Program and the Tropospheric Chemistry Program. NASA HQ showed its support further when Michael Freilich, the NASA HQ Earth Science Director, Jack Kaye, the NASA HQ R&A Program Director, and Andy Roberts, the NASA HQ Airborne Science Program Manager visited the deployment in Costa Rica.

More detailed information on the TC4 mission is available at the mission web site located at http://www.espo.nasa.gov/tc4/.

Fig. 33: WB-57 Group photo during the TC4 experiment.

Fig. 34: DC-8 Group photo during the TC4 experiment.

Biospheric Science Branch

James A. Brass
Branch Chief

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, inspire and motivate the nation's students and teachers, engage and educate the public, and advance the scientific and technological capabilities of the nation. The 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, developing and validating enabling technologies, and 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, and land cover and land use change. The Branch develops and applies remote sensing, ecological modeling 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.

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. 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 2007, 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 predict how productivity will change in response to various cycles and trends in land use, disturbance and climate change.

(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 wildland fires; and

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

THE [BIOSPHERIC SCIENCE] BRANCH ENGAGES THE PUBLIC AND COMMERCIAL SECTORS TO EDUCATE AND ADVANCE THE SCIENTIFIC AND TECHNOLOGICAL CAPABILITIES OF THE NATION.

Fifty earth scientists, engineers, programmers, geographers, chemists and educators comprise the branch and cover a range of disciplines from ecology to engineering and computer science. A number of staff are associated with Ames through cooperative agreements with California State University at Monterey Bay, San Jose State University and Bay Area Environmental Research Institute. Other science staff supports branch research through on-site contracts, visiting professor programs and educational grants and programs. The branch hosted more than ten visiting scientists in 2007, several through the National Research Council 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, Monterey Bay Aquarium Research Institute, San Francisco Estuarine Institute and the College of San Mateo. 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 and the National Remote Sensing Center in Egypt. 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, U.S. Department of Interior, Bureau of Land Management, National Oceanic and Atmospheric Administration, Department of Transportation, 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, the Branch collaborated 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: UAV Collaborative, San Bernabe Winery, Lockheed Martin Corp., Bay Area Shared Information Consortium, General Atomics, British Petroleum and Shell Oil. 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 Life Sciences Division, the Space Projects Division, Intelligent Systems Division, Computational Sciences, Business Development Office, and Human Factors Division, the Atmospheric branch within the Earth Science Division, and the Airborne Science and Technology Lab. These collaborations 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.

2007 Western States UAS Fire Mission

PI: Vince Ambrosia

Supporting Program:
Applied Science Program, Disaster Management
Program Manager: Steve Ambrose

The Western States UAS (unmanned aerial system) Fire Imaging Mission demonstrated the capabilities of the NASA-funded Wildfire Research and Applications Partnership (WRAP) project. WRAP is a collaboration between NASA and the USDA Forest Service (USFS) to improve response to, and monitoring of, wildfire events in the US through the use of airborne and space borne imaging systems and cutting-edge technologies. WRAP demonstrated four key technologies for fire management: 1) airborne observations with UAS; 2) sensor technologies derived from NASA instrumentation; 3) real-time data communication and telemetry; and 4) data manipulation and information extraction.

In partnership with the NASA Airborne Science Program and NASA-Dryden, WRAP flew two missions in 2006 and four missions in 2007 over wildfire events during the western US fire season. The two missions in 2006 were the first flights into the National Airspace (NAS) for a large UAS by NASA and covered events in the vicinity of Yosemite National Park and the Esperanza Fire near Los Angeles, California.

In 2007, the project team conducted extended operational missions over the western US with the AMS-Wildfire sensor operating aboard the newly-acquired Ikhana UAS research aircraft. An autonomous processor accompanying the

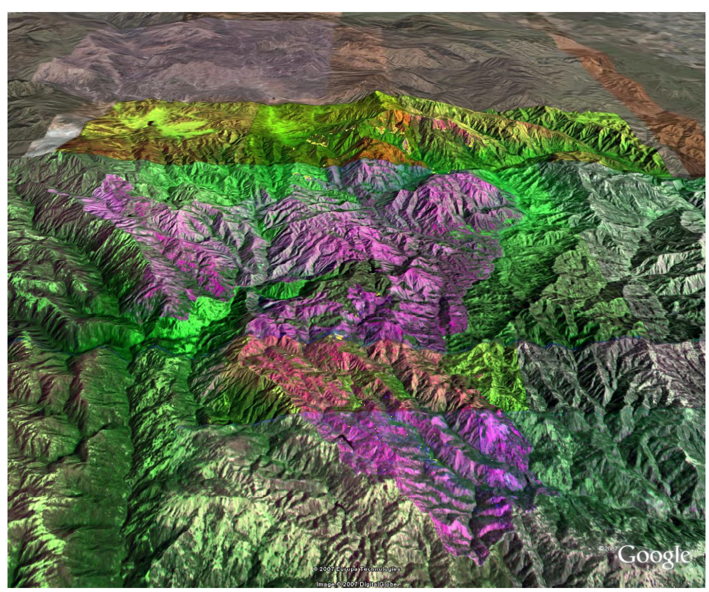


Fig. 35: AMS-Wildfire image collected over the Lick Fire (CA) and draped over 3D topography. Burning stages appear in purple; active fire regions in yellow. Fire managers viewed such data products via GoogleEarth.

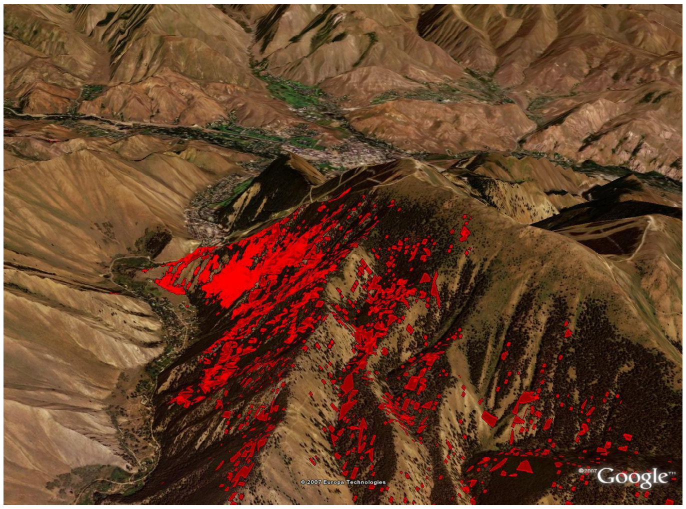


Fig. 36: A 3D perspective showing the active wildfire threat (red) to Ketchum, Idaho from the Castle Rock Fire (29 August 2007). Data derived from the AMS-Wildfire instrument and processed autonomously aboard the Ikhana UAS platform.

AMS-Wildfire sensor, generated real-time geo- and terrain-rectified image data sets transmitted the data through a satellite communications system on the Ikhana to personnel on the ground. Real-time GIS-enabled products were in the hands of disaster managers within minutes of collection.

The four Ikhana missions in 2007 were the first flights in the NAS by the aircraft and established a benchmark for future operations. Each mission featured the new NASA Ikhana UAS (a Predator-B derivative airframe; Ikhana is a Native American, Choctaw Nation word meaning, "intelligent, conscious, or aware"), outfitted with an autonomous 12-channel scanning / imaging instrument, on-board image processing capabilities, and a satellite communications system. The four missions, traversed eight western states (California, Oregon, Washington, Nevada, Utah, Idaho, Montana, and Wyoming), collecting critical fire information and relaying real-time data to fire Incident Command Teams on the ground and the National Interagency Fire Center (NIFC) in Boise, Idaho. These data were delivered from the AMS-Wildfire instrument through a satellite communications link to a server at NASA-Ames and redistributed autonomously in real-time to a GoogleEarth data visualization capability that served as a Decision Support System (DSS) for fire data integration and information sharing.

The four missions accounted for 56 hours of UAS operations including approximately 50 hours in the NAS. Twenty-six fires were imaged. Post-fire, burn-assessment imagery was also collected over various fires to aid teams in ecosystem rehabilitation following major fire events.

The GoogleEarth DSS provided access to other real-time fire-related information including satellite weather data, MODIS fire data, Remote Automated Weather Station (RAWS) readings, real-time lightning strike detection data, and other critical fire data-base source and aircraft information. These shareable data and information layers, combined into a Collaborative Decision Environment (CDE), allowed the Incident Command teams and others to make real-time fire management strategy decisions. The CDE data were also accessed by personnel throughout the U.S. who were involved in the mission and imaging efforts. Fire Incident Command Teams used the thermal imagery and products to develop management strategies, redeploy resources and direct operations to critical areas.

NASA and the USFS are considering further mission during the 2008 western US fire season, using the unique NASA Ikhana UAS and the AMS-Wildfire sensor system for experiments and demonstrations to enhance real-time processing, data delivery, and sensor-web technologies.

Agent-based support for Ecological Forecasting

PI: Ramakrishna Nemani

Supporting Program:
Applied Science Program, Ecological Forecasting
Program Manager: Woody Turner

Ecological Forecasting (EF) predicts the effects of changes in the physical, chemical, and biological environments on ecosystem state and activity. Operational production of ecological forecasts requires rapid retrieval and integration of a wide range of data sources (satellite observations, meteorological measurements, model outputs, etc.). Delivery of forecasts for use by agricultural producers, land managers, public health officials and others requires detailed metadata and delivery of products in a range of formats. In this project, we are developing a software system called the Terrestrial Observation and Prediction System (TOPS) as an end-to-end framework for operational data retrieval, processing, modeling, and distribution of ecological forecasts.

TOPS is a modeling framework that integrates operational satellite data, microclimate mapping, and ecosystem simulation models to characterize ecosystem status and trends. We have applied TOPS to investigate trends and patterns in landscape indicators using test cases at both national and park-level scales to demonstrate the potential utility of TOPS for supporting efforts by the National Park Service to develop standardized indicators for protected area monitoring. Our analysis of coarse-resolution satellite-derived normalized difference vegetation index (NDVI) measurements for North America from 1982-2006 indicates that all but a few PAs are located in areas that exhibited a sustained decline in vegetation condition. We used Yosemite National Park as our park-level test case, and while no significant trends in NDVI were detected during the same period, evidence of drought-induced vegetation mortality and recovery patterns dominated the 25-year record. In our Yosemite analysis, we show that analyzing MODIS (Moderate Resolution Imaging Spectro-radiometer) products (vegetation indices, absorbed radiation, land surface temperature and gross primary production) in conjunction with ground-based measurements, such as runoff, lends additional utility to satellite-based monitoring of ecosystems indicators, as together they provide a comprehensive view of ecosystem condition. Analyses of MODIS products from 2001-2006 show that year-to-year changes in the onset of spring at Yosemite were as large as 45 days, and this signal in the satellite

