FOURTEENTH ANNUAL REPORT
JOINT CENTER FOR EARTH SYSTEMS TECHNOLOGY

A Cooperative Agreement Between:
University of Maryland, Baltimore County
and
NASA Goddard Space Flight Center

October 1, 2008 – September 30, 2009

The Joint Center for Earth Systems Technology

Fourteenth Annual Report
October 1, 2008 – September 30, 2009

This page intentionally left blank

Preface

This volume is the fourteenth annual report describing the scientific accomplishments and status of the Joint Center for Earth Systems Technology (JCET). This Center was established July 1, 1995 to promote close collaboration between scientists at the University of Maryland, Baltimore County (UMBC) and the NASA Goddard Space Flight Center (GSFC) in areas of common interest related to developing new technologies for environmental remote sensing. The Center's objective is to conduct multidisciplinary research on advanced concepts for observing Earth and planetary atmospheres, the solid Earth and planets, and the hydrosphere, all from ground stations, aircraft, and space-based platforms. This research continues to lead to improved understanding of global processes and increased capability to predict global environmental changes. The Center serves as a means to increase the effectiveness of university research and teaching resulting from the collaboration, and provides a venue to train personnel for research in relevant Earth science and technology areas. The NASA Earth Sciences Division and the Solar System Exploration Division have participated in establishing, funding, and collaborating with JCET. At UMBC, JCET is administered through the Office of the Vice President for Research. JCET personnel are currently associated with the university Departments of Physics, Geography and Environmental Systems, Chemistry, Mathematics and Statistics, and Computer Science and Electrical Engineering. JCET's administrative office is in the second building of the new technology park expansion at UMBC, which also includes space for a few faculty members and a conference room. JCET also has offices in the Physics and Academic IV-A buildings on the UMBC campus.

There are 35 JCET faculty members (listed in Section III.10). The number of JCET Fellows remained steady at 20 (listed in Section III.11). This category of JCET membership includes civil servants from NASA, other government agencies and private research institutions in addition to UMBC faculty. JCET research is also supported by two associate staff members (listed in Section III.12). Brief biographies of each JCET faculty and associate staff members are presented in Section III.8. The overall management and administration of JCET is governed by the executive board and carried out by an expert administrative staff, which also supports JCET's sister center GEST (listed in Section III.12). In the spirit of cooperation between UMBC and GSFC, the Director is also a Professor of Physics at UMBC, the Associate Director for Academics is an Associate Professor of Geography, and the Board Chairman and an Associate Director are civil servant scientists at GSFC.

The body of this report (see Section II) is divided into eight sections, each of which is devoted to the scientific activities of eight research groups. The eight groups are aligned with GSFC research areas. Within each section are presented brief accounts of group members' accomplishments, provided by the respective principal

investigators supported through a JCET task and/or grant from NASA or other government agencies that was active during the reporting year October 1, 2008 to September 30, 2009. Each report includes a description of the research, accomplishments for FY 08-09, and objectives for FY 09-10. Although some of the efforts were not initiated at the beginning of the fiscal year, research completed during this period that was supported by both JCET and previous sources is also included in these descriptions. References cited in the reports are listed in Section III.1, while those papers that were submitted, in press, or published in the refereed literature by JCET authors this fiscal year are also listed separately in Sections III.2 and III.3. The 64 refereed papers (and 26 others submitted for review), along with 173 conference presentations and publications and nonrefereed publications (see Section III.4) comprise the principal direct contribution of JCET scientists to the Earth sciences. In addition to their current research, JCET scientists planned for the future through submission of 60 grant proposals, listed in Section III.7.

JCET scientists also contributed to education at UMBC by teaching and mentoring graduate students in the Departments of Physics and Mathematics/Statistics. The 18 different courses they taught this fiscal year are listed in Section III.5. Colloquia and seminars are an integral method to share knowledge in the academic community, and JCET researchers regularly provide such instruction, as listed in Section III.6. In addition, JCET faculty are mentoring or providing direct supervision for 13 graduate students, and providing research opportunities for a number of additional undergraduate and graduate students from UMBC and other universities.

R. E. Hartle, Associate Director
J. B. Halverson, Associate Director
D. Eichenlaub, Acting Director
R. M. Hoff, Executive Director

September 2009

TABLE OF CONTENTS

This page intentionally left blank

Executive Summary

Maintaining Excellence In Earth Science Research

Now in its 14th Year, the Joint Center for Earth Systems Technology (JCET) continues to define and expand the frontiers of Earth Systems Science. All of us in JCET are extremely proud of the fact that our host institution, UMBC, has now been ranked #1 as an "up and coming" university by *U.S. News and World Report*. Less well-known, but just as significant, UMBC has also earned a top five ranking as a university that promotes undergraduate research and is the only public university in that group. Based on the latest fedspending.org rankings, UMBC earned honors as #4 in the nation for NASA funding for 2007 (as of press time, we were still waiting on the 2008 ranking). And we are also proud of our President Freeman Hrabowski III being named one of the top ten university presidents in the country by *Time Magazine*.

Dr. Forrest Hall, Senior Research Scientist in JCET, has received the highly prestigious William T. Pecora Award, conferred at the December 2009 AGU Meeting in San Francisco. This annual award recognizes outstanding contributions by individuals or groups toward understanding the Earth by means of remote sensing, and is sponsored jointly by the Department of the Interior and NASA. Dr. Hall works in the Goddard Office of Global Carbon Studies as part of NASA's Carbon Cycle Initiative, served as project manager for the Boreal Ecosystem-Atmosphere Study (BOREAS), and is principal investigator for the International Satellite Land Surface Climatology Project (ISLSCP). We congratulate Forrest on this well-deserved and highly acclaimed honor!

In the past year, both JCET and GEST have stayed connected with significant mission opportunities at NASA, and through our partnership with Northrop-Grumman Corporation, we have pursued opportunities with NASA's proposed Venture-class projects. Along with a NASA team of scientists in the Mesoscale Atmospheric Processes and Atmospheric Chemistry and Dynamics Branches, we have proposed a three-year mission to monitor hurricane intensification using the Northrop-Grumman Global Hawk Unmanned Aerial Vehicle (UAV). These missions will revolutionize the manner in which severe tropical storms are monitored, by providing up to 30 hours of uninterrupted surveillance of the storm and its environment. An additional venture class proposal was submitted by NASA Langley Research Center and UMBC to use NASA airborne assets to determine the relationship between column optical measurements and surface air quality measurements.

Since our last Annual Report, Dr. Lazaros Oraiopoulos left JCET for a NASA Goddard Civil Service position. Dr. Jeffrey Halverson, JCET Associate Director for Academics, received tenure in the Department of Geography. Mr. Ernest Hilsenrath, Visiting Professor of the Practice, retired from JCET in 2009. Mr. Hilsenrath spent the past

several years directing funding programs at NASA Headquarters under the auspices of an Intergovernmental Personnel Agreement (IPA), and he has been appointed as a JCET Fellow. Dr. Melöe Kacenelenbogen, a Research Associate in Dr. Raymond Hoff's laboratory, also left JCET for an NASA Postdoctoral Program (NPP) Fellowship at NASA Ames. Dr. Juying Warner was promoted to the level of Associate Research Professor and became affiliated within the Department of Geography and Environmental Systems. Dr. Tamas Varnai was promoted to Research Associate Professor and Affiliate Associate Professor in Physics. Three graduate students in Physics, supported under JCET Graduate Research Assistantships, graduated during Spring 2009: Ross Dixon obtained his M.S. in Physics and has matriculated in the Ph.D. program at University of Wisconsin-Madison; Dr. Nikisa Jordan, who earned her Ph.D. in Marine Estuarine and Environmental Systems, took a position with Northrop-Grumman Corporation in Azusa, CA; and Dr. Mengsteab Weldegaber, who also earned his Ph.D., took a post-doctoral position at the University of California at Davis. Ms. Katie Nguyen joined the JCET-GEST staff as a new business specialist, and Dr. Tom Low, who had served as GEST Associate Director, left our staff. And Dr. Raymond Hoff began enjoying a well-earned one-year sabbatical as JCET Director. During Summer 2009, he redirected his research efforts in the Physics laboratory, turning over the reins to Ms. Danita Eichenlaub, who is serving as the JCET Acting Director until Summer 2010.

Finally, we wish Dr. Franco Einaudi best wishes as he retires in 2009 from NASA Goddard Space Flight Center. Fifteen years ago, Dr. Einaudi's vision was to establish a cooperative research center between NASA Goddard and UMBC. Since that time, under the guidance of two center Directors (Dr. Harvey Melfi and Dr. Raymond Hoff), JCET has become an internationally recognized center of excellence in Earth sciences research. As you will note from the impressive body of scientific knowledge contained in this report, the continued world-class contributions of JCET to the Earth sciences continue to push the frontier of our discipline.

Raymond Hoff	Danita Eichenlaub	Jeffrey B. Halverson
JCET, Executive Director *Professor, Physics*	*JCET, Acting Director*	*JCET, Assoc. Director - Academics* *Associate Professor, Geography & Environmental Systems*

December 2009

II. TECHNICAL VOLUME

This page intentionally left blank

Global Modeling and Assimilation Office (Code 610.1)

This page intentionally left blank

NSF Grant:	CMG: Variational Approaches to Geomagnetic Data Assimilation
NASA Grant:	Assimilation of MOPITT Carbon Monoxide Observations
Task 49:	Carbon Cycle Data Assimilation *(Sponsor: M. Rienecker)*
Investigators:	Andrew Tangborn, Research Associate Professor, Mathematics; Weijia Kuang, JCET fellow, Goddard Space Flight Center; Steven Pawson, Goddard Space Flight Center: Ivanka Stajner, Noblis, Inc.; Gary Egbert, Professor, Oregon State University, Louis-Francois Meunier, Meteo-France.

Description of Research

Research is carried out in the field of data assimilation, with applications in Earth's core research (geodynamo), Carbon cycle research and stratospheric polar winds.

The geomagnetic data assimilation research group, funded by both NSF and NASA, is a collaborative project involving scientists and graduate students from UMBC, Goddard Space Flight Center, Oregon State University and Harvard University. This group has been employing techniques traditionally used in Numerical Weather Prediction (NWP) with the goals of predicting future changes to the Earth's magnetic field, and gaining better estimates of the fluid motion inside the Earth's core. Carbon cycle data assimilation, funded by a NASA MAP (Modeling Analysis and Prediction) grant, is concerned with developing the means to assimilate measurements of carbon species into the constituent assimilation system in the Global Modeling and Assimilation Office at GSFC. Stratospheric polar balloon assimilation uses Lagrangian observations from long-lived polar balloons to produce highly accurate analyses of the spring warming and polar vortex breakdown over the Antarctic.

Accomplishments for FY 08-09

Carbon cycle data assimilation has been focused on carbon monoxide observations from MOPITT (Measurement Of Pollution In The Troposphere) and SCIAMACHY (Scanning Imaging Absorption SectroMeter for Atmospheric CartograpHY). Tangborn and his team have published a study on the impact of SCIAMACHY observations on estimates of carbon monoxide in the GEOS-4 constituent assimilation system (Tangborn *et al.,* 2009). This work has shown that data assimilation can be used not only to improve estimation of the distribution of long-lived trace gases in the atmosphere, but also to help to improve the estimation of surface emissions.

The investigators have also been involved in the transition from the GEOS-4 to GEOS-5 data assimilation systems. The existing constituent assimilation system has been connected to the GEOS-5 system, to be run in a 'replay' mode, in which stored meteorological analysis fields are used to restart the model and transport the trace gases. This system efficiently makes use of the new GEOS-5 meteorological fields in the assimilation of carbon monoxide

observations.

The geomagnetic data assimilation group has continued testing and developing the current system, and the results of this work are summarized in Kuang *et al.* (2009). Work continues on improving the ability to forecast future changes to the geomagnetic field and improving estimates to the dynamics of the Earth's core. Tangborn continues to pursue national and international collaborations in this work and with continued funding from NSF. He and his team have begun to develop a variational data assimilation system in a collaborative project with Oregon State University. A review paper on geomagnetic data assimilation is being written with colleagues in France, and is the result of a terrestrial geomagnetism in Bern this past March.

Polar vortex studies have been carried out using observations from the 2005-06 Vorcore experiments. A student, Louis-Francois Meunier, from METEO-France visited the GMAO for 6 monhts. He developed a Lagrangian approach to assimilate the balloon positions rather than the derived winds using the GEOS-5 assimilation system. The goal of this work is to improve researchers' knowledge of the polar vortex that develops during the Antarctic winter and its subsequent breakdown in the spring. Assimilation of the balloon data is found to improve wind estimates at all times, especially during the vortex breakdown process. This should lead to better estimates of the duration and strength of the Antarctic ozone as a whole and to an improved understanding of climate change processes.

Objectives for FY 09-10

Work on geomagnetic data assimilation is continuing with a focus on variational methods. A post-doctoral researcher has been hired through Oregon State University who is developing the adjoint of the geodynamo model.