Continued on page 58

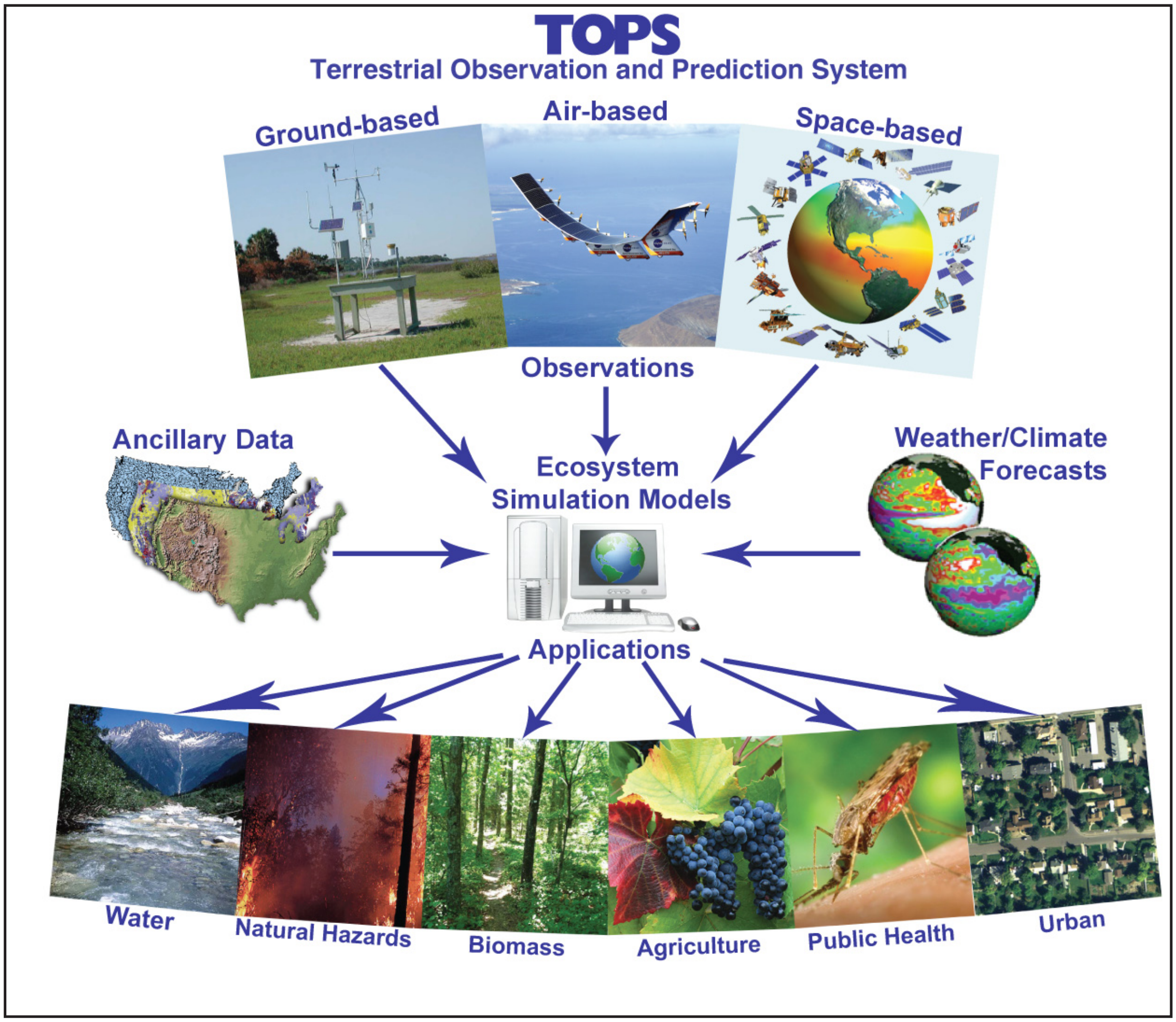
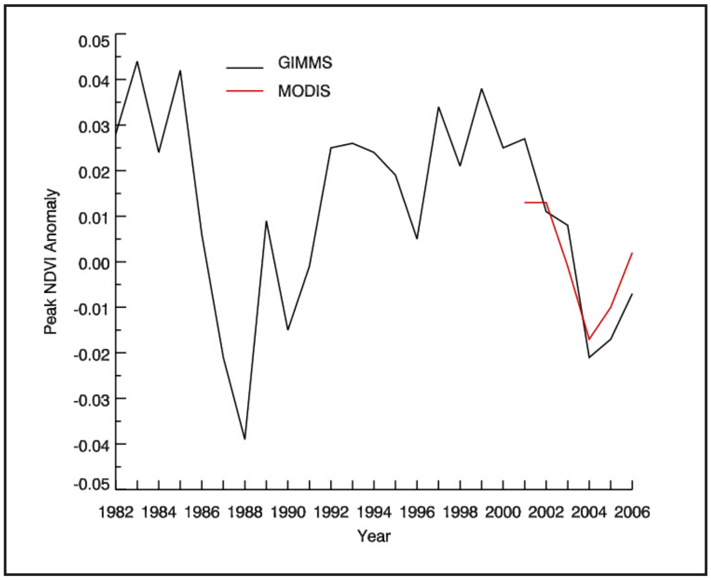
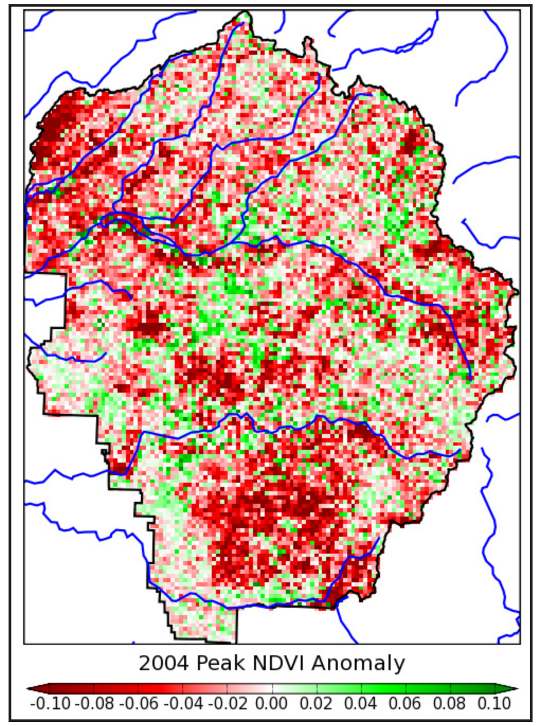


Fig. 37: A schematic representation of data-model integration enabled by the Terrestrial Observation and Prediction System (TOPS) for serving a variety of applications.



Figs. 38



Figs. 39

Figs. 38 & 39: Although a time series of annual average peak AVHRR NDVI of the Yosemite National Park shows no significant trends from 1982-2006, drought between 1987 to 1990 and 2002 to 2004 are clearly defined, with subsequent evidence of recovery by 2006. Fig. 36 shows similarities in NDVI acquired by AVHRR since 1982 (black line) and MODIS since 2001 (red line) provide confidence in the continuity of the reflectance signal. Fig. 47 shows change in MODIS NDVI at 500m as a result of the 2004 drought compared to the 2001-2006 NDVI average, as estimated from MODIS NDVI 500m data.

data record is corroborated by observed changes in spring runoff patterns. Finally, we applied TOPS to assess long-term climate impacts on ecosystem condition at the scale of an individual park. When driven by projected climatic changes at Yosemite of 4-6°C warming by 2100 with no changes in precipitation patterns, TOPS predicts significantly reduced winter snowpack and an earlier onset of the growing season, resulting in prolonged summer drought and reduced vegetation productivity.

Astrobiology: Hindcasting Ecosystems Project

Extreme Environments in a Forest Ecosystem of Ushuaia, Argentina

PI: Hector D'Antoni

Supporting Program: NASA Astrobiology Institute, Carl Pilcher

The detection of shortwave ultraviolet radiation at ground level in Southern Patagonia and Tierra del Fuego (Argentina) at about the same time (November 2005) our colleagues L. Rothschild and D. Rogoff detected it in the Bolivian Altiplano, added a new chapter to this research and concentrated our fieldwork during 2006 and 2007.

The Isla Grande de Tierra del Fuego is the largest landmass at the southern tip of South America. This unique territory is often under the direct influence of the "ozone hole" that hovers above Antarctica in the Austral spring. Ushuaia is the main town of the big island and one of its noticeable features is the upper timberline I n the nearby Andes mountains.

A survey over two mountain slopes (Glaciar Martial and Cerro Guanaco) in the vicinity of the city of Ushuaia (Tierra del Fuego, Argentina) showed results not significantly different from those found in other locations of the subantarctic forests in terms of chlorophyll concentration in the leaves of the dominant tree species, *Nothofagus antarctica*, *N. pumilio* and *N. betuloides*, and soil variables such as temperature, moisture, pH, and

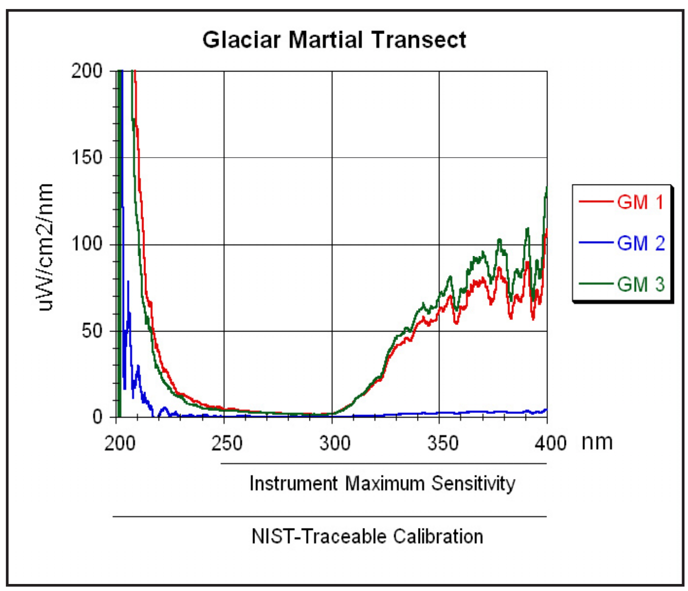


Figure 40: Solar UV spectrum of Glaciar Martial Transect (GM1=572 m; GM2=452 m; GM3=245 m).

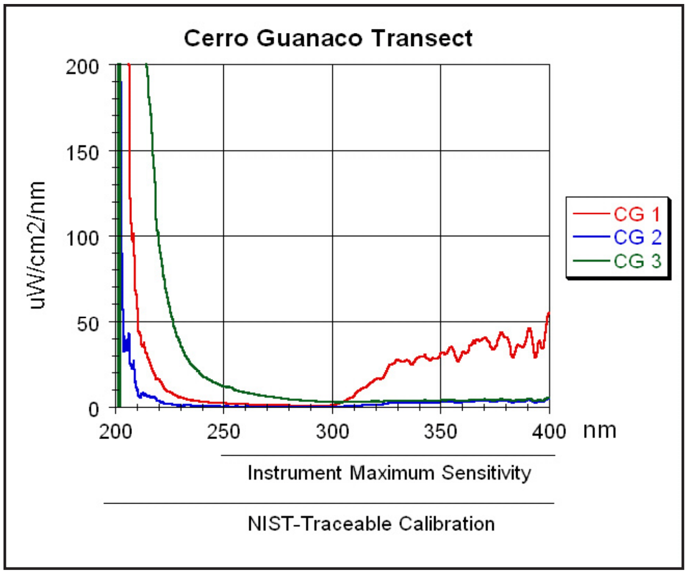


Figure 41: Solar UV spectrum of Cerro Guanaco Transect (CG1=655 m; CG2=504 m; CG3=485m).

the concentration of nitrogen, sodium and potassium. Solar radiation, however, showed high levels of ultraviolet in the 200-400 nm range (Figs. 31 and 32), suggesting that the environment is extreme in terms of incoming solar radiation.

An extensive belt of dwarfed trees ("krummholz" from the German for twisted trees) forms the upper timberline. Given the deleterious effects of UV radiation on biomolecules, such as nucleic acids, proteins and amino acids, growth hormones and others, we suggest that the krummholz formation is due in part to the extreme environment in terms of solar radiation.

The forest canopy absorbs and/or reflects a significant amount of that radiation. In a previous work we showed that these tree species contain UV-absorbing pigments (cyanidin, delphidin, and flavonol glycosides). We submit that the rippled and glossy surface of leaves serves as a reflection/backscattering mechanism that protect their inner structure and function. The upper timberline zone of Tierra del Fuego can be characterized as an extreme environment for solar radiation. The high levels of UV-A (400-3315 nm) and part of the UV-B (315 to 300 nm) in three of the spectra discussed in this article suggests that plants and other organisms are exposed to potentially damaging fluxes of UV-A and UV-B radiation. From the previous figures it is evident that UV-C reaches the surface in sizeable amounts at around 260 nm and continues rising until it reaches the 200 nm level. The absorption spectrum for DNA shows peaks between 280 and 260 nm and a steep rise from 240 through 220 nm. Similar cases can be made for vital molecules of proteins, fats and hormones. Thus, high UV-A, UV-B and, as we have shown, UV-C radiation fluxes contribute to make the upper timberline an extreme environment.

In 1994, A. Mayoral found cyanidin, delphidin, and flavonol glycosides in extracts from leaves of *Nothofagus sp.* using reverse phase HPLC techniques. The UV-absorbing pigments in the leaves of *Nothofagus sp*. suggests that these trees developed and kept a protective system that prevents UV radiation from reaching targets such as DNA, proteins, and lipids in the leaves. In addition, the leaves have a rippled profile and glossy surface that can be viewed as an apparatus for reflection. Such a mechanism may have been selected in response to the need to backscatter the energy-laden shorter wavelengths of UV. This interpretation based on chemical and genetic grounds should not exclude the structural and functional views nor those based on changes in the abiotic components of the environmental complex. We submit the UV portion of the electromagnetic spectrum has a significant role in the definition of the extreme environment at the upper timberline. The organisms' abilities to cope with the lower temperatures, frozen soils and the consequent water stress, the strong winds and the destructive exposure to UV-A, UV-B and, UV-C are put to test in the upper timberline. A sequence of variations (a cline) that loses diversity with the increase of elevation was found in *Nothofagus sp*. (Premoli 2003).

This sequence of genetic variations may originate through the molecular effect (breakage of chemical bonding) of high energy UV radiation and the following repair process. The resulting phenotype would be then selected by biotic (competition, herbivory, etc.) and abiotic (radiation, temperature, wind, water stress, etc.) factors. Successful plants will carry UV-blocking pigments (cyaniding, delphidin, and flavonol glycosides) to protect cellular structure and function, DNA repair mechanisms, and the ability to cope with temperature, wind, and water stress.

Fieldwork for this study was performed by Hector D'Antoni, Cynthia Schultz, and Seth Burgess. J.W.Skiles and L. Rothschild contributed to the discussion of results. Jeanette Zamora produced Figs. 40 and 41.

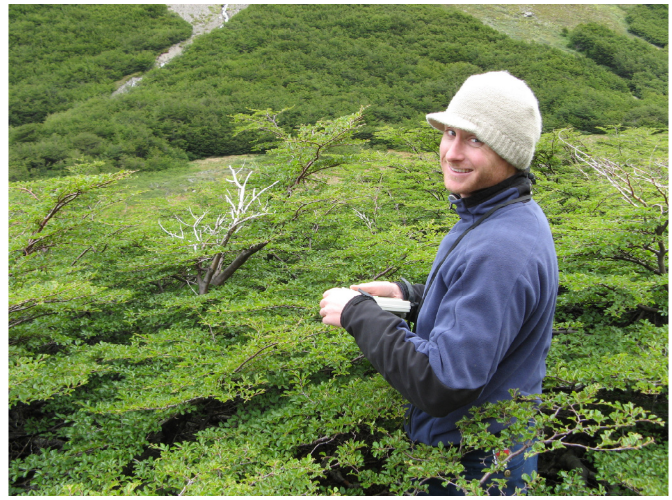


Figure 42: Seth Burgess measuring chlorophyll concentration in the dwarfed forest (krummholz) at the upper timberline of Cerro Guanaco.

DEVELOP

A Human Capital Development Internship Program

PIs: Joseph W. Skiles
ARC Program Manager

Cynthia L. Schmidt
ARC Program Coordinator

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

DEVELOP is a Human Capital Development Internship Program funded by the Applied Sciences Program in the Earth Science Division of the Science Mission Directorate at NASA Headquarters. Student run and student lead projects are conducted during the summer. Students are responsible for designing projects to meet the needs of potential users such as government or tribal organizations. Students collect necessary satellite and field data, analyze those data, present results to the collaborators, and write scientific papers on the study and the study results.

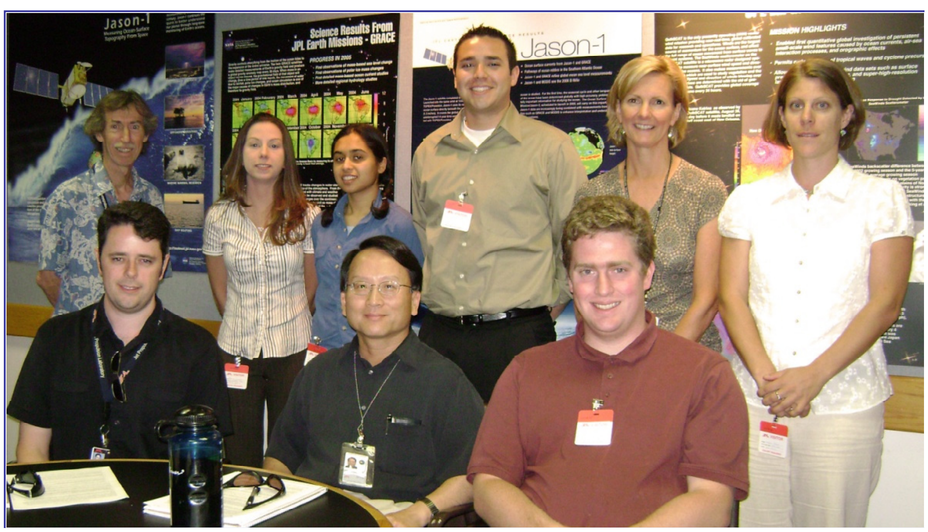


Fig. 43: DEVELOP PRICIP project team visits JASON and PODAAC (Physical Oceanography Distributed Active Archive Center) scientists at the Jet Propulsion Laboratory.

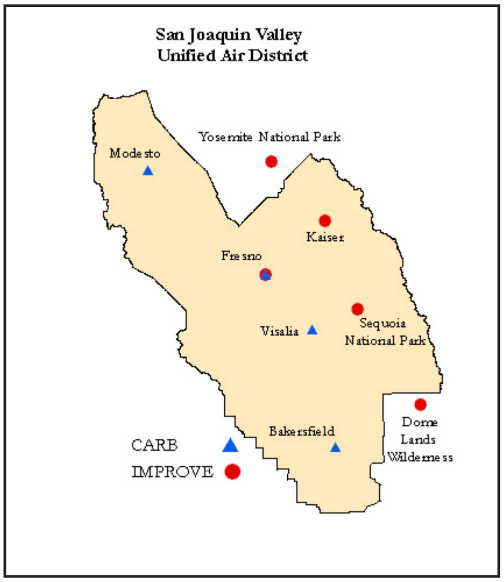


Fig. 44: IMPROVE and CARB data collection locations in the San Joaquin Valley.

Fig. 45: DEVELOP interns use three MicroTops II handheld sun photometers to measure surface aerosol optical thickness in Fresno, California.

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 2007 were:

San Joaquin Valley Air Quality

Air quality in the San Joaquin Valley has failed to meet state and federal attainment standards for particulate matter (PM) for several years. This is attributed to anthropogenic and natural sources. State and federal agencies monitor valley air quality from selected ground sites These efforts can be enhanced by the broad spatial coverage provided by satellites. While previous studies show good correlations between satellite derived aerosol optical thickness (AOT) and PM data on the East Coast, this is not the case in the San Joaquin Valley. Students compared PM2.5 ground data from California Air Resources Board (CARB) and Interagency Monitoring of Protected Environments (IMPROVE) sites with MODIS and MISR satellite data in an effort to understand the reason behind this discrepancy.

AOT values from the Aerosol Robotic Network (AERONET) offer an opportunity to verify satellite accuracy to coincide with the AOT and PM2.5 comparison. Fieldwork was conducted using the MicroTops II Sun Photometer to measure AOT values in the city of Fresno and correlate with satellite data. Good correlation between Moderate Resolution Imaging Spectroradiometer (MODIS), Multiangle Imaging Spectroradiometer (MISR) and AERONET was found. Statistical and spatial analysis of satellite and ground data, demonstrated weak correlations between AOT and PM2.5. Further investigation into the effects of meteorological conditions or aerosol layers aloft is needed to determine the causes of the weak correlation.

Pacific Region Integrated Climatology Information Products (PRICIP) Project

Hurricanes, typhoons, and cyclones devastate coastal areas throughout the world, especially in the Pacific region. The strong winds, heavy rains, and high seas elements that accompany tropical storm events are of interest to researchers and forecasters alike. DEVELOP interns teamed with NOAA researchers to enhance their ongoing Pacific Region Integrated Climatology Products (PRICIP) project by integrating NASA mission data products. The PRICIP project will eventually become an interactive decision support tool that will assist decision makers in mitigating and recovering from natural hazards, reducing coastal vulnerability. DEVELOP's contribution to this ongoing project included creating hindcasts for three past extreme storm events. The hindcasts were in the form of interactive geovisualizations, and highlighted the strong winds, heavy rains, and high sea storm elements that were of interest to NOAA researchers. These interactive geovisualizations will contribute directly to NOAA's PRICIP decision support tool, and will be accessible to researchers and the public through a web browser. This project will continue in 2008.

Fig. 46: Snapshot from the animation of Super Typhoon Pongsona's track combined with precipitation.

Harnessing the Sensor Web through Model-based Observation

PI: Jennifer L. Dungan

Supporting Programs:
- *NASA Earth Science Technology Office, Karen Moe*
- *Advanced Information Systems Technology Program, Steven Smith*

Scientists are designing complex, interdisciplinary campaigns to exploit the diverse capabilities of Earth-sensing instruments on satellites and aircraft. In addition, platforms, sensors, data systems, etc., are being configured into webs, clusters, constellations, and other distributed structures to improve the quality and extent of observations. International efforts, such as the Global Earth Observation System of Systems (GEOSS), intend to encourage coordination across systems launched by different nations. These advances in the complexity of science campaigns, and in 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. This project is helping to build an information infrastructure to enable the scheduling of coordinated observations involving multiple sensors to execute science campaigns involving multiple assets.

An Earth science campaign is a sequence of observations over time that collectively carry out an Earth science goal, such as comparing pre-wildfire and post-wildfire states to detect burn scars or mapping changing proportions of urban, agriculture and land uses over large areas. This project seeks a method to create plans for Earth science campaigns from a sensor web based on a high-level, or abstract, description. Scientists specify constraints that must be met in accomplishing the goals; primarily these constraints include sensor requirements, temporal requirements, location requirements, and cost.

This three-year project began in 2007. The problem was broken down into two parts (Figure 48, page 66), the generation of an "abstract plan", to be parsed from a goal specification, and the generation of a "concrete plan" that contains all the specific information needed to actually complete the campaign. The sequences of actions needed in a campaign as modeled using finite state processes. The action sequence is converted to graphical form by the Labeled Transition System Analyzer (Magee and Kramer, 2006) and made, subsequently, into a concrete "finite state" machine (FSM). Parameters given or implied by the user are saved in a parameter table to be used in the concrete plan. A mapping between states and transitions in the finite state machine and actual commands needed to retrieve or store data is enabled by a procedure map. Finally, the FSM, parameters and procedures are combined by a "web manager," or system that interfaces with sensor data systems or data archives.

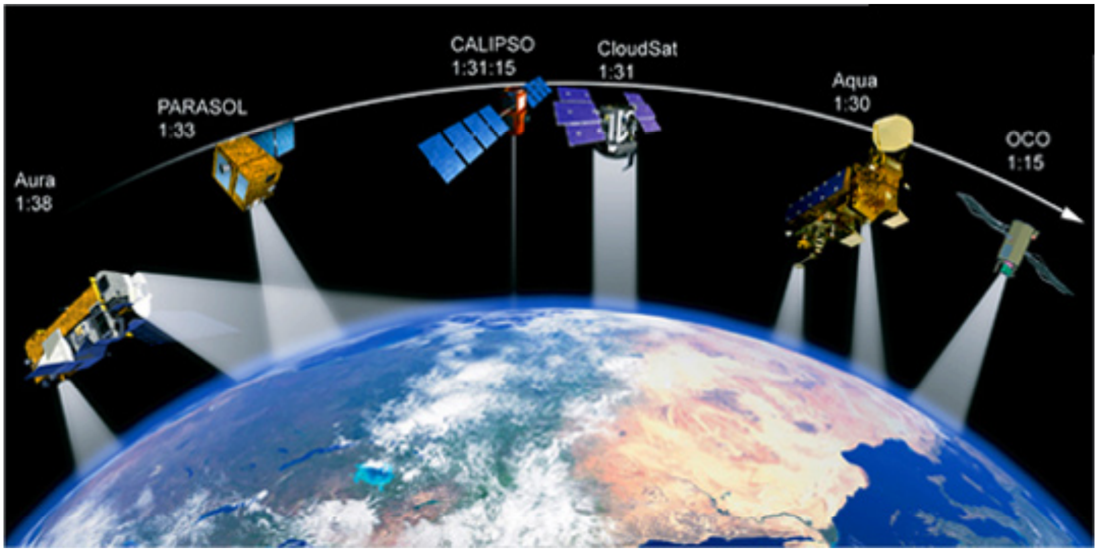


Fig. 47: NASA's A-train satellite constellation including sensors launched since 2000.

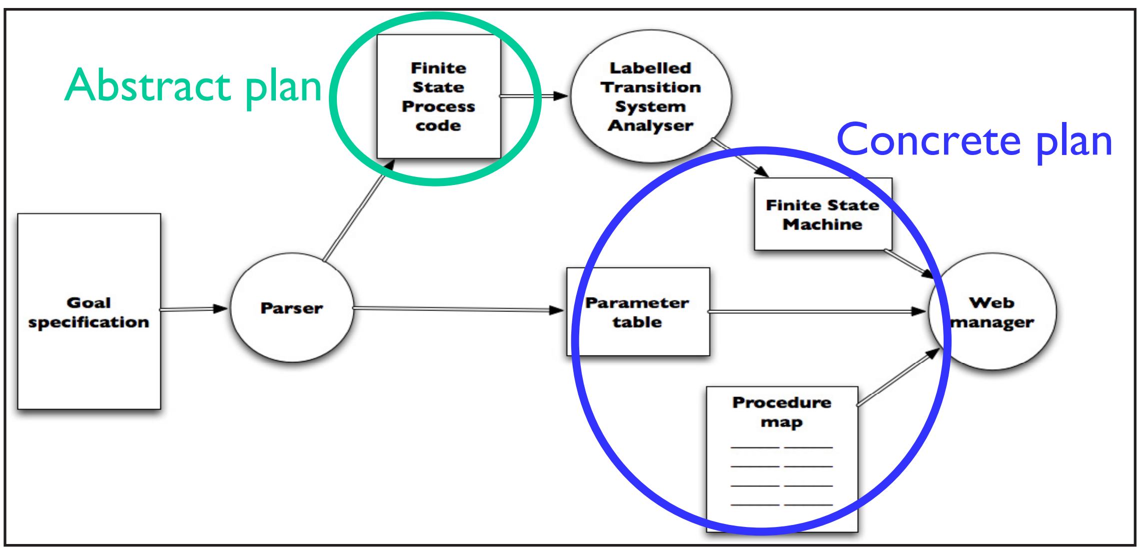


Fig. 48: Conceptual architecture for the planning system being designed.