Carbon cycle research will be focused on the continued implementation of the carbon monoxide measurements from MLS, eventually expanding to AIRS and IASI. Tangborn also plans to begin to implement CO_2 observations from AIRS into the system as well.

Work on extending the state vector in GEOS-5 to handle several trace gases in the analysis is also planned for the coming year; however, this depends in part on the status of the GEOS-5 system, which is undergoing continued development and testing.

Software Integration & Visualization Office-SIVO (Code 610.3)

This page intentionally left blank

NASA Grant: The Swift Neurological Acceleration of Atmospheric Photochemistry and Aerosol Calculations [SNAPA]: Development and Application to Atmospheric Chemistry and Aerosol Simulations with a Focus on UT/LS Ozone

NASA Grant: Validation of Non-Coincident Trace Species Measured by AURA Using Trajectory Mapping and Statistical Analysis.

NASA Grant: An Objectively Optimized Sensor Web

NASA Grant: A General Framework and System Prototype for the Self-Adaptive Earth Predictive Systems (SEPS) for Atmospheric Chemistry - Dynamic Coupling Sensor Web with Earth System Models.

NASA Grant: Assimilation of Chemical Constituents for Evaluation and Intercomparison of Aura Observations: (ACEi-Aura)

NASA Grant: Validation of Non-Coincident Chemical Trace Species Measured by AURA Using Trajectory Mapping and Statistical Analysis

Investigator: David Lary, Research Professor

Description of Research

Lary's research is split into two main areas, beginning with the validation of earth observation data, in particular the observations made from the NASA Aura satellite. Lary has taken validation to the next level by using machine learning to cross-calibrate sensors and effectively account for inter-instrument bias. This greatly facilitates the use and fusion of multiple datasets to address key scientific issues, for example, ozone depletion. The second area is the development of the next generation of an autonomous earth observing system, based on a variety of distributed assets that form a 'sensor web'.

Accomplishments for FY 08-09

Eight works have been published during the reporting period: Bae *et al.*, 2008; Brown *et al.*, 2008; Lary, 2008; Lary and Aulov, 2008; Lary, 2009a; Lary, 2009b; Noelle *et al.*, 2008; Schoeberl *et al.*, 2008. Two of these were invited contributions (Lary, 2009a and 2009b), which look at the role of machine learning in the geosciences.

Several teaching contributions were made by Lary, including the 2009 PHYS440/660 Computational Physics course. He supervised UMBC Graduate Student Andy Rickert, who finished his masters in atmospheric physics entitled "Neural Network in Atmospheric Physics: Application to Lorenz-Mie Theory." Lary also supervised UMBC PhD Student Oleg Aulov for a project entitled "Objectively Optimized Earth Observation."

Lary was elected to the GSFC Science Directors Council and played a leading role in coordinating and compiling a report on recruiting and retaining staff for Laurie Leshin. He was cited as part of a NASA group achievement award.

Objectives for FY 09-10

The research over the coming year will be split into three main areas: first, the validation of earth observation data, in particular the observations made from the NASA Aura satellite; second, the use of machine learning in a variety of Earth Science areas; and third, the compilation and use of a boundary layer aerosol product for health applications produced from an intelligent fusion of CALIPSO, MODIS, OMI, and MISR data.

Earth Sciences Division
(Code 610.6)

This page intentionally left blank

CCNY Subcontract: Cooperative Remote Sensing Science and Technology (NOAA-CREST) Center (49100-00-02-B)

MDE Grant: Measurement of Nocturnal Low Level Jets and Air Quality Events over Baltimore with the UMBC ELF Lidar (U00P8201154)

Investigators: Rubén Delgado, Research Associate, JCET; Raymond Hoff, Director, JCET and GEST; Kevin McCann, Research Associate Professor, JCET/Physics; Meloë Kacenelenbogen, Research Associate, JCET; Nikisa S. Jordan, Research Associate, JCET; and, several co-investigators from institutions outside UMBC

Students: Jaime Compton, Undergraduate Student; Rory Holderness, Undergraduate Student; Patricia Sawamura, Graduate Student

Description of Research

Elastic and Raman lidar measurements have been conducted to measure the vertical distribution of aerosols and water vapor over the Baltimore-Washington metro area, to understand the transport of particulates and air pollutants. The UMBC Elastic and Raman lidar were operated for 95 days (over 700 hours of observations). Active remote sensing lidar measurements support the NOAA CREST Lidar Network, which monitors air quality in the vertical from multiple locations on the eastern coast of the United States; the North American Global Atmospheric Watch: Aerosol Lidar Observation Network, and Nocturnal Low Level Jet studies, sponsored by the Maryland Department of the Environment (MDE).

Accomplishments for FY 08-09

Lidar measurements carried out by UMBC's Atmospheric Lidar Group (ALG) provide a set of atmospheric profiles of water vapor and aerosols, by which analysts can query their vertical distribution in near real-time and compare them to the input of three-dimensional forecast models of aerosols. The lidar measurements have been useful for AURA/Aqua and CALIPSO satellite retrieval studies, performing instrument accuracy assessments and using data generated by various independent active and passive remote sensing instruments for case studies of regional water vapor and aerosol variability due to the long-range transport of smoke, dust and pollutants, and to determine the relative impact of long-range transport versus local emissions during nocturnal low level jet (NLLJ) and wintertime pollution events over the Baltimore-Washington region.

A CREST-funded initiative was the doctoral research of Nikisa Jordan, who retrieved planetary boundary layer heights from the CALIPSO lidar overpasses over the western hemisphere with a view to improving the Goddard GEOS-5 predictions of that variable. With Dr. Julio Bacmeister (GEST), Ms. Jordan has developed a hybrid PBL retrieval technique that can be automated to process a large number of CALIPSO overpasses and compare with GEOS-5 output. A manuscript is in preparation that documents the comparison of PBL height retrievals with the hybrid method and covariance methods to radiosonde

measurements.

UMBC is leading the management activities of the new World Meteorological Organization Global Atmosphere Watch Atmospheric Lidar Network (GALION), to which Dr. Hoff has contributed since its conception and current development. A NOAA CREST LIDAR Network whitepaper (Hoff *et al.*, 2009) was written with the purpose of identifying the unique contributions from lidar measurements to the US capability in profiling the lower troposphere.

Elastic lidar measurements aided the MDE justification of the "Exclusion of Air Quality Exceedances due to Exceptional Events: North Carolina Fires and 8-Hour Ozone and 24-Hour $PM_{2.5}$ Exceedances in Maryland on June 14, 2008". The transport of smoke from North Carolina to Maryland was enhanced by the formation of a LLJ. The characteristic signature of the NLLJ, a stratified and turbulent inhomogeneous boundary layer, developed in the elastic lidar timeseries. The NLLJ air parcel can travel in excess of 300 km along the eastern seaboard overnight to mix with the local air under the jet, ensuing vertical mixing during the daytime. Maximum wind speeds on that evening coincided spatially and temporally with the increase of aerosols near the ground, as ground-based $PM_{2.5}$ monitors recorded Moderate to Unhealthy $PM_{2.5}$ concentrations during and after the NLLJ event, clearly indicating the role it plays in the development of major air-pollution episodes.

During February 6-9, 2009, a wintertime pollution event developed over Baltimore, as meteorological conditions (warm air aloft, moisture and strong surface temperature inversion) enhanced particle matter formation. The elastic lidar measurements indicated a dominant presence of non-spherical particles within the planetary boundary layer. The increase in the lidar scattering signal throughout the pollution event showed agreement with the temporal trend of particulate matter concentrations recorded in downtown Baltimore. Ambient urban particulate matter that was collected on filters were examined with a scanning electron microscope (SEM) interfaced with an energy-dispersive X-ray analysis. This analysis indicated that the source of the non-spherical particles observed was road-salt dust, which was launched into the atmosphere as the salt was abraded from the roads.

Planetary boundary layer (PBL) heights from elastic lidar measurements have been generated with a wavelet covariance technique and compared to adiosondes launched in Beltsville, Maryland. The derived lidar PBL heights will be assimilated to improve the forecasting models' ability to reproduce current distributions of aerosols and oxidants in urban areas and to improve their accuracy in forecasting air quality and understanding of regional pollution dynamics.

Objectives for FY 09-10

Extinction, as well as optical depth derived from UMBC lidar observations, will be given to EPA Remote Sensing Information Gateway (RSIG) to be used in conjunction with MODIS, OMI, MISR, GASP, and CALIPSO data to compare with EPA ground based $PM_{2.5}$ sites and with CMAQ output from the NOAA-EPA model. Lidar observations will be integrated to the real

time monitoring of $PM_{2.5}$ from BAM, TEOM, nephelometer and sulfate particle analyzer instruments for the characterization of temporal and spatial changes of aerosols, oxidants, and their precursors, primarily by surface measurements near urban areas and their downwind. Ambient $PM_{2.5}$ filters will be collected at UMBC to determine the chemical composition of pollutants. These objectives parallel the Profiling Air Quality over the Baltimore project (see Dr. Kacenelenbogen's report)

The real-time planetary boundary layer height from lidar measurements will be assimilated to improve the EPA's and NOAA' s forecasting models' ability to reproduce current distributions of aerosols and oxidants in urban areas and to improve their accuracy in forecasting air quality and understanding of regional pollution dynamics.

JCET Task: Particle Absorption Characterization for the Retrieval of Aerosol Optical Depth from Calipso Observations

NASA Grant: CloudSat and CALIPSO Science Team and Modeling/Analysis of A-Train related data (NNH05ZDA001N-CCST)

Investigators: Sergio DeSouza-Machado, Research Assistant Professor, Physics, JCET; Omar Torres, PI (Hampton University)

Description of Research

Desert dust storms play an important yet not completely understood role in climate radiative forcing. Dust storms can be detected, tracked and studied from space using, among others, the broad suite of instruments on board NASA's A-train. Traditionally most studies use visible or ultraviolet passive instruments, as well as active lidar instruments; however, there is a wealth of information also available from AIRS, a hyperspectral infrared instrument on the Aqua platform.

UV/VIS instruments primarily retrieve optical depth information (as well as other important parameters, such as Angstrom coefficient), and their retrieval accuracies have been extensively validated against the ground-based AERONET sun photometer network. However, other than active (lidar) instruments, these UV/VIS instruments cannot be used at night. In addition, the VIS instruments cannot provide information about the height of the scattering aerosol layer, although this is possible with the UV instruments.

Conversely, AIRS thermal infrared radiance data can be used to detect cirrus cloud and dust aerosol layers, day and night, over ocean and land. In addition, since the detected radiation is primarily emitted by the scattering layer, IR instruments can be used to provide information about the vertical placement of the scattering layer. With this information, the UV aerosol studies can be further constrained to provide improved estimates of single scattering albedos, which is an important radiative forcing parameter.

This research focuses on extracting information about the height placement using AIRS thermal infrared radiances and ancillary information from MODIS-retrieved optical depths during the day. Data from a number of intense dust storms over the Sahara and Atlantic will be used. Preliminary studies of dust storms off the coast of West Africa in late August/early September 2006 have already been completed.

Accomplishments for FY 08-09

Some preliminary comparisons of atmospheric state retrievals from AIRS data against MODIS retrievals indicate that there is a straight-line relationship between the MODIS- and AIRS-retrieved optical depths, which varies systematically with placement of the dust layer. IR retrievals are inherently ill posed; therefore, the researchers plan to implement a 1D-variational retrieval scheme to stabilize the retrieval.

Objectives for FY 09-10

Torres and deSouza-Machado plan to start an intensive comparison of a number of collocated MODIS and AIRS dust-contaminated FOVS, to improve their height retrieval

algorithm. These results can then directly be used to improve collocated OMI retrievals in the presence of absorbing aerosols. The preliminary work will be done over ocean, but the researchers plan to extend the study over the Sahara as well.

NASA Grant: A Three-Dimensional Air Quality System with augmentation for SERVIR-Air (NNS06AA02A)

Investigators: Raymond M. Hoff, Professor of Physics and Director, JCET/GEST; Meloë Kacenelenbogen, Hai Zhang and Ruben Delgado, Research Associates, JCET; Amy Huff, Stephanie Weber, and Erica Zell, Battelle Memorial Institute, plus a number of agency collaborators.

Description of Research

3D-AQS is a NASA-funded Applications Science program to use satellite and ground-based remote sensing data to augment the EPA and NOAA air quality efforts. Designed to augment surface observations from EPA, data from the NOAA Infusing Satellite Data into Environmental Applications (IDEA) is pushed to the EPA's AirQuest and Remote Sensing Information Gateway (RSIG). Multiple satellite platforms (MODIS Terra and MODIS Aqua, OMI, and MISR) are used to provide aerosol optical depth data. Vertical profiling data from the UMBC lidar systems are used to provide planetary boundary layer heights and extinction profiles. The data will fill gaps between ground-based sensors and provide layers of continuous information, which can be used for comparison with models and health indicators. 3D-AQS has transitioned the IDEA product into an operational environment at NOAA NESDIS. In addition, Hoff and his team continue with the highly successful U.S. Air Quality Weblog ("The Smog Blog", http://alg.umbc.edu/usaq/).