The project is using the Terrestrial Observation and Prediction System, a web manager for ecological modeling and forecasting, to prototype early versions of the system.

The project principal investigator is Robert Morris of the Intelligent Systems Division, NASA Ames Research Center.

Project collaborators are from the Earth Science Division.

Reference: Magee, J. and J. Kramer (2006) Concurrency: State Models & Java Programs, 2nd edition, John Wiley & Sons.

Invasive Plant Species Management and Ecosystem Assessment on Western Lands

PI: David Bubenheim

Supporting Program:
NASA Applied Sciences Program, Invasive Species
Program Manager: Woody Turner

This is a collaborative project with the US Department of Agriculture involving both the Agricultural Research Service (USDA-ARS) and Natural Resources Conservation Service (USDA-NRCS). A combination of remote sensing and simulation modeling is being adapted to assess the condition of western lands and to quantify the impact of environmental change and invasive species on ecosystems. The objective is to utilize the unique capabilities of NASA to enhance the USDA capability to assess and plan conservation efforts in the Western United States.

Several prominent invasive species such as saltcedar (*Tamarix spp.*), yellow starthistle (*Centaurea solstitialis*), cheatgrass (*Bromus tectorum*), knapweed (*Acroptilion repens*), tall whitetop (*Lepidium latifolium*), cheatgrass (*Bromus tectorum*), and red bromegrass (*Bromus rubens*) and important aquatic weeds, such as waterprimrose (*Ludwigia hexapetala*), are targeted due to their environmental, social and economic importance in the Western United States. Remote sensing imagery (both airborne and satellite) is being used to assess invasive species distribution and spread, as well as to determine control methods impact and control success. Linking the remote sensing with ecosystem simulation models such as the Soil Water Assessment Tool (SWAT) provides significant improvement in representation of important ecosystem processes. Current emphasis is placed on characterizing cover and spread of invasive plant species and predicting potential ecosystem impact, and quantifying the impact and effectiveness of conservation practices aimed at reducing ecosystem vulnerability to invasive plant species. In 2007 efforts focused on linking remote sensing sources with the ecosystem model, to input invasive species coverage and density, and developing new model components characterizing the impact of a species on ecosystem functions

The ALMANAC (Agricultural Land Management Alternative with Numerical Assessment Criteria) model is a component in SWAT and provides a robust tool with demonstrated potential for application in simulating growth of rangeland plants and competition within communities. However, ALMANAC requires inputs describing structural and developmental characterization, biophysical performance and resource use efficiency for realistic simulation for both natives and invasive plants. Initially, model input data are being developed for rangeland plant communities and prominent invasive plants. Additionally, ALMANAC was originally developed to describe agricultural ecosystems. In 2007, we initiated the process of developing model input data for rangeland plant communities and prominent invasive plants not included in ALMANAC. The model is adapted to respond to species and functional community types that are discriminated using remote sensing methods. As a result, we have focused on two model invasive plants, yellow starthistle and cheatgrass, to develop remote sensing methods and define plant community performance response to a range on environmental factors necessary to drive ALMANAC.

Invasive species can rapidly invade areas and alter ecological processes, ultimately moving formerly diverse ecosystems towards pure stands of the invasive plant. The physical effect of invasion can dramatically alter the landscape and changes both the function and form. Management on invasive species impacted lands is very different from those dominated by native communities. The effective response of SWAT to the impacts of invasive species (environmental effects, soil erosion, water and nutrient use, biological diversity, etc.) is critical to assessment and management planning. The widespread invasion of cheatgrass in the western rangelands and associated changes in plant community characteristics is a prominent factor in the increased frequency and scale of wildfires. A dense and continuous carpet of high-fuel load cheatgrass replaces low-density bunch grasses as the cheatgrass effectively utilizes water and nutrients in the spring before most native plants and rapidly out competes them. Our controlled environment studies show that the elevated temperatures and CO_2 levels associated with climate change on areas of the western U.S. such as the Great Basin, elevated temperatures and CO_2 levels, further promote invasive species competitive advantage.

Remote sensing provides the critical land cover and climate information required to define the current state of the landscape. When combined with appropriate ecosystem models the combined NASA / USDA effort should supply a valuable tool for assessment and planning for western land management that is responsive to changing environment and invasion of exotic plants.

NASA's Airborne Remote Sensing of Coral Reefs for Ecosystems Research

PI: Liane S. Guild

Supporting Program:
NASA Interdisciplinary Research in Earth Science (IDS)
Program Manager: Woody Turner

NASA's suborbital assets have been used to fly over strategic coral reef sites in Puerto Rico in 2004 and 2005 to collect high resolution imagery to support coral reef ecosystem biodiversity research. In 2005, the most devastating regional-scale coral reef bleaching event on record occurred in the Caribbean due to increased sea water temperature. NASA's 2005 airborne mission acquired data just following the bleaching event for assessment of the coral following bleaching. The goal of the research is to quantify the optical properties of the shallow water coral reef ecosystem in La Parguera, Puerto Rico and to investigate change in the optical properties in these reefs following the Caribbean bleaching event.

The airborne sensors consist of a high resolution digital camera system (DCS) and the Airborne Visible Infrared Imaging Spectrometer (AVIRIS), a hyperspectral imaging sensor. NASA's airborne platforms supporting these payloads include the ER-2 and Twin Otter aircraft. Coincident to the airborne missions, field spectra were collected underwater for water column characterization and developing spectral libraries of benthic types (coral, algae, and seagrass) to relate to the AVIRIS data for creating benthic habitat maps and analysis of within and between habitat spectral variations. The expected outcomes of this research for coral reef ecosystems are improved interpretation of coral reef habitat variability and change and enhanced benthic habitat classification algorithms.

In 2007, the team focused on development of preprocessing algorithms to correct the AVIRIS hyperspectral data for stray light features, atmospheric constituents, and sun glint. These corrections enhance the remote sensing signal of the coral reef ecosystem on the sea floor as seen from the sea surface. The next step is to correct for water column effects so that the optical properties of the benthic types can be distinguished. Further field spectra of the reef bottom types are being processed for the image processing algorithms to output the reef classification map.

Continued on page 71

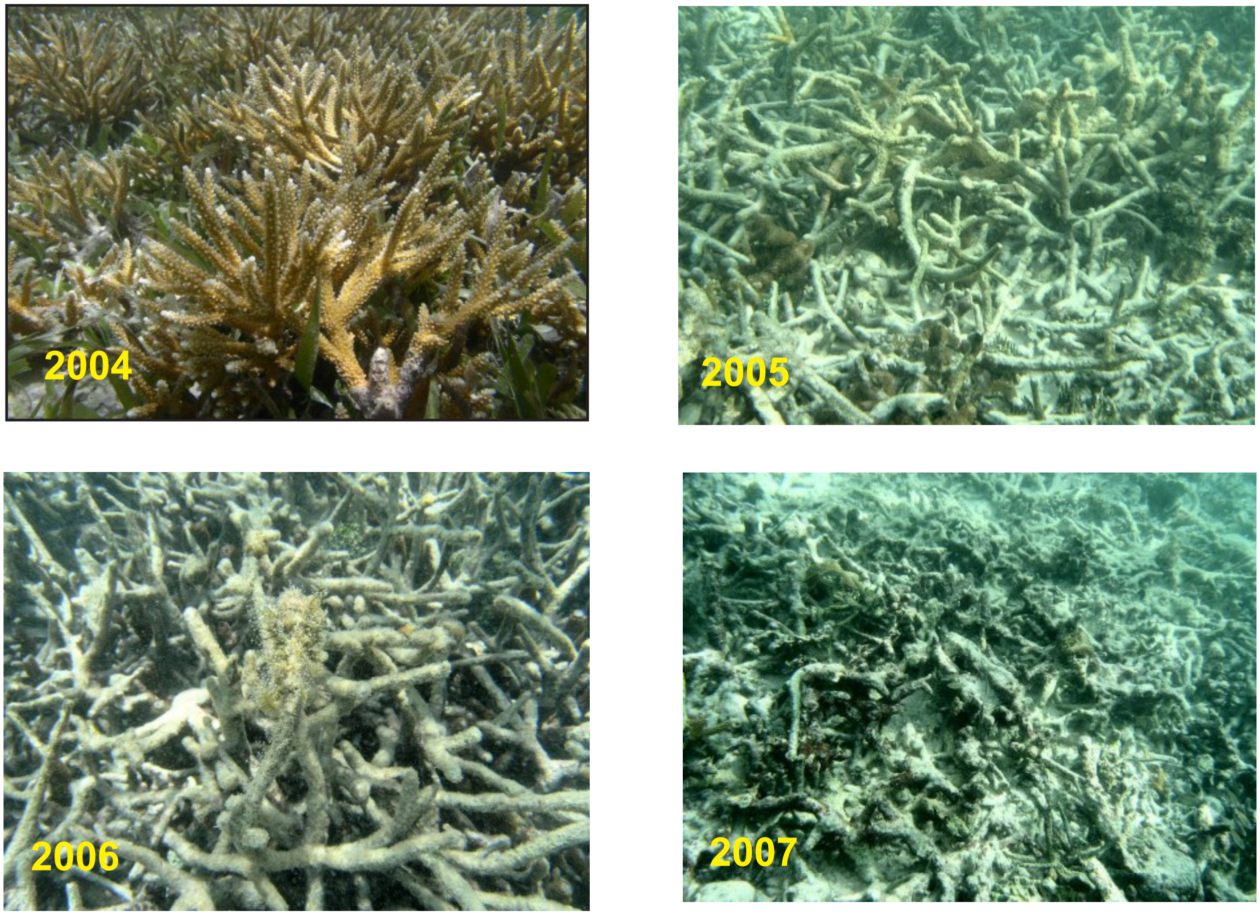


Fig. 49: Acropora cervicornis (staghorn coral) degradation in La Parguera, Puerto Rico following the 2005 Caribbean coral reef bleaching event and Hurricane Dean in 2007.

Fieldwork Deployment to Puerto Rico, November 2007

Guild, Randy Berthold (ARC SGE), Brad Lobitz and Jeremy Kerr (CSUMB), in collaboration with Dr. Roy Armstrong (University of Puerto Rico), conducted fieldwork in La Parguera, Puerto Rico. Fieldwork in La Parguera patch reefs included collection of field spectra in established transects and new transects of coral reef bottom types for evaluation of the current status of the patch reefs, percent cover of coral (healthy, pale, rubble, diseased) and other reef benthic types (soft coral, algae, sand). We continue to monitor previous sites and note that most of the coral that has died, remains dead and the coral rubble has algal overgrowth. There are few sites with limited evidence of coral regrowth. Last year there was a site with a large stand of elkhorn coral (*Acropora palmata*) that was in good health. However, this year due to severe wave action from Hurricane Dean (August 16, 2007) the *A. palmata* existed as piles of rubble with algal overgrowth.

Airborne Hyperspectral Mission Fieldwork, Puerto Rico, December 2007

Guild, Berthold, and Lobitz supported University of Puerto Rico's airborne hyperspectral mission over coral reefs lead by Dr. James Goodman. The mission covered an extensive area in southwest Puerto Rico from Nov. 28 to Dec. 21, 2007 using the AISA sensor (http://galileo-gp.com/aisa_eagle.html). This mission was originated to support ongoing research at UPRM related to hyperspectral remote sensing, with a particular focus on benthic aquatic ecosystems. The Ames team stationed in La Parguera and worked at the main study sites of the IDS project collecting field spectra of bottom types and photo grids along 10 m transects. Goodman is a Co-I on the IDS project and this airborne hyperspectral data will complement the IDS project AVIRIS data.

Fernando Gilbes (University of Puerto Rico at Mayaguez) was a project participant and collaborator.

Website: http://earthscience.arc.nasa.gov/sge/coral-health/

NASA Ikhana UAS and AMS-Wildfire Sensor Support to Southern California Firestorms, October 2007

PI: Vincent G. Ambrosia

Supporting Program:
NASA Applied Science Program, Disaster Management
Program Manager: Steve Ambrose

In late October 2007, Santa Ana winds helped develop and spread over eleven major wildland fires in the Los Angeles and San Diego regions of Southern California. The fires, spread by the 40-80 knot winds, pushed through populated areas and devastated a region of wildland, homes, and businesses. Over 500,000 people were evacuated in the region.