As an augmentation to the project, the researchers have been funded to provide advice, guidance and training to create a parallel air quality analysis system in Central America through the SERVIR project. SERVIR has been a seminal project to incubate the use of satellite data into applications in Central America, but, until this project, had not studied atmospheric measurements of pollutants. Since biomass burning and Saharan dust impact Central America, increasing the experience of the participants in SERVIR is of interest to NASA and its agency partners. The project has cloned the U.S. Air Quality Smog Blog on servers running at The Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) into the "Blog de Calidad del Aire".

Accomplishments for FY 08-09

Hoff has reached the end of the original three-year period for the project and he and his team were granted a one-year no-cost extension, extending the period of performance for the project to April 30, 2010. Routine project management and communications with co-investigators and collaborators were conducted, including monthly team conference calls and bi-monthly reporting.

During the year they continued to operate the U.S. Air Quality Smog Blog, the REALM lidars, and the NESDIS IDEA site. They continued processing and delivering the next datasets to incorporate into AirQuest and RSIG. The status of incorporating these datasets is as follows: MODIS AOD were matched to $PM_{2.5}$ monitors across the U.S and the dataset was completed and submitted to AirQuest, quality assured, and available to EPA and select other users. GASP AOD was matched to $PM_{2.5}$ monitors and the dataset was completed,

submitted to AirQuest, quality assured, and available to EPA and select other users. MISR AOD was matched to $PM_{2.5}$ monitors and the dataset was completed, submitted to AirQuest, and has undergone final quality assurance. OMI NO_2 has been matched to EPA monitoring sites, and the dataset is completed and awaiting final quality assurance and incorporation into AirQuest. MODIS AOD has been gridded to 12×12 km^2 CMAQ grid with the dataset completed and is awaiting final quality assurance and incorporation into RSIG. GASP AOD has been gridded to the 12×12 km^2 CMAQ grid, with the dataset completed and awaiting final quality assurance and incorporation into RSIG. For lidar data, the UMBC ground-based lidar, averaged hourly with 15 m average vertical profiles for 2004-2008, has been prepared, including the incorporation of PBL heights and AOD calculation. This data will be submitted to RSIG when completed in fall 2009. Hoff and his team have received permission from CREST Lidar Network members (*e.g.*, CCNY) to incorporate their lidar datasets in RSIG. Finally, CALIPSO data was processed to match with ground-based sites and CMAQ 12 x 12 km^2 grids. Unfortunately, the CALIPSO project identified a problem with the extinction product in V2.01 and requested this version not be distributed until CALIPSO Version 3 is available in Fall 2009. This required an extension of the PI's project timelime.

The final remaining deliverable on the project is a benchmark demonstration of the NESDIS IDEA site, which will tentatively be held in late 2009 at NESDIS headquarters in Camp Springs, MD.

The project was augmented to support SERVIR-Air Activities at CATHALAC. To do so, Hoff and his team designed a new weblog, based on the Smog Blog (http://alg.umbc.edu/mac/), initially called the Mesoamerican and Caribbean Smog Blog, now called the "Blog de Calidad del Aire", to the SERVIR system at CATHALAC in Panama (www.servir.net/aire/blog). Posts are made regularly by CATHALAC (Mondays and Thursdays) and by the University of Panama (Wednesdays and Fridays). By the end of September 2009, two new bloggers from National University in Costa Rica will begin contributing regular posts to the Blog de Calidad del Aire. Hoff also has verbal commitments from members of the El Salvador Environmental Ministry to participate in the Blog, beginning in the next few months. With NOAA funding, Hoff and his team continued producing experimental daily near real-time MODIS Terra/Aqua AOD and GASP images of the Mesoamerican and Caribbean region for use on the Blog de Calidad del Aire. In addition, they analyzed historical monthly-average PM_{10} data from gravimetric monitors in Panama City, Panama and San José, Costa Rica, and daily $PM_{2.5}$ data from the new real-time monitor in Panama City. The ground-based monitor data are being compared to MODIS aerosol optical depth data.

They also conducted a 2.5-day satellite and "Blog de Calidad del Aire" training session at National University in Costa Rica on July 20-22. Participants included 26 local and regional air quality analysts. In collaboration with their colleagues at CATHALAC, the PI and his collaborators organized and hosted a 2-day workshop on "Communicating Air Quality Information in Central America"on September 10-11 in Panama City, Panama. Participants included local, regional, and national health and environmental officials and the air quality experts from Panama, Costa Rica, and El Salvador. Topics included how to communicate directly to the public, the media, and government officials. For the Communication

Workshop, the researchers prepared two one-page case studies of air quality events in Central America using satellite data.

Objectives for FY 09-10

The responsibility for 3D-AQS has been handed off to partner agencies (NOAA, EPA, and CATHALAC). Hoff and his collaborators have some completion work to do on the quality assessment of these data and program transfers. There is a benchmarking demonstration to complete for IDEA at NESDIS, and this will be a high-level presentation of the product to the funders.

For the CALIPSO extinction matchups, completion of the data by the end of the project will be very difficult. Version 3.0 of the CALIPSO algorithm will be needed to perform the matchups with the CMAQ model grid. Version 3 is not expected to be available until November 2009 and this will stress the researchers' ability to complete the work by the project end date. This part of the project may be reserved to a follow-on project, subject to available grant funding.

NASA Grant: **Profiling Air Quality over Baltimore: A Global Earth Observing System of Systems Test-bed Project**

Investigators: Dr. Meloë Kacenelenbogen, Dr. Raymond Hoff, Dr. Kevin McCann, Timothy Berkoff, Ruben Delgado, Dr. Hai Zhang

Students: Chris Cahoon, Jaime Compton, Rory Holderness, Patricia Sawamura

Description of Research

Particulate Matter (PM, $\mu g/m^3$) measured at the near surface is used as a standard by the US EPA (Environmental Protection Agency) to evaluate air quality. However, most PM-monitoring stations are located close to major urban areas, leaving large regions without any operational observations. Satellite remote sensing is well suited for daily monitoring of the total aerosol load (Kaufman *et al.,* 2002). The primary aerosol quantity derived from space-borne remote sensors operating in the solar spectrum is the Aerosol Optical Depth (AOD). The direct satellite AOD – PM comparison has been explored using retrievals from MODIS (MODerate Imaging Spectroradiometer), onboard TERRA and AQUA, (Kaufman *et al.,* 1998; Wang and Christopher*,* 2003; Chu *et al.,* 2003; Engel-Cox *et al.,* 2004; Li *et al.,* 2005; Koelemeijer *et al.,* 2006; Gupta and Christopher*,* 2008), MISR (Multiangle Imaging Spectroradiometer on board TERRA, (Diner *et al.,* 1998, and Liu *et al*., 2004) and POLDER (Polarization and Directionality of Earth's Reflectances), (Deuzé *et al*., 2001 and Kacenelenbogen *et al.,* 2006). These studies all emphasize the importance of understanding and considering some additional factors that strongly infer the relationship between PM and satellite AOD, that is, the vertical distribution of the particles, the type of aerosols, and the satellite's horizontal resolution and uncertainties on both satellite and PM measurements. The goal of UMAP-The Box (Urban Mid-Atlantic Profiling- The Baltimore mOnitoring eXperiment) is mostly to study these factors and their impact on air quality.

The information on the vertical distribution of the aerosols is provided by four different LIDARs (Light Detection And Ranging): an all-weather Micro Pulse LIDAR (MPL), an Elastic LIDAR Facility (ELF), a H_2O Raman Atmospheric Lidar Experiment (ALEX) and a volumetric scanning commercial LEOSPHERE LIDAR. Those four instruments allow the researchers multiwavelength LIDAR development and calibration in an urban/suburban setting. Other instruments, such as the Integrating nephelometer and the AERONET sunphotometer, are especially intended to constrain the AOD retrieval. They then will be able to assure the quality of LIDAR retrievals from the UV to the near IR wavelengths. This makes UMBC a good candidate to lead in the development and quality assurance of the WMO Global Atmosphere Lidar Observation Network (GALION). In addition to GALION, the UMBC site is envisaged to be a state-of-the-art LIDAR observation facility in the Global Earth Observing System of Systems (GEOSS).

The types of aerosols can indirectly be informed by their source. Combined with simulated air mass back-trajectories, the LIDAR measurements can inform on a local or long-range transport of aerosols. The volumetric LEOSPHERE scan over Baltimore

provides additional information to discriminate these sources against the background regional haze. While general information on particle size and shape can be inferred by the four LIDARS, the sunphotometer provides integrated total column aerosols properties (*i.e.,* size distribution, absorption properties). Finally, the amount of sulfate can be inferred by a Sulfate Particulate Analyzer (SPA), while the aerosol size distribution, shape, and qualitative chemical composition are inferred by a Scanning Electron Microscope (SEM), interfaced with an X-ray analysis.

Higher resolution satellite data will help to assess the detailed distribution of pollution plume over cities (Li *et al.,* 2005; De Almeida Castanho *et al.,* 2007). To achieve a higher spatial resolution from satellites, it's important to reduce the uncertainties in the satellite AOD retrieval over those urban areas. Uncertainties of satellite optical measurements can be investigated using the AERONET sunphotometer instrument. Satellite extinction measurements are strongly dependent on the surface reflectance underlying the atmospheric constituents. The heterogeneity of the surface cover in an urban environment like Baltimore increases the uncertainties in the estimation of the surface reflectance and, consequently, the AOD retrieval. These urban scale issues can be addressed with the 3-D aerosol structure information provided by the volumetric scanning LEOSPHERE LIDAR.

Conversely, although the PM values are usually determined using a TEOM, there is a well-known underestimation of the measurements caused by the evaporation of ammonium nitrate (Hodzic *et al.,* 2005). Uncertainties of PM measurements can be studied by comparing different particulate monitoring instruments like the Tapered Element Oscillating Microbalance (TEOM), the Beta-Attenuation Monitor (BAM) and the PARTISOL analyzer.

Accomplishments for FY 08-09

The vertical pointing Elastic LIDARS (ELF and MPL), the TEOM and Sulfate particulate sampling monitors, the Integrating nephelometer and the sunphotometer are now operational and providing near-real time measurements, although most of those measurements are not yet quality controlled and assured. The significant track record of observations over the last years has already helped the researchers identify pollution events (Engel-Cox *et al.,* 2006) and transport-related features, such as low-level jets (Delgado *et al.,* 2008). Elastic LIDAR measurements helped the MDE justification of Air Quality Exceedances due to exceptional events like the North Carolina fires on June 14, 2008. The aerosol type was studied during a pollution event in February 2009 using elastic LIDAR measurements (ELF), PM sampling and a Scanning Electron Microscope (SEM) interfaced with an X-ray analysis. Additionally, planetary boundary layer heights were generated using the elastic LIDAR (ELF) and compared to radiosonde launches in Beltsville, Maryland. Finally, ELF vertical extinction profiles were compared to the space-borne CALIPSO measurements for a few close overpasses during Summer 2007.

Objectives for FY 09-10

The PI's goal is to finish the setup, logging and quality control/ assurance of all the UMAP-TheBox instruments. Significant amounts of time will be spent on improving LIDAR AOD retrieval using a set of different instruments. Strong collaboration will be determined to

perform aerosol speciation and chemical characterization on a regular basis. Also, the researchers are planning a joint effort with NASA-GSFC to study the aerosol variability in a satellite sub-pixel and the effects of retrieving a finer satellite resolution. Finally, they will concentrate on assimilating UMBC measurements, like LIDAR-retrieved PBL heights, and help improve EPA's and NOAA's air quality forecasting models.

UMBC: **Remote Sensing of Volcanic and Anthropogenic SO_2 Emissions**

NASA Grant: **Near Real-time NASA Volcanic Cloud Data for NOAA, FAA and USGS Decision Support Systems (NNS06AA05G)**

NASA Grant: **Mapping SO_2 Emissions with NASA AURA Ozone Monitoring Instrument (OMI) and GOCART Model for Air Quality and Climate Science (ROSES 2005 Atmospheric Composition NRA)**

NASA Grant: **Validation of OMI L_2 Sulfur Dioxide Retrievals over Volcanic and Anthropogenic Sources (NNG06GJ02G)**

Investigators: Arlin Krueger, Research Professor, Physics; Nickolay Krotkov, Senior Research Scientist, Research Faculty, GEST; Kai Yang, Assistant Research Scientist, GEST; Eric Hughes, Research Analyst, JCET; Keith Evans, Research Analyst, JCET

Description of Research

Krueger's group leads the development and validation of sulfur dioxide (SO_2) algorithms for the Ozone Monitoring Instrument (OMI) on the Aura satellite. These data are being applied to detect volcanic eruption clouds in near real-time (NRT) for aviation hazard mitigation, and to quantify SO_2 emissions from volcanic and anthropogenic sources. In 2008-2009, a number of large volcanic eruptions that were monitored with OMI disrupted aviation across the northern hemisphere. The impact of OMI data on operations is currently being evaluated. An extremely important aspect of the ISF algorithm is that SO_2 cloud heights can be determined with high precision, as this allows estimation of ash cloud heights for aviation safety applications.