On October 22, the National Interagency Fire Center (NIFC) in Boise, ID and the California Governor's Office of Emergency Services (CA-OES) requested NASA airborne and remote sensing resources to assist in observing and monitoring the fast-moving fires. The Wildfire Research and Applications Partnership (WRAP) team at NASA-Ames and the Airborne Sciences team at NASA-Dryden stepped forward and rapidly developed a series of mission profiles to support real-time information-collection missions using the new NASA Ikhana UAV platform and an advanced, autonomous thermal sensor system developed by NASA-Ames. The WRAP team had recently completed four major western U.S. fire missions, demonstrating the real-time fire information capabilities of the sensor and long-duration UAV flights. The two NASA Center teams quickly re-configured the platform and sensor and prepared for an emergency support mission by the morning of October 24.

On October 24 at 8:35 AM PDT, the NASA Ikhana UAS took-off from NASA-Dryden to begin an all-day mission of collecting thermal imagery data over 10 fires raging in the southern California area. Data collected by the AMS-Wildfire scanner on the Ikhana were autonomously processed on-board to provide real-time, critical fire hot spot detection information and accompanying thermal imagery to each of the fire Incident Command Centers and the various County Emergency Operations Centers (EOC). By the time the Ikhana had landed in late afternoon, the sensor had collected, processed and transmitted 100 thermal-infrared data scenes and many more fire-detection shape files. These real-time, GIS-enabled products were in the hands of disaster managers within minutes of collection. This success led to a request for further support by the agencies and an additional three missions were subsequently flown.

(Continued on page 74)

Fig. 50: (above): NASA's Ikhana UAS with the AMS-Wildfire Sensor installed in the wing pod, during flights over the Southern California wildfires in fall of 2007.

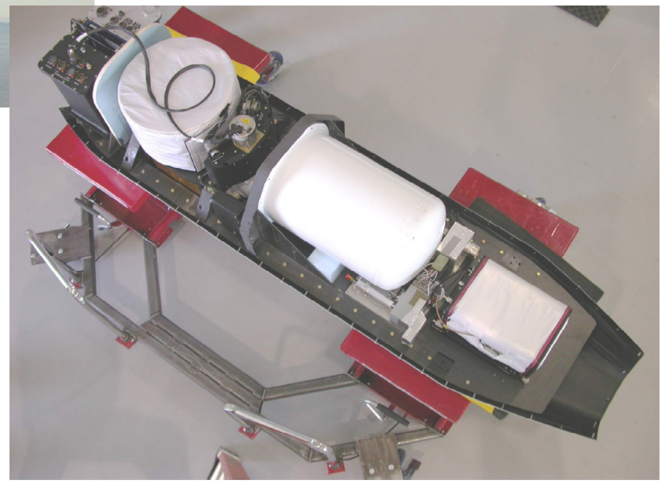


Fig 51: NASA Autonomous Modular Sensor (AMS) – WILDFIRE Instrument mounted in the wing-pod for flight on Ikhana during the fire imaging missions.

Fig 52 (left): Ikhana Ground Control Station at NASA Dryden during flight operations for So. California firestorm emergency support missions.

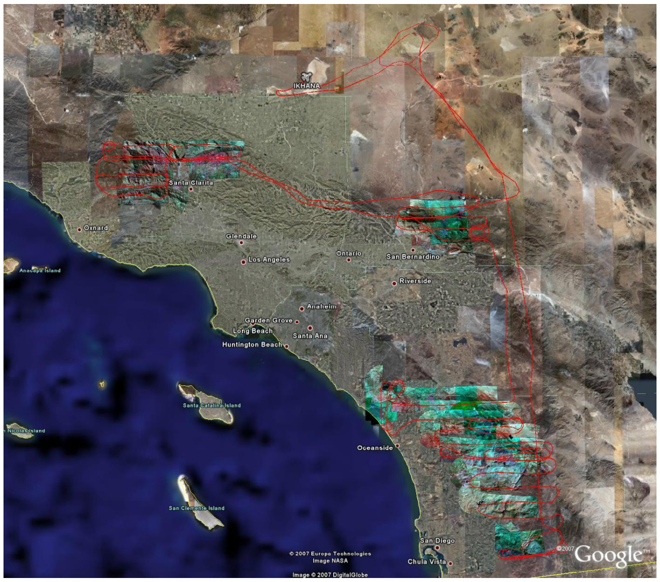


Fig. 53: Ikhana flight track during first mission on October 24, 2007 shown as red line. AMS-Wildfire sensor thermal infrared data over the fire areas shown for the areas collected. Data displayed in GoogleEarth.

Each of the ICs and EOCs employed the AMS-Wildfire data extensively for day-to-day fire management and resource deployment. The IC and EOC teams readily adapted the GoogleEarth visualization capability into their operations to allow AMS-Wildfire information integration with other critical data layers (weather, terrain, population areas, etc).

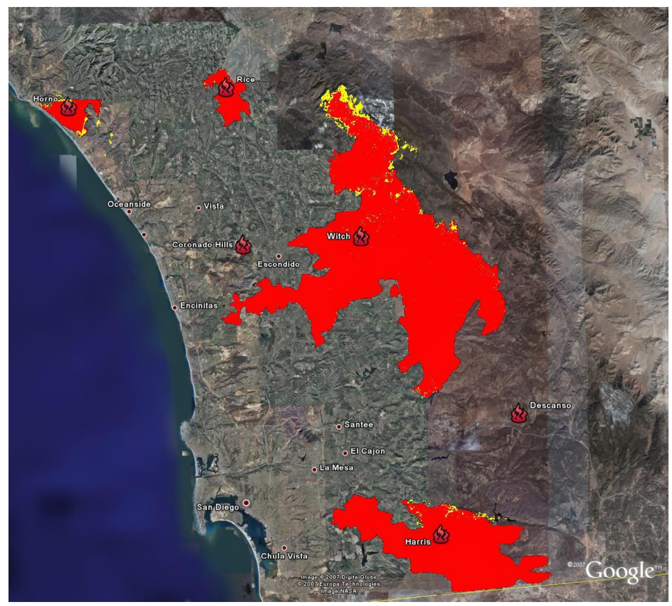


Fig. 54: Incident Fire Perimeters of San Diego County Fires on Oct. 25 (red) with AMS-Wildfire-acquired fire detect data (in yellow) collected that same day, showing the real-time fire progression beyond known fire containment lines.

Southern California Firestorm Support Missions - Between 24-28 October, the NASA Ikhana UAS with the AMS-Wildfire sensor on-board, flew four missions over the wildfires. Each day's mission profile changed, depending on the fire priority. Each data collection were relayed in real-time to all the ICCs and EOCs operating on the fires. Missions were flown on October 24th, 25th 26th and 28th. A total of ~100 scenes were collected each mission day and relayed to ICC and the EOCs.

By October 28th, some of the mission focus changed to collecting Burn Severity imagery to support ecological recovery efforts in the affected areas. The multi-channel capabilities of the AMS-Wildfire allowed real-time, sensor-reconfiguration in-flight for either active fire mapping or burn severity to be seamlessly collected and disseminated.

Mission Series Summation - During the four Southern California wildfire imaging missions, a total of ~36 hours of Ikhana UAS operations occurred. Up to eleven fires a day, including the Harris, McCoy, Witch, Poomacha, Horno / Ammo, Slide, Rice, Grass Valley, Buckweed, Ranch, Magic, and Santiago fires, were imaged with real-time data provided to ICCs and EOCs.

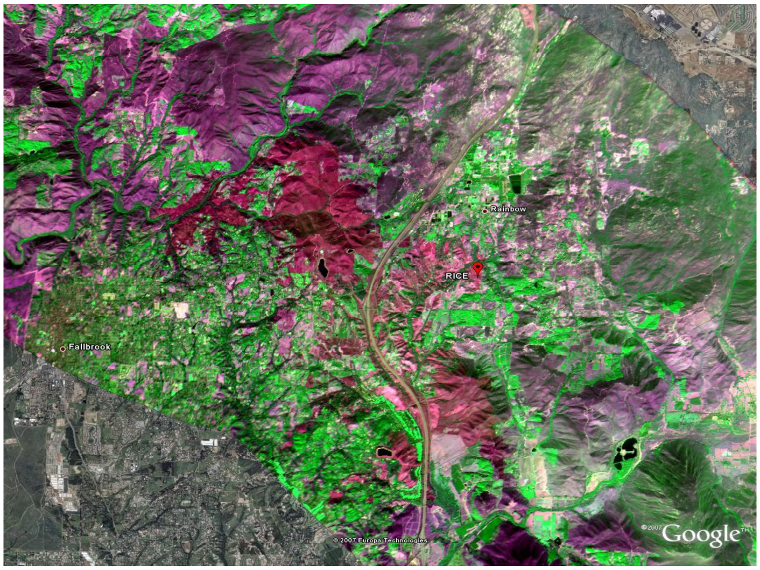


Fig. 55: AMS-Wildfire-collected, post-fire Burn Area Emergency Rehabilitation (BAER) imagery from the Rice Fire on 28 October 2007 showing the various burn severity conditions (purple hues) Displayed in GoogleEarth for visualization ease by fire managers.

Post-fire, burn-assessment imagery was also collected over various fires to aid teams in ecosystem rehabilitation on those fires. Over 400 total AMS-Wildfire images were collected during the four missions, with total downloads exceeding 40,000. The emergency support missions were an overall success and demonstrated the important role of federal agencies integrating capabilities into disaster areas of national concern.

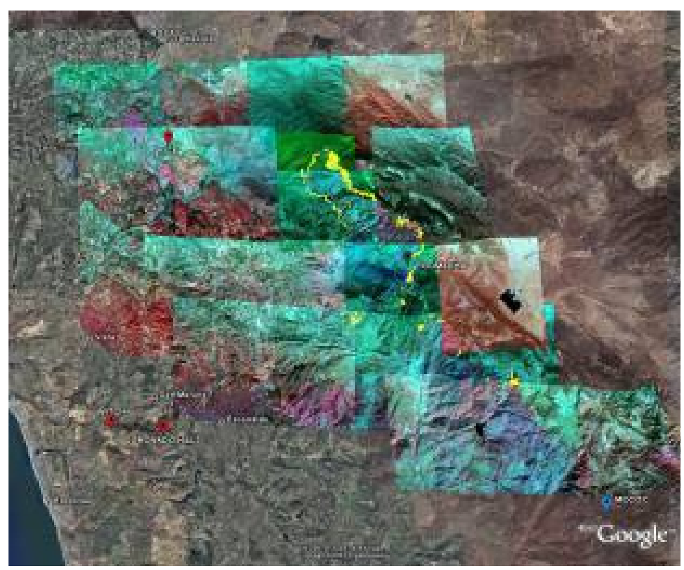


Fig. 56: AMS-Wildfire sensor-derived active fire hot spots (in yellow) overlain on the AMS-Wildfire 3-band thermal IR composite imagery for the Poomacha /Witch Fire in San Diego County. Data collected on 24 October 2007 and relayed in real-time to the fire Incident Command Center. Data displayed in GoogleEarth.

Open water, inundated vegetation and upland vegetation discriminated through a disturbing atmosphere

PI: Vern C. Vanderbilt

Supporting Programs:
NASA Earth Science Applications, Remote Sensing Science Program (Discontinued)
Program Manager: Diane Wickland

Methane is an important greenhouse gas. The areal extent of Boreal wetlands, source areas for methane, is poorly known, which contributes uncertainty to present day energy and carbon budgets and to projections of future climates.

In this research we applied optical remote sensing technology to discriminate inundated plant communities, open water areas and non-inundated (upland) areas with reference to a model of the reflectance of surface waters, Fig.47, noting that high radiance values measured in and near the subsolar direction signals the presence of surface water (either open water or inundated plant communities; source areas for methane), in contrast to dry upland plant communities (methane sinks).

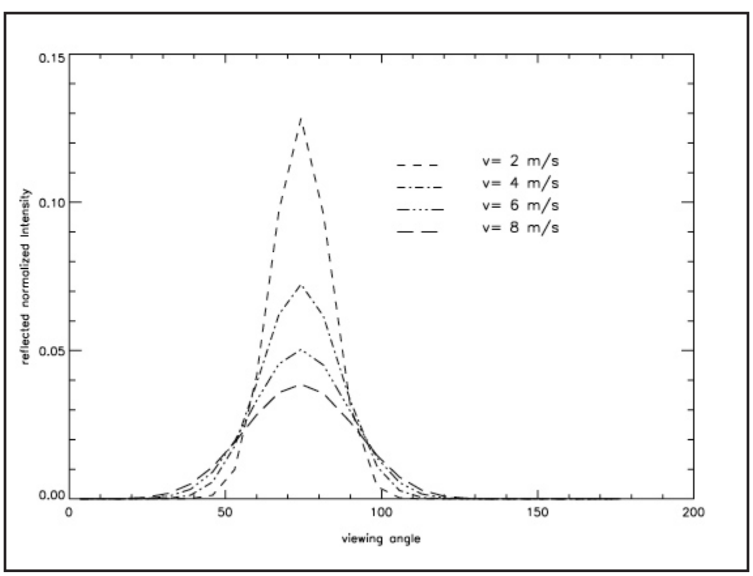


Fig. 57: Reflection function of a wind driven water surface for surface wind speeds of 1 m/s, 4 m/s, 6 m/s and 8 m/s. The sun incident angle is 22°.

Our discrimination procedure, Fig. 48, extends our prior approach to include correction for the disturbing effects of the atmosphere. Here we take advantage of our previously published result (Vanderbilt et al., 2002) that a light-to- moderate wind ruffles open water areas but does not ruffle surface waters sheltered by emergent vegetation, which allows us to discriminate the BRDF signatures for these two cover types. When compared with these two surface water cover types, upland exhibits small radiance values in all view directions. Our discrimination approach depends upon a ratio of two atmospherically corrected surface reflectances, one for the subsolar direction and the other 14° away from the subsolar direction, a direction selected through application of the discrimination algorithm to a synthetic data set. The results point to the probable importance of atmospheric correction to the discrimination procedure.

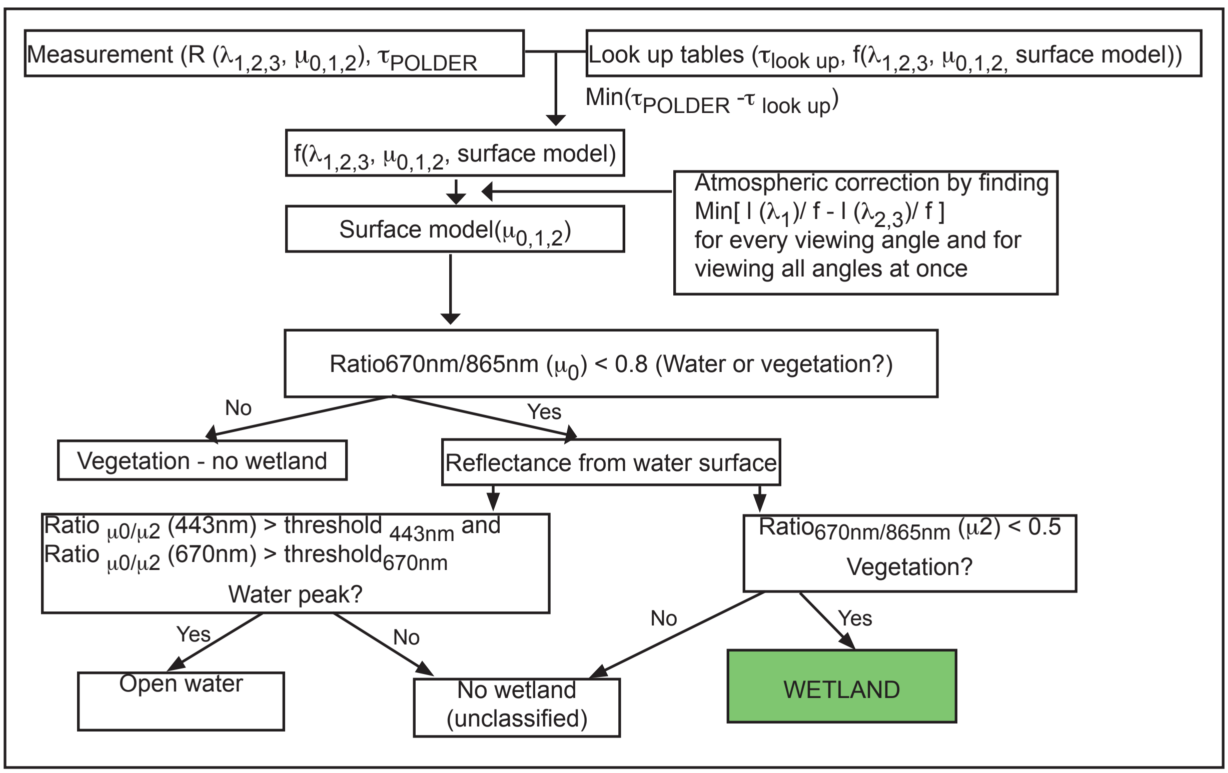


Fig. 58: Flowchart for discrimination of open water, inundated vegetation ('wetland') and upland vegetation ('no wetland').

SIERRA: Sensor Integration Evaluation Remote Research Aircraft

PI: Matthew M. Fladeland

Co-Is: Lesli Monforton (NRL)
Randy Berthold (NASA ARC)
Steve Dunagan (NASA ARC)
James Brass (NASA ARC)

Supporting Program:
NASA SMD Airborne Science Program
Program Manager: Andrew C. Roberts

SIERRA is a joint project with the Naval Research Laboratory to demonstrate, flight qualify, and operate a medium class, long range unmanned aircraft system (UAS) for Earth science missions and sensor development and testing.

The objectives of this project are to:

- Demonstrate unique capabilities for a low-cost, medium-class UAS for airborne science missions
- Enable airborne observations from remote or dangerous locations for extended durations >10 hours.
- Provide a test-bed for the development of new sensors

The SIERRA airframe, designed by Lesli Monforton (NRL), with heritage from the Dakota and Ghost UAVs, is very stable in flight and flown easily by humans and autopilot. The engine has excellent efficiency enabling extended range, while providing power to as much as 100lbs of payload for 10 hours. With few modifications this aircraft will likely be able to carry a payload of 50lbs for 20 hours. The Meterological Measurement System (MMS) developed by Paul Bui (NASA ARC) will be integrated on SIERRA to provide an inertial navigation unit, GPS, temperature, pressure, and winds. An instrument for measuring CO_2, under development through a NASA SBIR will be flown with the MMS system to derive CO_2 fluxes over land and ocean.

Progress and accomplishments in 2007:

Ship-1 completed assembly, wiring, ground tests

Ship-2 completed assembly, wiring, ground tests, flight

Objectives in FY08:

Ship-1 resolve engine issues, cooling modifications

Ship-2 integrate autopilot, modify fuselage and possibly tail boom for extended duration and range, develop multi-mission nose cones

- Begin the integration and testing of remote sensing instrumentation payloads

- Establish user communities and initiate mission planning to support remote sensing research
- Develop collaborations with external research/user communities
- Support NRL sponsored mission and payload

Fig. 59: The SIERRA in its first radio controlled flight over Fort Hunter-Liggett, CA.

Tracking Land Use Change Impacts on Carbon Pools

PI: Christopher S. Potter

Supporting Programs:

- *NASA Carbon Cycle and Ecosystems*
  Program Manager: Diane Wickland
- *NASA Applied Sciences Program, Carbon Management*
  Program Manager: Woody Turner

The conversion of natural land cover into human-dominated cover types is a change of global proportions with unknown environmental consequences. The time series of the Enhanced Vegetation Index (EVI) product, derived from NASA MODIS 250m data may prove useful for analysis of land cover conversion. This project examined time series EVI of California. Images from Google Earth provided independent visual evidence of land cover change for areas in California that exhibited multiyear change in EVI between 2001 and 2005. An example is shown in Figure 55. Red circles identify the center location of the MODIS 250-meter path where recent land cover change appeared as forest harvest and is apparent in the Google high resolution image. This unique merger of NASA MODIS data with commercial imagery from space is a notable advance in land cover change studies.

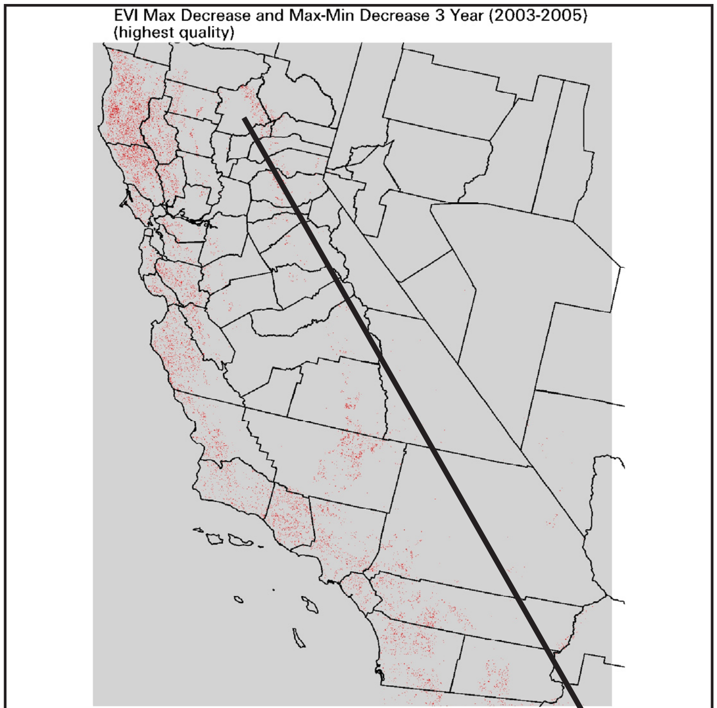


Fig. 60

Figs. 60 and 61: High-resolution satellite image showing cleared patches of land near the Plumas National Forest, California. Red circle lines (Fig. 61) are 1-km buffer boundaries around the center locations of NASA - MODIS 250-meter areas from which loss of green cover was detected.

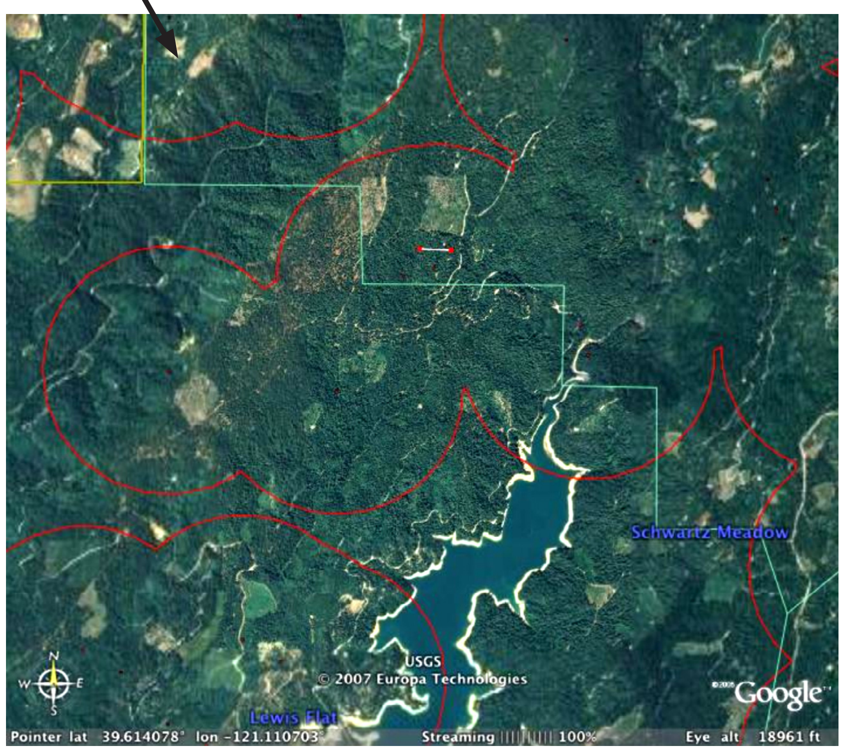


Fig. 61

Airborne Science Office

Matthew M. Fladeland
ASO Manager

The NASA Ames Airborne Science Office within the Earth Science Division (ESD) supports the Airborne Science Program (ASP) 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 ASP 5-yr plan provides an annual update on the near to mid-term requirements for the ASP 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 mission managers. The plan consists of major campaigns in each discipline, sensor development 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 airborne science program aircraft catalogue and the specifications of facility sensors and sub-systems. conferences, publications, workshops, and interviews provide inputs to science requirements for each of the focus areas. These summaries and analyses are reviewed and approved by the Program Managers and SMD executives and are updated on biannual 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 ASP 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.

Airborne Science Technology Roadmap

The ASP Technology Roadmap is a joint effort between the Science and New Technology program elements to assess the requirements for aircraft systems within the Earth Science community, determine technology solutions, and provide guidance on the priorities for future development and deployment of unmanned systems. The project convened six technology working groups that provided guidance to the program manager in the following areas: manned aircraft, unmanned aircraft, power and propulsion, UAS airspace policy, ground control and visualization, and payload accommodations and communications.

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.