JCET's SO_2 emissions group is renowned for UV remote sensing of volcanic clouds and for providing unique observations from the TOMS and OMI sensors to the scientific community. The general goals of this research are to determine the effects of volcanic eruptions and passive volcanic emissions of SO_2 on the environment and climate and to ascertain the time-dependent properties of volcanic clouds containing SO_2, ash and sulfate aerosols. This requires the development of algorithms to convert observed spectral UV backscattered radiances into column integral SO_2 amounts and codes to be written for operational data production. Because of the extremely wide dynamic range of column SO_2 amounts, several algorithms are required. In addition, volcanic ash can be uniquely detected at UV wavelengths without the artifacts that plague IR ash detection algorithms. However, the existing UV aerosol algorithm fails in volcanic cloud conditions, so a new algorithm was needed. Validation of the output products is necessary for scientific use of the data. OMI measurements are being used to develop an accurate inventory of global SO_2 emissions, and are exploited in operational environments such as volcanic eruption alarms and aviation hazard mitigation systems.

Accomplishments for FY 08-09

Krueger's group's OMI SO_2 algorithms were used to produce data at NASA/GSFC for use by partners in NOAA/NESDIS who were developing a NRT aviation hazard warning system. The current pre-operational system detected major eruptions of the Okmok volcano, Aleutian Islands in June 2008, the Kasatochi volcano, also in the Aleutian Islands, in August 2008, Redoubt in Alaska in March 2009, Fernandina, Galapagos in April 2009, Llaima, Chile in April 2009, Sarychev, Kurile Islands, June 2009 and an unidentified volcano in Ethiopia, also in June 2009. Persistent strong degassing of the Kilauea volcano in Hawaii was monitored throughout the year. The automatic eruption threshold system served to alert decision support systems of the hazardous clouds. Many airline flights were cancelled or diverted while the Aleutian and Kurile Island erupton clouds were carried across the northern hemisphere. The relation between SO_2 and ash, which is the dangerous component of volcanic clouds, is the subject of current research. However, it is now established that SO_2 is far easier to detect than ash. Drifting volcanic SO_2 clouds are notoriously hard to validate. However, the Okmok cloud drifted over a research station in Washington State, providing a very high quality comparison that confirmed that OMI retrievals of small SO_2 amounts were correct within a few percent.

A new off-line iterative spectral fit (ISF) algorithm produces accurate total ozone and sulfur dioxide retrievals in large volcanic clouds containing high SO_2 amounts above 300 DU. Cloud tonnages are shown to be underestimated by a factor of 2. The ISF algorithm produces information on the height of SO_2 layers which was validated by comparison of volcanic aerosol retrievals from the CALIPSO lidar flying in the same A-train of satellites as Aura/OMI. This result is of great interest to the aviation and climate change communities.

The OMI instrument was progressively affected by partial blockage of the field of view during the year. This required development of masks for erroneous data to avoid false alerts. Because of this degradation, work on GOME–2 on the MetOp spacecraft was accelerated. The OMI algorithm was modified to ingest GOME data to produce comparable SO_2 data. Production of GOME-2 data was initiated on the NOAA computers in Spring 2009. A comparison of volcanic cloud retrievals with OMI data shows a 35% smaller amount and a retrieval noise level twice larger. This may prevent monitoring of volcanic degassing which is a standard product of OMI data that is widely used for evaluating volcanic activity.

Objectives for FY 09-10

GOME-2 SO_2 data from the European MetOp platform will become the operational data source for volcano monitoring. The NRT system at NOAA is expected to become operational including OMI, GOME-2 and AIRS quantitative retrievals.

NASA Grant: CALIPSO Science Team Support (NAS1-99107)

Investigators: Kevin McCann, Research Associate Professor, Physics/JCET; Raymond Hoff, Director, GEST-JCET; Rubén Delgado, Associate Research Faculty, JCET; Meloe Kacenelenbogen, Postdoctoral Fellow/JCET.

Students: Nikisa Jordan, Graduate Student; Paul Schou, Graduate Student.

Description of Research

The primary research areas have been the development of improved data analysis algorithms, particularly the use of wavelet decomposition for cloud detection and PBL detection. McCann and his team have continued the validation of the existing CALIPSO spaceborne LIDAR data processing algorithms. They have also continued to use a multi-instrument approach to the measurement of aerosol optical depth (AOD) in conjuction with the passive instruments Aeronet, OMI, and AIRS. In the validation portion of the work a significant amount of data, collected by their ground-based systems during times of CALIPSO overpasses, have been used to help understand the CALIPSO data. Their work with the Aeronet, OMI, and AIRS instruments has provided their respective retrieval algorithms with the altitude structure of aerosol plumes, which has led to a significant improvement in the retrieval of aerosol properties by the passive instruments. In addition, the Aeronet photometer measurements have led to improvements in their own ground-based retrieval algorithms.

Accomplishments for FY 08-09

In this final year of McCann's ten years of work with the CALIPSO data and science team, he and his group have developed several potential improvements to processing the CALIPSO data. In particular, they have had success with the use of wavelet decomposition techniques for the detection of the Planetary Boundary Layer. Tests run on several data sets show that the technique is effective in the determination of the PBL to within 0.1 km over 90% of the time. They have also used the wavelet technique for cloud detection; however, it is not clear at this time whether or not this approach is a significant improvement over simple threshold detection.

McCann's team has also had success with the use of image processing techniques for the determination of features. This new feature finder takes advantage of the fact that features are extended objects; thus, the image processing approach takes advantage of the "big picture" rather than just using single profiles to detect features.

The elastic lidar (ELF) was operated by the UMBC Atmospheric Physics Group for 146 days between June 1, 2008 and June 30, 2009. Aerosol backscattering and extinction timeseries for these days are available on the group's website, http://alg.umbc.edu/umap/, and this information has been used in comparison with measurements made by CALIPSO during overpasses.

McCann and his researchers have examined several cases of dust and smoke plumes and have retrieved aerosol optical depths for these cases. These data have also been compared with optical depth measurements made by MODIS and AERONET. The use of Calipso data to determine aerosol height has led to the development of a dust detection algorithm for the AIRS instrument. A paper on this is in preparation for publication.

Objectives for FY 08-09

This grant has concluded.

NASA Grant:	AIRS Trace Gas Retrievals for INTEX-B: Mission Planning, Analysis and Satellite Validation (NNG06GB06G)
NASA Grant:	AIRS Trace Gas Retrieval Validation and Analysis and Fire Detection (NNG04GN42G)
JPL Subcontract:	Optimization, Validation, and Integrated EOS Analysis of AIRS Trace Gas Products
JCET Task 112:	A global model study of emissions and long-range transport of aerosols and trace gases using Terra and Aqua satellite data *(Sponsor: M. Chin)*
NSF:	US-Russia Planning Visit: North Asian Sources of Greenhouse Gases: Collaborative Research Using Ground- and Space-Based Instruments (OISE-0827507)
Investigators:	Dr. W. Wallace McMillan, Associate Professor of Physics, UMBC/JCET; Dr. Leonid Yurganov, Senior Research Scientist, JCET/UMBC; Mr. Keith Evans, Research Analyst, JCET/UMBC; Mr. Chris Wilson, Ph.D. Graduate Student, UMBC; Ms. Debra Wicks Kollonige, Ph.D. Graduate Student, UMBC; Mr. Barry Baker, Ph.D. Graduate Student, UMBC

Description of Research

McMillan's research has spearheaded the use of infrared spectra of atmospheric thermal emission for retrievals of tropospheric CO from ground, air, and space, and O_3 from the ground. Consulting with ABB Bomem of Quebec, Canada, McMillan equipped his Atmospheric Remote-sensing Facility (ARF) with the first commercial prototype FTIR atmospheric sounding system, the Baltimore Bomem AERI, BBAERI. Through participation in the MOPITT Correlative Measurements Team, AIRS Validation Team, and AIRS Science Team, McMillan's group has provided products for validation of satellite CO and O_3 measurements and is developing tropospheric CO and O_3 climatologies from archived ground-based FTIR spectra. As leader for the AIRS Science Team Minor Constituents Focus Group, McMillan continues to oversee validation and optimization of AIRS CO retrievals. CO was included as a new standard product in the version 5 AIRS team algorithm in 2007, and near-real-time CO products are available from JPL, the NASA GES DISC, and UMBC.

Accomplishments for FY 08-09

Validation, optimization, analysis, and interpretation of satellite (AIRS) and ground-based (AERI) CO and O_3 retrievals dominated the group's research activities in 2008-2009. In the past year, the group has contributed to four publications now in print, three under review, and five more in final preparation for submission. They have made 15 presentations at scientific conferences and NASA science meetings. Validation of the AIRS v4 CO retrievals was published in McMillan *et al.*, [2008]. The AIRS v4 CO retrievals were utilized in the validation of CO retrievals from the new airborne MicroMAPS instrument during INTEX-A in

2004 [Hopkins *et al.*, 2009] and in analysis of ground-based ozone retrievals from the Chesapeake Lighthouse during ABOVE-2003 [Lightner *et al.*, 2009]. Validation of AIRS v5 CO retrievals is ongoing, with a publication to be submitted in late 2009. Their research continues to evaluate new optimization and retrieval techniques for inclusion in AIRS v6 CO retrievals for delivery in early 2010. Research Analyst Keith Evans has supported the AIRS v5 validation analyses with data from the INTEX, HIPPO, and Brazilian field experiments. Comparison of AIRS v5 CO retrievals with other satellite CO retrievals continued with two publications bringing in IASI [George *et al.*, 2009] and SCIAMACHY [Kopacz *et al.* 2009]. Analysis of AIRS v5 CO data was key in identifying transport of smoke from the Pacific Northwest to Houston, TX during TexAQS-II and subsequent impacts on the air quality there [McMillan *et al.*, 2009]. The seven-year record of AIRS v5 CO retrievals was utilized in a study source attribution and interannual variability of CO in the Arctic [Fisher *et al.*, 2009]. McMillan's group began a new collaboration with Dr. Chin and Dr. Bian at NASA GSFC to utilize AIRS CO retrievals along with aerosol observations in conjunction with their GOCART model to understand transport dynamics and variations in anthropogenic and natural sources. For McMillan's group, this research builds on their previous analyses of CO long-range transport as revealed by AIRS [McMillan *et al.*, 2008; McMillan *et al.*, 2009].

Student Debra Wicks Kollonige continues her research of stratospheric-tropospheric exchange (STE) utilizing AIRS O_3, CO, and H_2O data in conjunction with other A-Train satellite observations and *in situ* aircraft measurements. A publication detailing her analysis of several STE events during the INTEX-B field experiment is in preparation for submission in late 2009. Student Chris Wilson continues his research regarding trace gas retrievals from AERI spectra with a focus on developing a new multiple-parameter CO retrieval. He successfully defended his thesis proposal in June 2009 and will operate BBAERI during a NOAA-coordinated planetary boundary layer field experiment in September 2009 in the Baltimore/Washington area. Student Barry Baker joined the group in June 2009 and is contributing to a study of long-range transport from fires in Southeast Asia to the US Pacific Northwest in March 2006.

Yurganov continues to lead the group's analysis and interpretation of AERI and BBAERI trace gas retrievals and incorporation into validation and analyses of AIRS retrievals. With NSF support, he began to develop collaborative links with Russian colleagues for AIRS validation in Siberia. Yurganov made two trips to Russia to lay the groundwork for new proposals, visit field sites, and deliver talks at two conferences and several Russian institutions. Wilson accompanied Yurganov on a trip to St. Petersburg due to McMillan's unavailability for such travel. Yurganov continued his analysis of AERI CO retrievals with the development of empirical regressions to account for errors in retrieved total column water vapor and aerosol scattering of sunlight. A manuscript validating AERI CO retrievals is in preparation along with a separate manuscript validating AIRS total column CO retrievals with ground-based solar tracking FTIRs.

Objectives for FY 09-10

The coming year will see validation and continued analysis of AIRS v5 CO and delivery of an improved v6 CO algorithm. McMillan's group will continue their collaborative analysis of

INTEX-A, INTEX-B, and TEXAQS data with several planned publications, and will extend AIRS CO validation to include data from the NSF-sponsored HIPPO experiment. They will expand their satellite CO analyses to include data from the European IASI instrument offering higher spatial and spectral resolution vs. AIRS but utilizing the same algorithm strategy as AIRS through collaboration with NOAA colleagues. They will continue to analyze data from targets of opportunity, including pyroCb events as they occur worldwide with a focus on long-range transport and source attribution. All of these analyses will continue in collaboration with modelers at Harvard and NASA GSFC. Yurganov will continue analysis of the AERI archive data as well as BBAERI data with publication of validation of the AERI CO retrieval algorithm. McMillan's graduate students will continue their efforts as well: Wilson will continue work on improving AERI trace gas retrievals as part of his dissertation research; Wicks Kollonige will continue her integrated analysis of AIRS products with other A-Train observations as part of her dissertation research; Baker will continue his analysis of long-range transport from fires in conjunction with a new collaboration with Dr. Charles Ichoku at NASA GSFC.

NASA Grant:	Improving and Air Quality Decision Support System through the integration of Satellite Data with Ground-Based, Modeled, and Emissions Data
NASA Grant:	Multi-Sensor Data Synergy Advisor
Task 116:	Monitoring the Air Quality Effects of Anthropogenic Emissions Reductions and Estimating Emissions from Natural Sources and Dynamic Updating of Emissions by Systematic Integration of Bottom-Up Activities and Satellite-Based Top-Down Constraints to Support Air Quality Forecasting and Analysis *(Sponsor: K. Pickering)*
Task 107:	Air Quality support for Giovanni and Coordination of NASA Training Activities *(Sponsor: G. Leptoukh)*
Investigators:	Ana I. Prados (co-I); Uma Shankar (PI), University of North Carolina; Greg Leptoukh (PI), NASA/GSFC; Ken Pickering (PI), NASA/GSFC and Greg Carmichael (PI), University of Iowa; Sundar Christopher, University of Alabama, Huntsville and Richard Kleidman, NASA/SSAI.

Description of Research

This work supported the development of two webtools, Giovanni, and the Visibility Exchange Web System (VIEWS). These webtools make available a variety of NASA Earth science data sets, modeling, and surface *in situ* observations. The purpose is to enhance decision support by providing simultaneous access to a variety of data sets and by facilitating comparisons among the various data sets. Prados also coordinated a NASA project providing training activities internationally and across the U.S., which involved both the development of instructional modules and instructional courses, with an emphasis on the use of NASA remote sensing observations for atmospheric air pollution. She also used Ozone Monitoring Instrument (OMI) NO_2 observations to examine trends in NOx emissions over the continental U.S and over eastern China during the 2008 summer Olympics.

Accomplishments for FY 08-09

During this reporting period, the PI provided support for the development of two webtools used for air quality decision support. The Giovanni online tool at NASA/GSFC provides access to a vast quantity of earth science data, and has recently incorporated model data. Specifically, Prados facilitated interoperability between the Giovanni online visualization tool and other web tools. Interoperability allows web tools to share data and enhances user access to science data. One of the aspects of interoperability is the development of standard protocols for data access. The Giovanni and the DataFed webtool teams are currently actively engaged in developing such protocols. This work along with the current Giovanni capabilities for air quality applications were described in a paper Prados recently submitted to the *IEEE Journal of Selected Topics in Earth Observations and Remote*

Sensing.

VIEWS is an existing tool for access to *in-situ* air quality observations at Colorado State University. The recently funded NASA ROSES grant will incorporate emissions data, air quality model output, and satellite observations to enhance decision support within VIEWS. Prados' main role since its inception has been to provide guidance and expertise on numerous aspects of the satellite data products being incorporated into VIEWS, including data formats, data quality, data access, and interoperability opportunities, and to provide expertise on the applicability and characteristics of the various NASA satellite remote sensing aerosol products.

In 2009, the PI began work on the ROSES 09 Multi-Sensor Data Synergy Advisor project. The project will develop semantic web technologies and ontologies within the Giovanni. This new framework will enable scientists to gain information and make better decisions about dataset intercomparisons. Prados' initial role has been to help develop data ontologies that bring together the relevant information about the various aerosol products currently provided by Giovanni.

For the past year Prados has been coordinating and developing NASA instructional workshops on the use of NASA satellite measurements for applied science users. During the reporting time period, she coordinated a total of four training workshops at national and international conferences, and one conference demonstration. Several additional training activities are planned for the remainder of 2009 and for 2010. One of the challenges of these instructional activities is finding a level of instruction that meets the needs of users with a wide range of expertise. Thus, she and her collaborators worked on developing the instructional materials to be accessible to all users while still providing the necessary science background for appropriate use of the data. In March 2009, Prados chaired a satellite session at the EPA AIRNow Air Quality conference, and coordinated a one-day satellite workshop for air quality forecasters. She also developed a pilot satellite training workshop for modelers at the University of North Carolina, Chapel Hill.

During the past year, Prados has been actively involved in research examining OMI NO_2 trends over the eastern half of the continental U.S. The purpose of this project is to determine whether NO_2 measurements from OMI are sensitive to known emissions reductions over the eastern U.S over the last several years. As part of this same task, she also provided daily OMI NO_2 imagery during the summer 2008 Olympics in Beijing. The purpose of that effort was to examine whether emissions reductions in Beijing and in surrounding regions had led to the expected air quality improvements. NO_2 is emitted by cars and various industrial sources, many of which had decreased their pollutant output during the summer of 2008. Both of these research activities suggest that the OMI instrument has wide applicability for tracking changes in NO_2 pollution worldwide.

Objectives for FY 09-10

For the next fiscal year, Prados will continue all of the above-mentioned projects, with most of the Giovanni work focused on the Data Synergy Advisor project. To this end, she will work with aerosol scientists at NASA/GSFC to share information relevant to the

development to the data ontologies. Support for the VIEWS project will also continue, as the system fully integrates all the needed satellite data sets, and she will explore interoperability options between Giovanni and VIEWS as a means to increase access to MODIS and OMI products within VIEWS.

Research activities related to OMI NO_2 trends during this second year will focus on more precise quantification of OMI NO_2 changes and comparisons with various emissions inventory datasets, and to air quality model output. Prados will continue to coordinate NASA satellite training activities for a second year, including a three-day workshop for air quality modelers. Her team will also be reaching an additional set of users, primarily policy oriented users. She also will help coordinate the standardization of the already developed training materials, the expansion of the project webpage, and the development of an Air Quality Case Study Inventory. This inventory will help expand available examples to more regions of the world, and thus increase the usability of these data sets for applied science users.

NASA Grant:	Validation of non-coincident trace species measured by AURA using trajectory mapping and statistical analysis(NNX07AD87G)
JCET Task 47:	Statistical analysis of geophysical variability *(Sponsor: M. Schoeberl)*
UMBC SFF:	Investigations of Tropical Cyclone (TC) inner core dynamics and its impact on storm intensity
MD DNR:	Statistical Analysis of Low Level Winds in Western Maryland from a Numerical Weather Prediction Model (KOOP8201019)
MD DNR:	Mesoscale model analysis of windpower intermittency for a geographically distributed wind facility (K00P8201496)
MD DNR:	Mesoscale Model Simulation of Low Level Winds at High Resolution and Comparison to Wind Profiler Data (K00P9201501)
DOE:	20% Wind by 2030: Overcoming the Challenges
NSF:	Acquisition of an Interdisciplinary Facility for High - Performance Computing
Investigators:	Lynn Sparling, Associate Professor of Physics, UMBC
Students:	PhD: Sam Trahan, Mengs Weldegaber, Nathan Kurtz; MS: Eric Hughes, Ross Dixon, Andrew Rickert

Description of Research

The research under this task is aimed at an understanding of the dynamical, chemical, and transport processes in the atmosphere that contribute to the observed variability in trace gases and meteorological fields over a wide range of spatial and temporal scales. Satellite observations of chemical tracers are used to investigate the statistical properties of large scale transport and dynamical processes, while high resolution aircraft and balloon observations are used to obtain a statistical view of smaller scale processes. The observations are interpreted using a combination of theory and comparisons with numerical models and Lagrangian transport models. This research includes studies of subgrid scale variability of moisture, winds and temperature in tropical cyclones, transport and mixing in the upper troposphere, mesoscale variability in extratropical transition of Atlantic TCs, and the statistical characterization of low level winds in the PBL with applications for pollution transport and wind energy. Other practical applications include the impact of subgrid/subpixel scale geophysical variability on satellite validation.

Accomplishments for FY 08-09

Research projects that apply the statistics of small-scale variability trace gases, winds and temperatures to a variety of problems are continuing. An analysis of Arctic *in-situ* snow depth data characterized statistical sampling errors and scale-dependent variability in order to find an approach that could be used to combine AMSR-E snow depth and ICESat altimeter data to derive a sea ice thickness product (*Kurtz, et al.*, 2009). The statistics are necessary in order to properly take into account the different spatial resolution and coverage of the measurements. This work is part of the PhD research of student Kurtz (co-mentored by JCET fellow Thorsten Markus (GSFC)), who is on track to complete and defend his PhD work by the end of 2009. Other work included an extensive analysis of scale-dependent statistics of NOAA P3 wind data for several tropical cyclones. The results suggest that the horizontal correlation length of the vertical velocity field is on the order of a few km with little variation from storm to storm (*Trahan, et al.*, 2008). Work is also continuing on the development of methods to estimate the contribution of real geophysical variability to validation of satellite measurements with ground-based or *in-situ* measurements, using the asymptotic properties of two-point statistics in the limit as the spatial and temporal separation approaches zero. The analysis is being applied to trace gas data from the AIRS and AURA satellites and correlative aircraft measurements.

Lagrangian modeling studies were used to characterize the northerly long-range transport of CO from the July 2004 Canadian/Alaskan fires during INTEX-A (*McMillan, et al.*, 2008) and to show how remote sources can impact local air quality (*McMillan, et al.*, 2009). In another completed project, a trajectory analysis was used to infer the height of an SO_2 plume from the Nyamiragira volcano by initializing AURA OMI observations and tracking them back in time at several vertical levels (*Hughes et al.*, 2008). The work produced a probability distribution for emission altitude vs. time that was found to be consistent with available CALIPSO AOD measurements. This research has important applications for aircraft flight safety and also gives insights into the dynamics, transport and mixing processes in the upper troposphere. It is also being used to constrain the vertical distribution of SO_2 for OMI validation purposes. This work was the MS thesis of student Hughes, whose MS degree was awarded in May 2009.

New tropical cyclone (TC) research initiated during the past year is aimed at understanding intense precipitation events during the extratropical transition of mid-Atlantic TCs. The MS thesis work of student Dixon on the extratropical transitions of Hurricane Gaston (2004) and Ernesto (2006) investigated mechanisms in precipitation forcing from both quasi-geostrophic and potential vorticity approaches. In the case of Ernesto, the research found possible upper level baroclinic forcing of an easterly low-level jet that contributed to the large rainfall amounts. Dixon, co-mentored by Jeff Halverson (UMBC/JCET), will be awarded the MS degree in August 2009. Student Trahan's work on TC modeling is continuing with high resolution HWRF simulations aimed at investigating the resolution and model configuration dependence of small-scale inner core dynamics and its impact on storm intensity. The computationally intensive simulations are being run on the Teragrid through a Teragrid allocation award. This work, in combination with the observational analysis, comprises Trahan's PhD research, which should be completed next year. Other TC work

included collaboration with the UMBC Computer Sciences Department in hurricane visualization that led to innovative illustration-inspired representations of eyewall structure [*Joshi et al.*, 2009].

Student Mengs Weldegaber (co-mentored by Belay Demoz, Howard University) was awarded the PhD in May 2009 for his observational and modeling studies of stable and unstable PBL phenomena that included an analysis of convective initiation along a southern Great Plains dryline and studies of the mid-Atlantic nocturnal low-level jet. High-resolution WRF modeling studies of the low-level jet show reasonable agreement with MDE profiler measurements (Weldegaber, 2009) for some PBL schemes, but important challenges remain for PBL modeling under stable conditions. A new research project on mid-Atlantic low level winds was initiated. The work has applications to low-level pollution transport and wind energy. Other studies of low level winds include an spatio-temporal correlation analysis using winds from a one-year 12 km MM5 simulation (*Zhang, et al.*, 2006).

MS student Rickert (co-mentored by David Lary, JCET) completed his thesis research and graduated in August 2009. His MS research focused on the use of neural networks for scattering calculations in order to speed up the photochemistry calculations in global climate models.

Objectives for FY 09-10

Goals for the next year include continuation with multiplatform analysis trace gases, especially AURA measurements and publication of results. The next phase of the tropical cyclone modeling and data analysis research is to continue objective statistical scale-dependent characterization of variability at O (1km) scales from the data, and to compare with the high resolution HWRF model simulations using the same statistical measures and publish the results. Low level observational and high resolution WRF modeling wind studies will continue on the new high-performance cluster at UMBC, with post-doctoral researcher Weldegaber. Additional studies of low-level winds at inland and coastal mid-Atlantic locations are being planned. Several papers based on the work of students Hughes, Dixon, Trahan and Weldegaber are in preparation and will be submitted for publication.