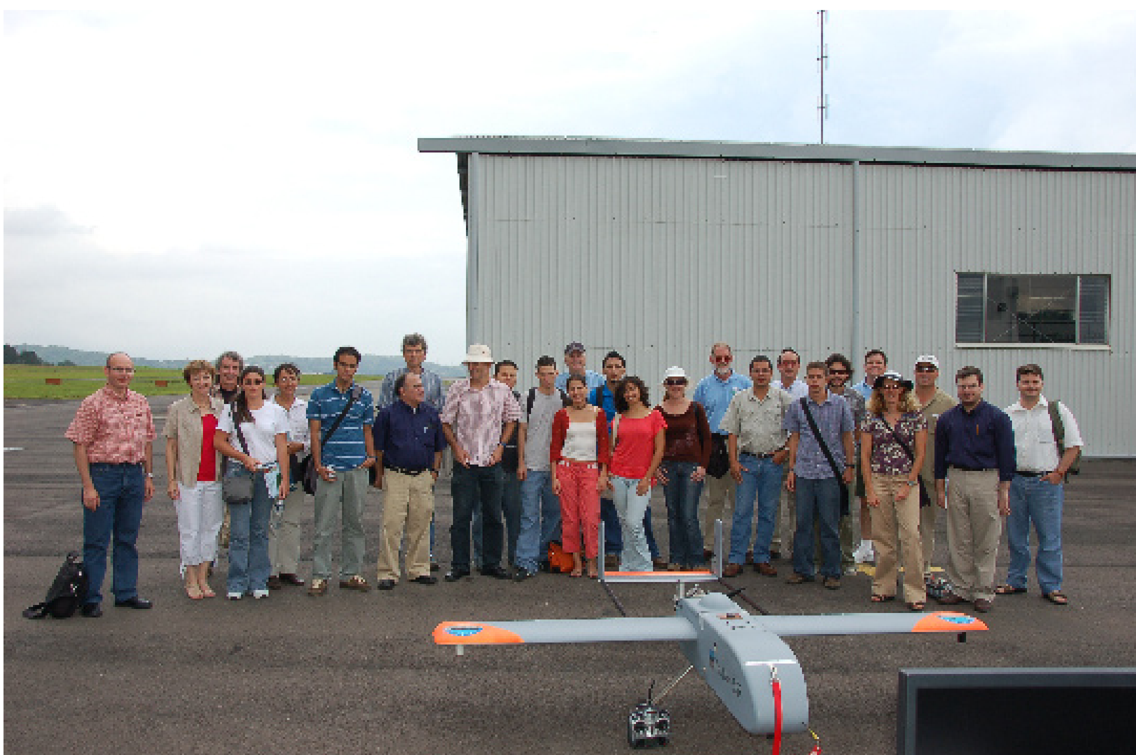


Fig. 62: UAV Remote Sensing Workshop students view the Vector P at Tobias Bolanos airport in Costa Rica during the ISRSE Conference.

Airborne Science & Technology Lab

Jeffrey Myers
Manager

The Earth Science Division Airborne Science and Technology Laboratory (ASTL) supports NASA through the development and operation of instrumentation and related science support activities. The ASTL is part of the Ames University Affiliated Research Center, and is staffed by the University of California at Santa Cruz. Although specializing in infrared imaging devices, it also conducts a range of other support activities for the Airborne Science Program, including platform integrations and engineering services for the catalog aircraft. It is also actively developing technologies to increase the portability and interoperability of science instrumentation between platforms.

Technology Development

Autonomous Modular Sensor. The ASTL developed the new Autonomous Modular Sensor (AMS) system in 2006 for use on large UAS platforms, such as the Ikhana Predator-B or the Global Hawk. This year the Western State Fire Missions provided the opportunity to refine the AMS further and demonstrated the concepts of extended autonomous operation, extensive on board data reduction, and sat-com-based networking. A key element in this system is a combined data reduction and high-speed telemetry module, which will be a fundamental building block for future science missions on these platforms. (Fig. 63)

The hardware and software infrastructure developed on this project are directly applicable to the observation of other rapidly evolving phenomena with a long-duration UAS as well (e.g. hurricane evolution, the development of convective systems, tracking algal blooms or oil spills, etc.)

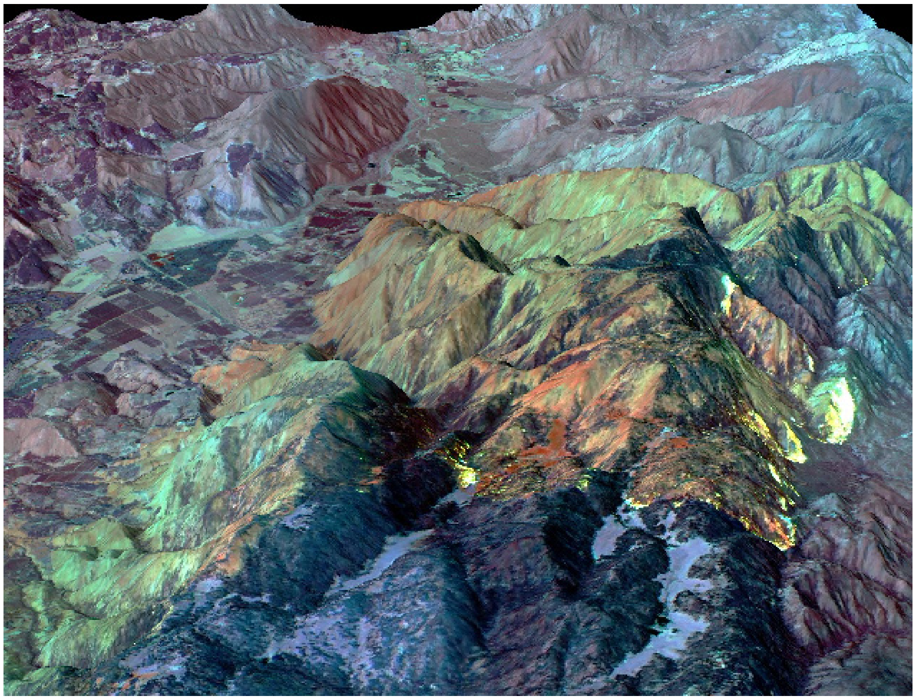


Fig. 63: AMS imagery acquired 28 October 2007, over the Poomacha Fire, northeast of San Diego California. It is a thermal mid-IR, and shortwave IR composite of an active fire line. The data have been geo-located and draped over a 10m digital elevation model.

Next-Generation Navigation Data Recorder System: The ASTL will develop a new system for the NASA airborne science platforms that will combine the functions of airborne navigation data recording and real-time data communications for payload instruments to scientists on the ground. This is a joint project with Dryden Flight Research Center. Dryden will incorporate some of its existing REVEAL system architecture, together with a universal interface to wide-band satellite communications systems, and other features developed under the AMS sensor project. The new system will provide common instrument interfaces across all the core NASA aircraft, and will incorporate some of the new data standards being developed by the IGWADTS inter-agency data systems working group. The new system will be primarily Ethernet-based, and will serve as a common gateway to future sat-com systems, as they become available.

Digital and Video Camera Systems. A new nadir-viewing time-lapse digital video camera installation (MVIS) was tested successfully on the ER-2 during the TC4 deployment. This is intended for visual scene context documentation, in support of the primary science payload. The higher-resolution still-frame DCS camera system was also further refined, this year on the WB-57 and B200 aircraft (Fig. 64, page 86).

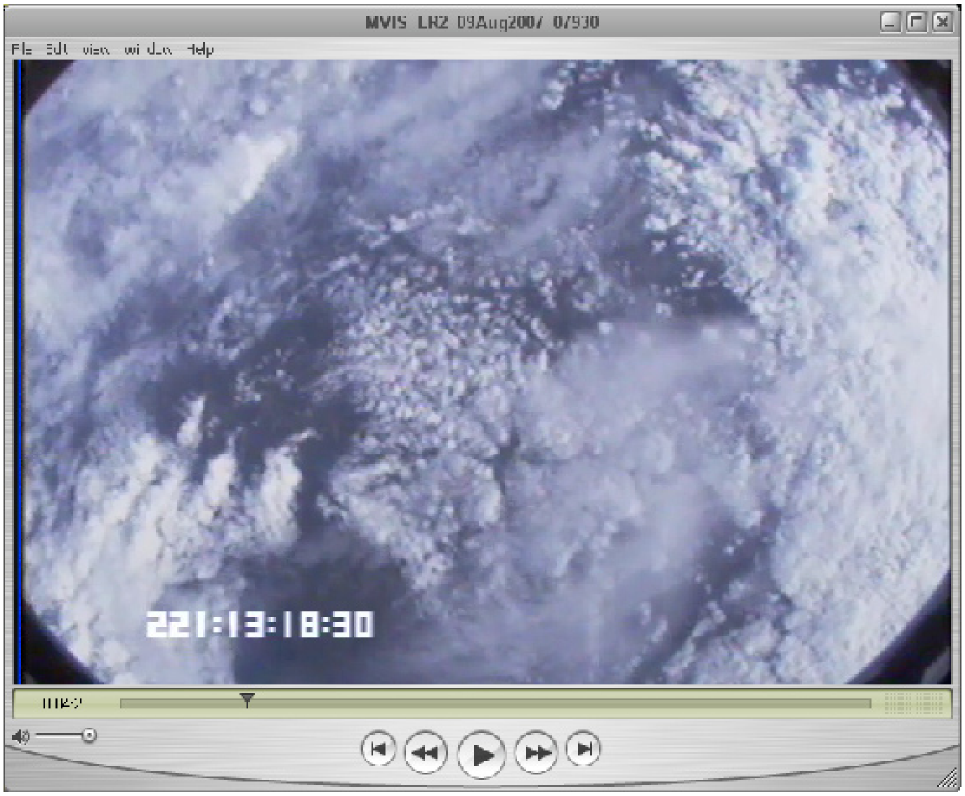


Fig. 64: MVIS video frame acquired during TC4 flight 07-9030, 9 August 2007.

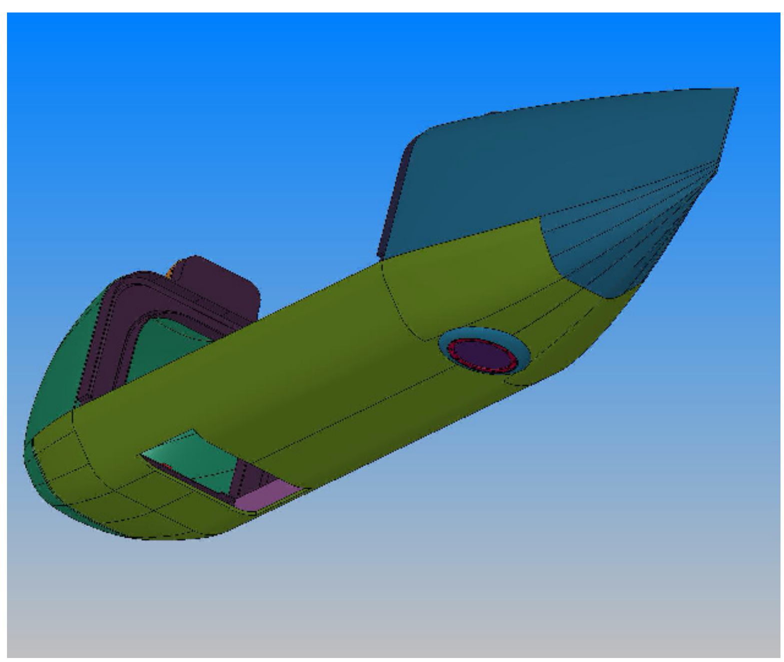


Fig. 65: Design for 5" aft window to be added to the Ikhana sensor pod tray.

Science support

ASTL provided engineering support to various instrument teams, including integrations of the ARGUS and HyMap systems on the WB-57. We also designed a window for the Ikhana sensor pod, together with an instrument mounting structure. Initially intended to accommodate the Langley MicroMAPS radiometer, the window will support a variety of nadir-viewing instruments. (Fig. 65)

ASTL personnel also provided flight planning services and mission logistics for various remote sensing missions on the ER-2, B-200, Caravan, J-31 and Ikhana.