NASA Grant:	Cross-Validation of TES with AIRS: Radiances and Radiative Transfer (NNX07AG73G)
NASA Grant:	A Hyperspectral Infrared Radiance Climate Record Using AIRS, IASI and CrIS (NNX08AD34G)
NOAA Grant:	NOAA NPOESS Internal Government Studies (IGS) Analysis of CrIS/ATMS Instrument Test DATA and Operation Software (DG133E06CQ0024)
JPL:	AIRS Climate and Calibration (Contract 1364443)
NOAA Grant:	Fast Radiative Transfer Modules For IASI and CrIS (NA08NES42800024)
JPL:	An Improved OLR Algorithm for AIRS (NM0710861)
Investigators:	L. Larrabee Strow, Full Research Professor, Physics, JCET; Sergio DeSouza-Machado, Research Assistant Professor, JCET, Physics; Scott Hannon, Faculty Research Assistant, JCET; Breno Imbiriba, Research Associate, JCET; Paul Schou, Research Analyst, JCET.

Description of Research

The Atmospheric Spectroscopy Laboratory (ASL) activities center around the development, validation, and use of infrared hyperspectral sounders for weather and climate research. Strow's group has core expertise in infrared spectroscopy and radiative transfer modeling, and provides NASA and NOAA with operational radiative transfer models for NASA's Atmospheric Infrared Sounder (AIRS), EUMETSAT's Infrared Atmospheric Sounding Interferometer (IASI) flying on METOP, and the Cross-Track Infrared Sounder (CrIS) that will fly on NASA's NPP mission and on the future U.S. operational weather satellite system NPOESS.

The group's guiding philosophy is to actively participate in all phases of the lives of these sensors, including direct involvement in pre-launch thermal vacuum testing, retrieval algorithm development, and validation. This provides an in-depth understanding of both the sensor operation and performance, as well as the use of the sensor for geophysical research. Strow's research using these sensors concentrates on topics that stress both the sensor and forward model accuracy (CO_2 retrievals, climate trending) or involves the retrieval of geophysical variables not performed by NASA and NOAA (mineral dust, minor gases).

Strow and his researchers work closely with the Integrated Program Office (IPO) that is developing the CrIS sensor to ensure that instrument and algorithm development will meet the needs of the numerical weather prediction community. In addition, they have continually worked with the CrIS test data and in-orbit operations plans to help ensure that CrIS will be able to also contribute to climate monitoring. Most of their efforts in this regard concentrate on the spectral calibration of CrIS and subsequent spectral and radiometric validation of the sensor.

Strow's group provides the community with state-of-the-art clear sky radiative transfer algorithms, referred to as "Stand-Alone Radiative Transfer Algorithm'' (SARTA). The SARTA model is based on parameterizations of optical depths computed using Strow's line-by-line infrared radiative transfer algorithm, KCARTA, which is the Reference Forward Model for NASA's AIRS instrument, and can compute radiances in a clear or cloudy sky, as well as include daytime NLTE effects. They have also extended SARTA for scattering atmospheres to support their work in the retrieval of dust and cloud properties.

Recent research has concentrated on the retrieval of dust using hyperspectral infrared, where they have shown that AIRS dust retrievals are very competitive with those from visible sensors (MODIS, PARASOL, OMI), and of course provide nighttime observations. They have also recently produced a lower-tropospheric "column" CO_2 retrieval for 5+ years using AIRS.

Accomplishments for FY 08-09

A five-year climatology of mid-tropospheric CO_2 has been created from the AIRS data showing a wide variety of behaviors that will help understand large-scale CO_2 transport. The analysis has been extended to include land areas, and is being compared against models and *in-situ* measurements such as Carbon Tracker. Validation suggests accuracy on the ~1 ppm level and good agreement on the whole with NOAA's CarbonTracker assimilated CO_2 model. Recent observations include detection of the anthropogenic contribution of CO_2 to the total burden over the East Coast of the U.S. in the fall and in Western Europe. This new global CO_2 product should prove very useful in understanding and improving carbon cycle modelling, especially with regard to transport.

IASI data has been utilized for a preliminary retrieval of CH_4 over ocean. The shortwave data from IASI is particularly useful for this, as the CH_4 lines in this region sense the lower atmosphere and may provide early warning of increased CH_4 emissions from northern latitudes.

The AIRS retrieval system is very complicated and depends on *a priori* information, as do all infrared retrievals. This can complicate climate trending with these sensors. Consequently, Strow's group has developed an approach to measure climate trends with AIRS by directly retrieving geophysical trends from the radiance time derivative. Preliminary work has shown that this approach yields very accurate growth rates for minor atmospheric gases such as CO_2, CH_4, N_2O, and CFC11 (negative growth rate). Presently this analysis has been limited to clear observations, but they plan to move to full sampling of the AIRS radiances to avoid sampling biases for atmospheric temperature and humidity rates.

The group's dust retrieval algorithm has been extended from ocean-only to land scenes. The retrieval appears to exhibit more consistent behavior at the land/ocean interface than visible sensors. They have also shown that accurate estimates of the dust mean altitude are also possible with AIRS. A three-year collaboration is planned to relate AIRS and MODIS optical depths, to retrieve dust heights using both sensors.

Efforts were significantly increased to improve the AIRS spectral calibration this year, and the group has successfully calibrated the entire mission data to date. This is in preparation

for production of an AIRS L1c radiance product by the AIRS JPL Project that will be climate-quality.

Climate research using different hyperspectral sensors (AIRS and IASI, for example) require that any radiometric offsets between these two instruments are well understood and characterized. The PI's team has developed a technique to do this using "double-differences" that compares the bias of each instrument relative to model data (ECMWF). The use of model data is primarily to account for the 4-hour difference in observations times of AIRS and IASI, which can be done very accurately. Significant work has gone into methods to account for the different spectral response functions of these two instruments. They have shown that amazingly these instruments by and large agree to the 0.1K level (brightness temperature units) and the group is working to determine the accuracy of this intercomparison with a goal of tens of milli-Kelvins. This work involved a significant (but highly accurate) modification of the IASI radiances to account for spectral calibration mis-matches among the four detectors in each of the three IASI focal planes.

They completed the pre-launch spectral calibration of the CrIS sensor being prepared to fly on NASA's NPP platform. Spectral performance of the sensor was excellent, and their work showed performance exceeded the contractor's performance estimate.

Objectives for FY 09-10

From the research done this past year, Strow's team plans to submit a minimum of two papers for publications: one on global mid-tropospheric CO_2 retrievals over ocean and land, using six+ years of AIRS data, and another on using AIRS radiance data to retrieve growth rates of atmospheric trace gases. A paper on intercomparisons of dust ODs retrieved from A-Train instruments has been submitted. The group also plans to attend meetings such as the September Carbon meeting in Germany, and the AGU Fall Meeting in December 2009. In addition they will attend Science Team meetings for the AIRS (Greenbelt MD/Pasadena CA), IASI and CrIS instruments.

Strow and his researchers hope to enhance collaborations with the carbon/chemistry model community to examine and use their AIRS CO_2 climatology for model improvements and understanding. In collaboration with the AIRS Team, they hope to implement the retrieval of dust in the AIRS L2 production system. Work on the direct measurement of climate trends with AIRS will continue, with increased attention to clouds.

Increased focus also will be on preparing for the launch and validation of the CrIS sensor on NPP. One of their roles will be to provide very quick validation of the sensor (days) and feedback on changes to the CrIS SDR (L1b) radiance algorithm as the instrument is brought into operational status.

NASA Grant:	AURA Validation, TES CO and O3 Validations Using AIRS
NASA Grant:	Atmospheric Composition, Inter-comparison of EOS CO Sensors
NASA Grant:	Tropospheric Chemistry, ARCTAS Support and Analyses
NASA Grant:	A Global Modeling Initiative (GMI) Study of the Long-Range Transport of Pollution using Fused Carbon Monoxide Measurements from EOS
Investigators:	Juying Warner, Research Assistant Professor, Geographical and Environmental Systems; Zigang Wei, Assistant Research Scientist, JCET; Zhibin Sun, Research Associate, JCET; Allen Chu, Associate Research Scientist, GEST/UMBC, Bryan Duncan, NASA/GSFC.

Description of Research

Warner's projects involve evaluating the current NASA tropospheric trace gas measurements and developing more accurate methods to retrieve these quantities that are important to air quality and climate change studies. The objective is to build a bridge in understanding the differences between EOS sensors that measure the same trace gas products. The detailed aspects of her group's work can be summarized in the following areas: inter-comparison of AIRS/TES/MOPITT/MLS using current AIRS operational products; new trace gas products with improved accuracy using combined multiple sensor datasets; developing new retrievals using a uniform formulation for AIRS as used in TES/MOPITT/MLS; participating in and analyzing data for NASA field campaigns, such as ARCTAS experiment, for satellite data validation; and, collaborating with and supporting the greater scientific community.

Accomplishments for FY 08-09

Tropospheric CO comparisons between AIRS and MOPITT are partly published by Warner *et al.* [2007], and this year's efforts are focused on the comparisons of all the collocated CO profiles between AIRS and TES operational products for years 2006 and 2007. A paper describing the statistical differences between these products will soon be submitted, in which Warner and her team have used both *in situ* data from NASA field experiments and model results as platforms to compare the two sensors. CO distributions and transport are also discussed using statistical methods based on measurements from both sensors. Their results indicate that AIRS and TES CO agree the best at the mid-troposphere in the NH and the largest differences are in the lower troposphere and in the SH. They are continuing their efforts to fuse CO datasets using AIRS and TES operational retrievals and are adding MLS data to the new 3D products.

Warner's group developed a new algorithm to retrieve tropospheric CO from AIRS measurements using Rodger's Optimal Estimation (OE) techniques and found that the major improvements of using OE for AIRS CO retrievals is in the lower troposphere both in the NH and the SH. Figure 1 shows two CO profiles collected during INTEX-B from DC-8 spirals on Mar. 4, 2006 where the *in situ* measurements from DACOM are depicted by the green curves. On that particular day, this region was affected by the agricultural fires in the southeast US, which resulted in high CO concentrations near the surface. The spiral profile on Figure 1 (a) was collected over the Gulf of Mexico and that of (b) was collected over land near the fires. The blue curves on Figure 1 depict AIRS v5 CO profiles using the operational retrieval algorithm and downloaded from NASA/DAAC; the cyan curves are the *in situ* profiles convolved to AIRS v5; the red curves represent Warner's new OE CO profiles; and the yellow curves represent the *in situ* profiles convolved to their new OE retrieval space.

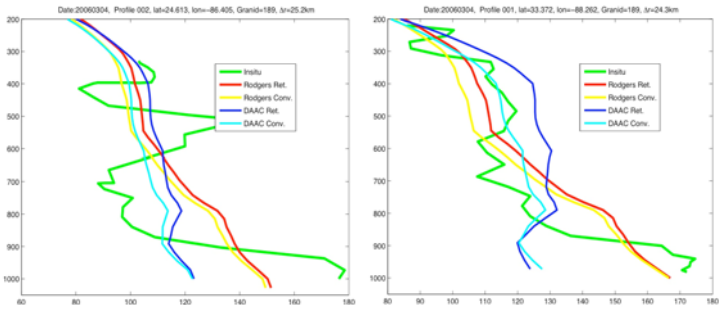


Figure 1. INTEX-B DC-8 spiral profiles on Mar. 4, 2006 collocated with AIRS DAAC V5 (blue lines) and AIRS OE (red and yellow lines).

In general the differences between the retrieval and the *in situ* profiles convolved using the AK provided in the retrieval algorithm indicate how well a remote sensor measures the atmospheric property. In this sense, the two algorithms provide similar information where the AIRS instrument is sensitive to CO, namely in the mid-troposphere, where the retrievals agree with the *in situ* measurements to within 5-10 ppbv. The largest differences between the two methods are in the lower troposphere, especially below 800 hPa. The AIRS OE CO provides much more realistic results compared to the *in situ* profiles, which is largely due to how the *a priori* information is used in the retrieval algorithm. The OE method constrains the retrieved profiles to the *a priori*, whereas AIRS operational results converge to the first guess where the measurement information is lacking.

Warner's team produced full-day AIRS CO retrievals using OE and compared them with the collocated TES CO profiles. Figure 2 demonstrates that using the AIRS OE CO improves the accuracy of the lower troposphere retrievals and the retrievals in clean regions such as the SH and the polar-regions. The top panel shows AIRS V5

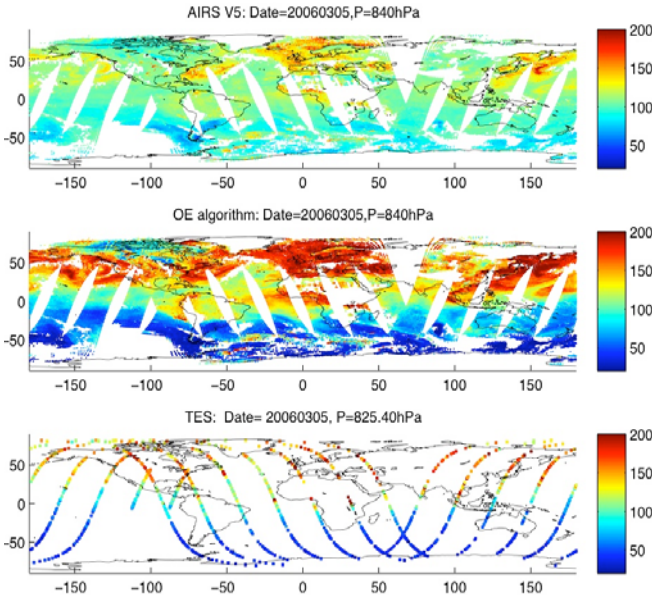


Figure 2. CO VMRs at 840 hPa retrieved using AIRS V5 (top), AIRS OE (middle), and TES

CO VMRs at 840 hPa, the middle panel shows AIRS CO retrieved from OE technique, and the bottom panel shows TES CO VMRs at the similar altitudes. The CO VMRs in the NH in the lower troposphere is significantly enhanced, which is justified by the fact that the emissions and the total concentrations in the NH are high in the spring season. The agreement between TES and AIRS CO VMRs (bottom panel) has also improved.