Sensor Operations

The ASTL operates the MODIS and ASTER Airborne Simulators (MAS and MASTER) for the EOS Project Science Office and the larger NASA Earth science community. These

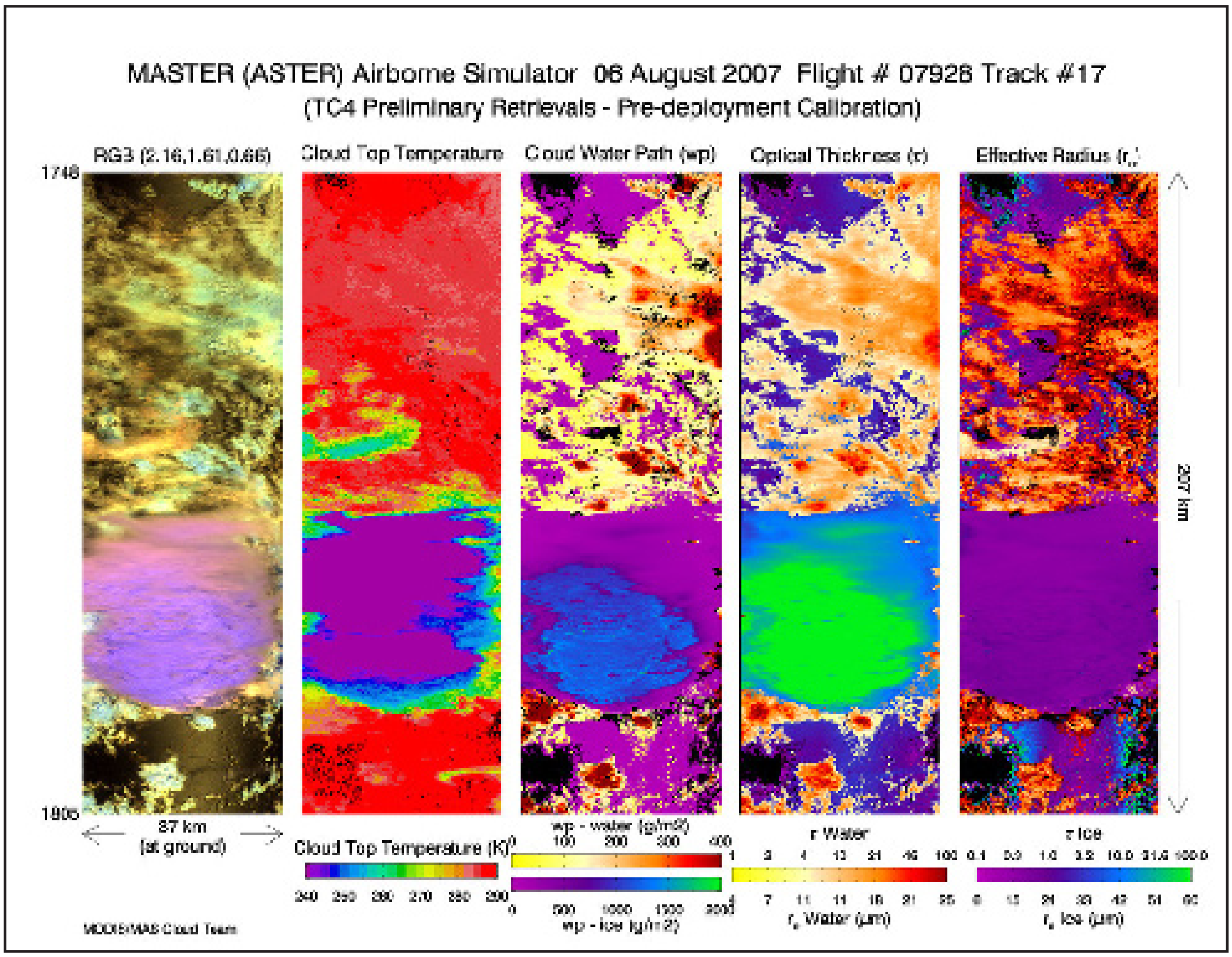


Fig. 66: MASTER Level-2 science products, produced in the field during TC4 by the GSFC MODIS team.

two systems were flown on a total of 44 science missions in 2007, including the TC4 experiment in Costa Rica (Fig 66, page 87), and various multi-disciplinary process studies onboard the ER-2 and DoE B-200 aircraft. NASA completed a large scale campaign to acquire data/night MASTER data with the DoE B-200 over the extensive seismic fault systems of southern California in August 2007 (Fig 67). The ASTL also maintains a suite of facility assets for the Airborne Science Program, including stand-alone precision navigation systems (Applanix POV-AV IMU/DGPS units), video and DCS digital tracking cameras, and environmental housings for instrument packaging. This utility hardware is available for community use via the Airborne Science Program Flight Request process.

Instrument Calibration

The ASTL Calibration Laboratory is a community resource that is co-funded by the Airborne 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 LCROSS Lunar imaging suite.

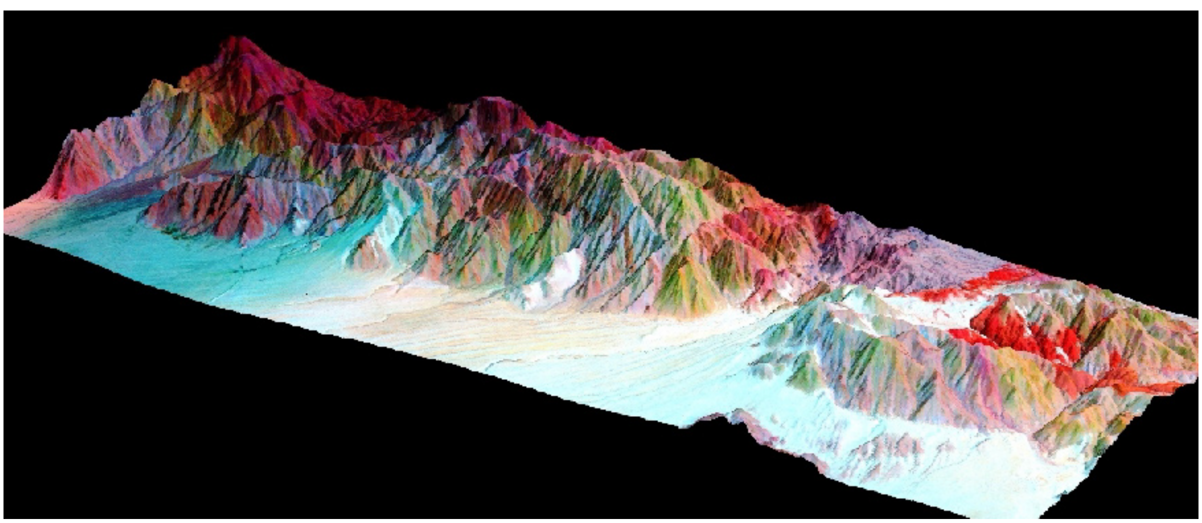


Fig. 67: MASTER imagery acquired September 1, 2007, over the Buillion Fault, east of Victorville California. This 3D image consists of thermal, mid-IR, and visible bands, highlighting geologic structure.

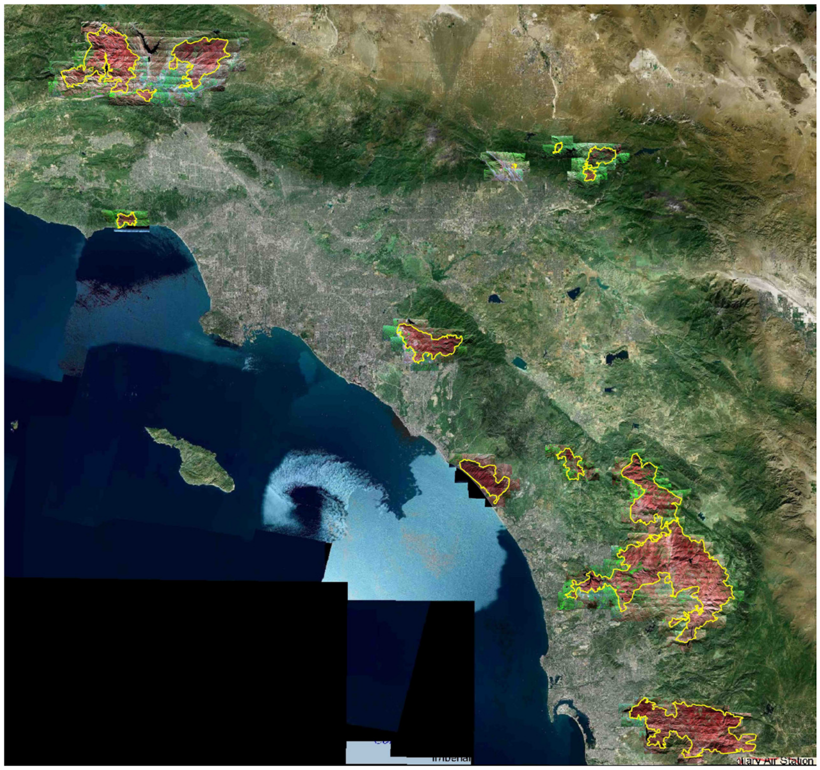


Fig 68: MASTER imagery acquired 5 November to 15 November 2007 over the extensive southern California burn sites.

FY08 Planned Activities

The prototype version of the new fleet-wide standard navigation data recorder will be deployed in the coming year, together with modified payload experimenter interface panels. Every effort will be made to accommodate legacy instruments with the data streams they are currently using, as the program moves toward a higher level of payload portability between the core NASA platforms. The new system will be installed onto both the Global Hawk and Ikhana UASs as well. Payload engineering support will be provided to new instruments integrating onto those platforms, as well as for the upcoming NOVICE missions on the WB-57. The design of a miniaturized, high speed data capture system applicable to the new generation of Offner hyper-spectral imagers will be developed, and initially tested with the new Headwall HSI. The Ocean Color Imager version of the AMS UAS sensor will also be tested, most likely on a Twin Otter aircraft. Post-fire MASTER data assessments of the southern California burn sites will continue with planned re-flights of all of the burn sites in April and August (Fig. 68). The MASTER sensor will also be migrated to a Twin Otter, and possibly the LaRC B200 as well.

Earth Science Projects Office

Michael S. Craig
ESPO Director

ESPO is supported by the Earth Science Division in NASA's Mission Directorate (SMD). The team provides science mission planning, project implementation and post mission support for scientific field campaigns, nationally and internationally, for over 20 years. ESPO has supplied this core functionality for over 20 years and has a record of success unequaled by any similar organizations in the world.

To ensure overall success, ESPO tailors each mission 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. ESPO assists Program Managers execute project activities, and it provides all the necessary communications and infrastructure support to complete mission objectives.

In recent years the Earth Science Project Office has been in very high demand. Research missions are becoming more and more multifaceted as agencies and universities combine resources and assets to answer more complex questions about the Earth's system. In 2007, ESPO managed one of the largest international NASA Earth Science missions to date: the Tropical Composition, Cloud and Climate Coupling (TC4) mission in Central America. TC4 included three NASA aircraft, multiple ground sites, and over 300 scientists. [Quote from Freilich]

In 2008 the ESPO group will participate in two large international NASA missions: the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS), conducted as part of the International Polar Year (IPY), and the Southern Ocean Gas Exchange Experiment in South America (GASEX). In addition to those missions, the ESPO is involved with other research efforts including the first integration of instrument suites onto the new Global Hawk Unpiloted Autonomous System for research campaigns in 2009.

(Continued on page 92)

Fig. 69

Fig. 70

Fig. 71

Fig. 73

Figs. 69-73: Sciences from TC4. Clockwise from upper left: Media Day at the Presidential Hangar (Fig. 69); C-5 aircraft with full equipment load ready to transit from DFRC to Costa Rica (Fig. 70); ER2 debrief (Fig. 71); ground site in Las Tablas, Panama, with NPOL radar (left), NATIVE trailer (right) and radiosonde balloon (center) preparing for launch (Fig. 72); weather briefing (Fig. 73).

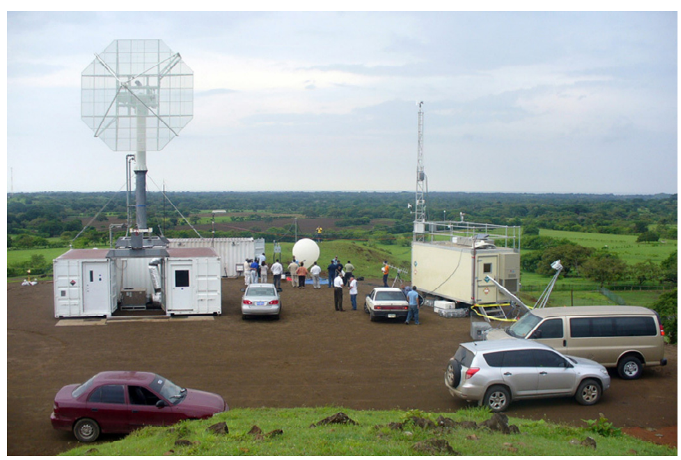


Fig. 72

ESPO mission management support is available to all of the NASA Science Mission Directorate Focus Areas. Current customers within the Focus Areas 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)

ESPO's unique capabilities are recognized by other agencies and organizations that have used ESPO to support their projects and programs. ESPO's non-NASA collaborators 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. Army, the U.S. Navy, and hundreds of commercial companies world-wide.

Airborne Science Program

ESPO plays a vital role in the direction of NASA's ASP through the Airborne Science Office at Ames. The team helps define the science requirements for the program through its field experience and the management of the Airborne Science Flight Request System. ESPO oversees aircraft and instrument transitions to minimize the loss of capabilities and plays a critical role in the development of new uses of Uninhabited Aerial Systems (UAS) and sensor web technologies.

ESPO shares the exciting results of its missions with the general public through direct interactions, press coverage and educational outreach.

Fig. 74: ESPO team at their home base of NASA Ames Research Center (clockwise, from top): Marilyn Vasquez, Mike Craig, Quincy Allison, Kent Shiffer, Steve Gaines, Sue Tolley, Dan Chirica, Mike Gaunce.

Appendix A

Earth Science Division 2007 Publications

Journal Articles

Alfred, J., M. Fromm, R. Bevilacqua, G. Nedoluha, A. Strawa, L. Poole, and J. Wickert. 2007. Observations and analysis of polar stratospheric clouds detected by POAM III and SAGE III during the SOLVE II/VINTERSOL campaign in the 2002/2003 Northern Hemisphere winter. *Atmos. Chem. Phys.*, 7: 2151-2163.

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