Objectives for FY 09-10

Looking ahead, Warner plans to publish research results that were produced in the last three years. She and her team will also analyze CO distributions and global pollution transport using their improved products with a focus on the added measurement capabilities that were not possible using the operational products. They will thoroughly compare AIRS CO using OE with all existing *in situ* measurements, MOPITT, and TES CO with all available multi-year/global datasets. In the new algorithm, they will add proper QA for the retrievals and add global and seasonal varying *a priori* as defined by MOPITT V4. Warner's team will study the spectral band information and try to further improve the retrieval in the lower troposphere and try to improve the computational speed so that near real-time products are possible. They also plan to expand their current algorithm and products for other trace gases, such as ozone and methane.

JPL Subcontract:	Optimization, Validation, and Integrated EOS Analysis of AIRS Trace Gas Products
NASA Grant:	AIRS Trace gas retrievals for INTEX-B: Mission Planning, Analysis and Satellite Validation (NNG-06-GB06G)
NSF:	US-Russia Planning Visit: North Asian Sources of Greenhouse Gases: Collaborative Research Using Ground– and Space-Based Instruments (OISE-0827507)
Investigators:	Dr. Leonid Yurganov, Senior Research Scientist, JCET (PI, NSF; co-PI, NASA and JPL); Dr. W. Wallace McMillan, Associate Professor, Physics (PI)

Description of Research

The goals of the first and second projects are validation and analysis of AIRS trace gas retrievals and comparison of AIRS and MOPITT CO results. Proper validation is necessary for successful use of these data by modelers and decision makers. The goal of the third project is to prepare a long-term program of cooperation with colleagues working in Siberia on satellite validation and carbon cycle research. This area of the world plays a critical role in the natural carbon cycle, especially with ongoing climate change, but is poorly covered by measurement networks.

Accomplishments in FY 08-09

Formerly, CO concentrations for the period between 1997 and 2008 at the ARM/SGP site were retrieved from the Atmospheric Emission Radiance Interferometer (AERI) spectra using Version 1 of McMillan's CO retrieval algorithm. The analysis carried out in the beginning of the reporting period revealed significant drawbacks in the forward model and input data. Further calculations enabled Yurganov and his team to make necessary corrections to the original algorithm; version 2 of the algorithm is now ready and validated using directly measured CO profiles by aircraft and on a 60m high tower. The available data set for this validation covers the period between early 2006 and late 2008 (~70 working days). A comparison for 2006-2008 demonstrated an agreement inside ±10 % (STD). The insufficient accuracy of the continuum radiance calculated by kCARTA is still a problem that goes beyond the scope of this project. A proposal to NSF for using this instrument and retrieval technique at the Bachelor Mountain Observatory was submitted but declined. A manuscript of the group's validation results is being prepared for submission.

A comprehensive analysis of CO total columns measured by MOPITT and AIRS [Yurganov *et al.*, 2008] elucidated several important issues and was described in the report for the previous year. The results of that work opened a door for permanent monitoring of biomass burning emissions using satellite CO measurements and to provide an early warning for periods of catastrophic fires, and this work continued during this reporting period. First, the number of validation sites was increased from 2 to 7. Second, validation was carried out for both MOPITT (version 3) and AIRS (version 5). As a reliability parameter for AIRS, the number of degrees of freedom (DOF) of the retrieval was chosen. It was found that for

DOF>0.7 (AIRS) and a Total Column Quality Parameter less than 60% (MOPITT), the STD of the difference between ground-based and space-based measurements of CO total column is less than 13%. The bias is different for Northern and Southern hemispheres and varies seasonally. Most significant was the discovery of a positive instrumental drift for MOPITT CO retrievals amounting to 1.3 % per year in both hemispheres. AIRS exhibits no such temporal trend. The preliminary results have been presented at the AGU meeting in Fall 2008. Further research requires additional funding and a proposal has been submitted to NASA.

Additional activity (not funded) was connected with the analysis of AIRS methane retrievals. As a result of the Russian visit, fruitful contacts were established with Russian researchers who are involved in methane measurements in Western Siberia. They have six permanent stations in this area and have been measuring methane and carbon dioxide since 2003. The very distinct seasonal cycle has a local maximum of methane surface concentration in July in perfect agreement with AIRS retrievals. This demonstrates the great potential of AIRS methane observations for research in Siberia. The AIRS data definitely show that areas of high methane in Eurasia are concentrated in West Siberian wetlands in July and along the tundra coast of the Arctic Ocean in September. Moreover, AIRS observations confirm the independent findings of ESRL and MIT regarding a global increase of methane in 2007-2008.

Objectives for FY 09-10

Pending additional funding of submitted and new proposals, Yurganov plans to continue analysis of global CO and CH_4 using all available satellite data. Validation of satellite data requires a close cooperation with colleagues involved in ground- and air-based measurements. New proposals to NASA, NATO, and NSF will be submitted. The PI also plans to continue CO retrieval algorithm development for ARM sites and UMBC. There are several operational AERI instruments across the world with spectra available from the ARM archive.

NOAA Grant: An IDEA product for GOES-R data (NA08NES4280023)

Investigators: Hai Zhang, Research Associate, Research Faculty; Raymond M. Hoff, Professor, Physics

Description of Research

Zhang's group at UMBC has been making contributions in the use of satellite measurements of aerosol optical depth (AOD) as a surrogate for air quality indices such as $PM_{2.5}$ for several years. They are collaborating with NOAA to develop and improve the Infusing satellite Data into Environmental Applications product (IDEA), which is currently running at NOAA/NESDIS and provides near real-time satellite aerosol measurements and forecasting guidance from multiple satellites instruments, including MODIS Terra, MODIS Aqua, GOES east, GOES west, and OMI (http://www.star.nesdis.noaa.gov/smcd/spb/aq/). Many air quality forecasters are using this product every day for their air quality forecasting. The IDEA system will be configured to support the inclusion of the GOES-R aerosol product as the primary AOD measurement when GOES-R becomes operational. Zhang's team is also making efforts to explore a new AOD retrieval algorithm to improve the retrieval accuracy from current operational GOES imager.

Accomplishments for FY 08-09

During the past year, they continued to work on improving the IDEA product and developing new AOD retrieving algorithm for GOES.

First, in regards to improving the IDEA product, the aerosol index from OMI was incorporated into the IDEA trajectory forecast from Aqua AOD such that the areas with high OMI AI are initialized at a high level (3 km above surface). The Aqua 48-hr trajectory forecast was modified so that the trajectories are initiated at 300mb above surface level (about 3km above surface) at the locations with high OMI AI (>2.0). The Terra 48-hr trajectory plot was not adjusted because the time difference between the overpass of Terra and OMI is large, about 3 hours. Anomalies were noticed in OMI AI product. The pixels with high abnormal aerosol index were removed in the Aqua trajectory forecast: the cross track scenes 54-55 (1- based), and cross-track scenes 38 to 43 (1- based) but only for northern latitudes, at solar zenith angles larger than 44.0 degrees. A notice was posted on the 48-hr trajectory section, and a paragraph was added in the product description for this change.

Two new tabs were added into the IDEA product with AOD data source from Aqua and GOES west. The work includes modifying the code for the five components in the IDEA product and modifying the web display to show the product on the internet.

Next, Zhang compared AI retrievals between OMI and GOME-2. The aerosol index retrievals were compared over 18 regions around the globe. The aerosol index retrievals from the two sensors were projected to a 1x1 degree latitude longitude grid, which has a similar resolution as GOME-2 (80x40 km^^{2}, OMI has higher resolution with 13x24 km^2). The results showed that the GOME-2 AI has lower average values than OMI AI over all the regions. Also, the GOME-2 AI has wider distributions in frequencies of occurrence for

different values, and has more negative values than OMI AI.

Finally, they developed a new retrieval algorithm for GOES based on the MAIAC algorithm for MODIS. In this algorithm, seasonally averaged MODIS surface BRDF at 2.1 μm band is used along with the GOES visible channel for retrieving surface reflectance and aerosol optical depth. This algorithm can retrieve surface reflectance using GOES images from a much shorter period of time than the 28-day period used in the current operational GASP (GOES Aerorol and Smoke Product) algorithm. In comparison to the AERONET AOD at several sites across US, Zhang's team found that this reduction in the time period can improve the accuracy of surface reflectance retrievals in time periods when solar angle variations are large. The AOD retrievals are consequently more accurate than those from the GASP algorithm. In the seasons when seasonal average BRDF shape do not accurately represent daily BRDF, the PI suggested a modified algorithm to compensate for it. The modified algorithm was found to have a similar accuracy to GASP. Over the bright site Railroad Valley, the MAIAC algorithm performs better than GASP, even with a relaxed surface reflectance threshold. The MAIAC algorithm should be especially suitable for arid areas where the BRDF do not change from season to season due to the seasonal change in vegetation.

In addition, the researchers developed a method for GOES image co-registration to reduce any image shift between images from different times. The GOES channel-1 images were found to have shifts between images taken from different times due to satellite jitters. The shifts are usually about 2 to 3 pixels, which can introduce errors in the retrieval of surface reflectance and AOD. The solution is to apply image co-registration to reduce the shift to below one pixel before applying the retrieval algorithm. A method of co-registration was developed by using control points of 40x40 window size with features such as islands, lakes, and complex coast lines. The image shift at the control points was calculated by analyzing the cross-correlations between the reference image and the image for registration over these control points. The shift of each pixel over the whole image was obtained through linear regression.

Objectives for FY 09-10

In the coming year, regarding development and research, Zhang and his team will add GOES-R ABI proxy data into IDEA when they receive the code for reading the data, and they will add a new product that estimates daily surface $PM_{2.5}$ using multi-satellite aerosol measurements. They will compare GASP and MAIAC AOD retrievals over arid areas and subsequently submit a journal paper on this research. They will have an inter-comparison between the channel-1 radiance GOES east and GOES west, and compare these radiances with the MODIS BRDF. Finally, Zhang plans to investigate the possibility of including both GOES east and GOES west in MAIAC to generate a combined aerosol retrieval algorithm for the western US.

Mesoscale Atmospheric Processes (Code 613.1)

JCET Highlight: Tropical Storm Gaston (2004) – The Physics of an Unpredicted Flash Flood and Unexpected Re-intensification over Land

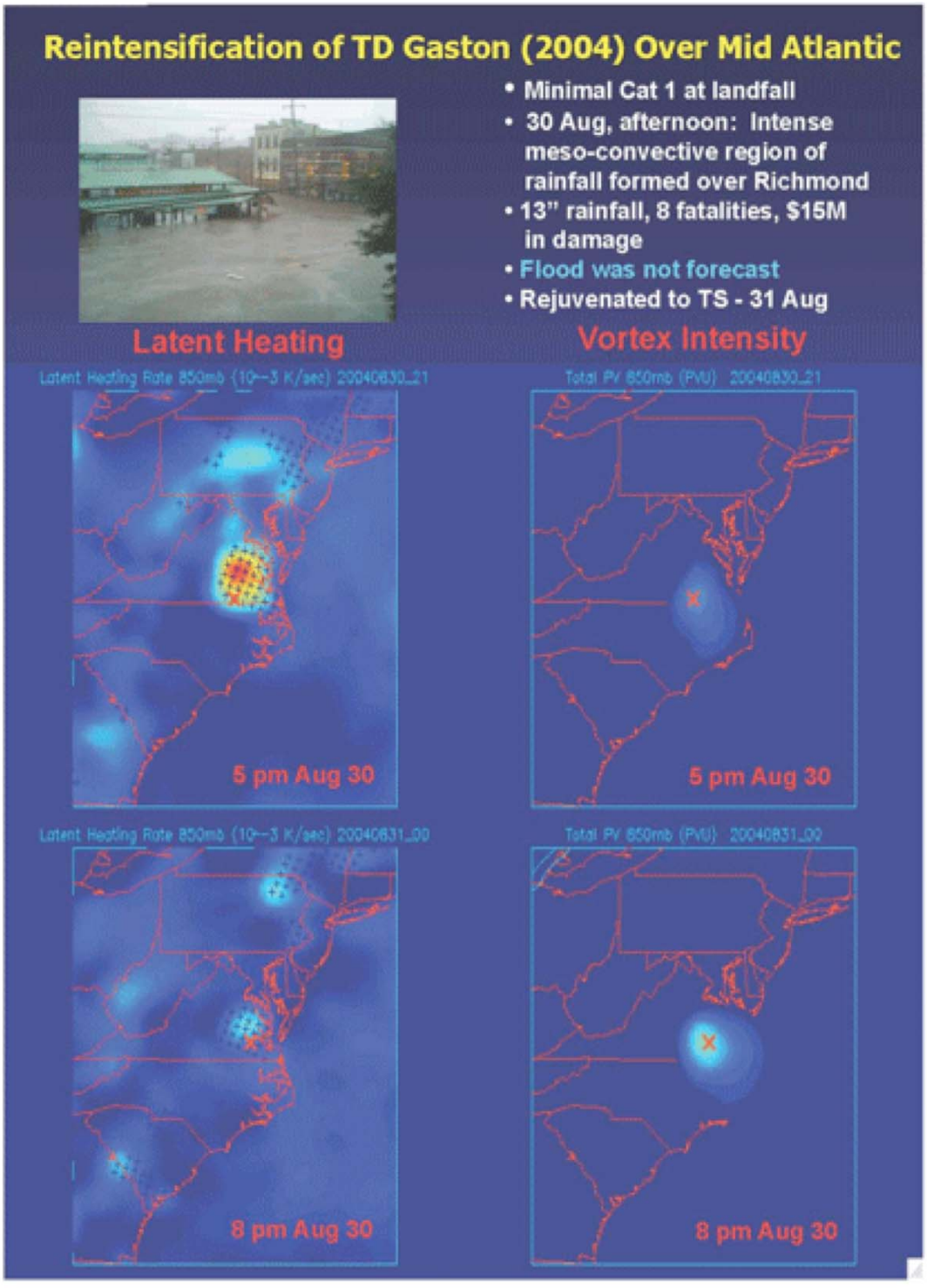
Investigators: Jeffrey B. Halverson, JCET Associate Director-Academics and Associate Professor of Geography; Haiyan Jiang, University of Utah

Hurricane Gaston made landfall as a weak Cat 1 hurricane on August 29th, near the South Carolina-Georgia border. On the afternoon of August 30th, the remnants of Gaston moved up the North Carolina Piedmont and into eastern Virginia. The storm quickly weakened to a tropical depression, as did the intensity of the rains it was producing. Quite unexpectedly, the storm generated a small complex of flash-flood producing thunderstorms on its northern flank late August 30th. The flood destroyed the Shokoe Bottom region of Richmond, inundating property and drowning eight individuals, as 13 inches of rain fell in just a few hours. The location, timing and magnitude of this severe weather event were not anticipated by the National Weather Service.

Jeff Halverson, Lynn Sparling, and Physics graduate student Ross Dixon have been studying the physics of heavy rain-producing storms such as Gaston over the Mid Atlantic. In particular, their goal is to better understand the meteorological factors that govern the extratropical transition (ET) of hurricanes – a complex, multi-scale process that transforms hurricanes into mid-latitude cyclones as they move out of the tropics and onto land. ET can sometimes lead to greater loss of life and property damage than would otherwise occur from just the tropical (hurricane) phase of the storm. Predicting a storm's hazardous weather – including flash floods, damaging winds and tornado swarms – is challenging because the physical processes that release energy occur on very small scales of motion, too small to be fully resolved by weather forecasting models.

The figure (right) illustrates another unusual facet of Gaston: the storm's rejuvenation to a tropical storm, while over land. The re-intensification occurred during and immediately after the heavy rainfall. Halverson and Dixon hypothesize that the heat energy released inside clouds during the conversion of water vapor into rain (condensation) was the primary reason why Gaston rejuvenated. It is unlikely that interactions with the storm's larger environment imparted any additional energy, including nearby fronts, jet streams and upper-level weather systems. The localized but strong pulse of heat energy into the core of Gaston (left column) led to immediate spin-up of its vortex (right column), albeit for a short duration.

Inland flash flooding remains the number one killer during hurricane landfall. Much work is needed to better understand why some tropical storms create hazardous weather, and others do not, even in instances when the intensity and track across the Mid Atlantic are quite similar.


Reintensification of TD Gaston (2004) Over Mid Atlantic
• Minimal Cat 1 at landfall
• 30 Aug, afternoon: Intense meso-convective region of rainfall formed over Richmond
• 13" rainfall, 8 fatalities, $15M in damage
• Flood was not forecast
• Rejuvenated to TS - 31 Aug
Latent Heating
Vortex Intensity
5 pm Aug 30
5 pm Aug 30
8 pm Aug 30
8 pm Aug 30

This page intentionally left blank

NASA Grant: **Differences and Similarities of Tropical Cyclone Rainfall Over Land and Sea Using Multisatellite Analyses: Implications for Inland Flooding Prediction**

Investigators: Jeffrey B. Halverson, JCET Associate Director-Academics and Associate Professor of Geography; Haiyan Jiang, University of Utah

NASA Grant: **Multiscale Analysis of Tropical Storm Hot Tower And Warm Core Interactions Using Field Campaign Observations**

Investigators: Jeffrey B. Halverson, JCET Associate Director-Academics, Associate Professor of Geography; Gerald Heymsfield, NASA GSFC; Lin Tian, GEST

Corp. Grant: **Northrup Grumman - GEST**

Investigators: Jeffrey B. Halverson, JCET Associate Director-Academics, Associate Professor of Geography; Raymond Hoff, JCET/GEST

Corp. Grant: **Prototype Electronic Learning Module for Hurricane Science (Prentice Hall Inc.)**

Investigators: Jeffrey B. Halverson, JCET Associate Director-Academics and Associate Professor of Geography; David Stroud, GEST

Description of Research

Halverson studies the dynamics and thermodynamics of severe storms including tropical cyclones, Nor'easters and thunderstorms. His goal is to better understand how these storms develop and evolve in the complex physiographic setting of the Middle Atlantic Region, and also to discern their socioeconomic impacts.

Accomplishments in FY 08-09

During the past year, Halverson and the Physics M.S. student he co-mentored (Ross Dixon) examined the physical processes leading to heavy rain generation in two tropical cyclones that made landfall in the Mid Atlantic region. While both of these storms had similar tracks and intensity at landfall, one produced a localized flash flood (resulting in 8 fatalities) and the other produced widespread heavy rain spanning several states. The goal of the research is to better understand the meteorological evolution of these tropical systems that undergo extratropical transition, which includes interactions with mid-latitude frontal systems, jet streams and the Appalachian Mountains. Freshwater flooding is the number one inland killer by hurricanes and forecasts of heavy rains produced by tropical systems in the Mid Atlantic remain problematic. As one of these cases revealed, the forecast models had insufficient spatial resolution to capture the evolution of the short-lived flash flood event.

Halverson continued his research as a member of NASA's Hurricane Science Team. The thrust of activity has been planning for the next field campaign to investigate hurricane structure and evolution in the Atlantic Basin, GRIP (Genesis and Rapid Intensification Processes), during Fall 2010. Halverson has been extensively involved in helping implement a dropsonde system on the Northrup Grumman Global Hawk, a cooperative effort between NASA, NOAA and the National Center for Atmospheric Research (NCAR).

Objectives for FY 09-10

The research continues to focus on storminess in the Mid-Atlantic region. This important geographic region is home to the greatest concentration of eastern U.S. inhabitants within the D.C.-Baltimore-Philadelphia-New York City megalopolitan corridor. Diverse physiographic influences including the Atlantic, Chesapeake Bay, Blue Ridge Mountains and Appalachians interplay to weave a dynamic mosaic of meteorological processes influencing the genesis, evolution and decay of severe storms. The fate of cold-, warm- and tropical-season storm systems has profoundly shaped the history and socio-economic condition of millions in this region, and will continue to do so. The impact of severe storms on transportation webs and other vital infrastructures in the Mid-Atlantic requires intensive investigation.

Specifically, Halverson and Tom Rabenhorst (UMBC Geography) are authoring a paper on the meteorology of Hurricane Camille, a Category 5 hurricane that created a devastating flash flood in Nelson County, VA three days after landfall, with the loss of 156 lives. The paper explores the small-scale mechanism of heavy rain formation tied to the steep terrain of the region. Halverson is also co-authoring a manuscript on the heavy rain generation by two tropical cyclones in the Mid Atlantic (Gaston, 2004 and Ernesto, 2006) with Ross Dixon (University of Wisconsin) and Lynn Sparling (UMBC Physics).

Task 89: **Modeling of Rainfall Statistics from Satellite and Ground Based Remote Sensing Measurements (NNG05GQ79A)** ***(Sponsor: T. Bell)***

NASA Grant: **Error Estimates for TRMM and GPM Average Rain-rate Maps (Task 913-18-130)**

Investigators: Prasun K. Kundu, Research Associate Professor, Physics; Thomas L. Bell, GSFC Code 613.2

Description of Research

There are four major goals of the research performed under this task: developing mathematical models of rainfall statistics; applying these models to describe statistical behavior of precipitation data sets from a variety of sources, including satellite and ground-based remote sensing measurements as well as rain gauge networks; a detailed study of statistics of precipitation data obtained from low earth-orbiting satellites, such as TRMM Special Sensor Microwave/Imager (SSM/I); and, developing statistical validation techniques for intercomparison of satellite observations of rain and comparison with ground-based radar and rain gauge observations in connection with the validation problem for the rainfall products from the upcoming Global Precipitation Measurement (GPM) Mission that takes into account the natural variability of rain and the spatio-temporal mismatches for near collocated observations.

Accomplishments for FY 08-09

With the help of Dr. Ravi Siddani, a former graduate student at JCET, Kundu and Bell carried out an investigation of the temporal scale dependence of rainfall intermittence using the time-averaged precipitation data from a network of 300+ tipping bucket gauges located in Central and South Florida as part of the TRMM ground validation (GV) program. This study resulted in a simple stretched exponential type formula for the probability of zero rain over a length of time, which successfully fits the observed scaling behavior of wet periods over more than three decades of time scales ranging between 1 min to 3 days. The new formula approximates a power law scaling at large scales but predicts a nearly scale independent behavior at small scales in agreement with observation. The behavior at small time scales that is difficult to ascertain from tipping bucket gauge data is confirmed from disdrometer data from the NASA Wallops Flight Facility provided by Dr. Ali Tokay (JCET). A theoretical explanation was provided for the observed behavior of the probability of zeroes as a function of the averaging time scale in terms of a simple probabilistic model based on the premise that the rainfall process has an intrinsic memory. It was found that the observed behavior reveals an interesting aspect of the rainfall process that can be interpreted as a phenomenon of “persistence of drought”, namely, the longer a zero rain period, the less likely it is for it to end. The result was reported at the EGU 2009 General Assembly in Vienna and is being prepared for publication.

The theoretical framework established in an earlier work [Kundu and Siddani, 2007] for studying the scaling properties of the moments of a spatially averaged rain rate field was

applied to the multi-year gridded data set based on spatially averaged radar data from the TRMM ground validation (GV) site in Melbourne, Florida (TRMM standard product 2A53). A study of nearly 10 years of data with each year divided into four seasons was carried out. A preliminary result of the analysis is that the precipitation statistics of periods classified by seasons exhibit very little variation from year to year, *i.e.* a nearly universal behavior, when expressed in terms of the quantities introduced in the previous work based on statistics of gridded radar data from the Tropical Ocean Global Atmosphere - Coupled Ocean-Atmosphere Response Experiment (TOGA-COARE). The moments of the rain rate data aggregated at various spatial scales were found to exhibit non-trivial power law scaling, known as multiscaling or multifractal behavior. Based on the behavior of the large order moments, the underlying probability distribution of area-averaged rainfall was identified as a member of the log-infinitely divisible class of distributions previously discovered from the TOGA-COARE radar data.

Objectives for FY 09-10

In the coming year, Kundu's immediate goals are to obtain a probabilistic model of time-averaged precipitation based on different types of disdrometer and gauge measurements including the multi-year rain data from the TRMM ground validation (GV) sites; to examine spatial statistics of TRMM PR (Precipitation Radar) derived rain data and test the model predictions with regard to the multiscaling behavior; to formulate a framework for satellite-gauge comparison based on Kundu and Bell's previous work [Bell and Kundu, 2003]; and finally to pursue the problem of obtaining a parameterized model of the joint probability distribution of rain at slightly different times in terms of a suitably chosen copula using existing GV radar data as a step towards statistically characterizing the difference between two nearly collocated satellite data sets.

Task 28: Research Support For Precipitation Science *(Sponsor: E. Smith)*

Task 109: Research Support for Goddard Earth Sciences Data and Information Services *(Sponsor: G. Leptoukh)*

Investigator: Amita V. Mehta, Research Assistant Professor, Geography and Environmental Sciences

Description of Research

The main objective of this research for the past year has been to analyze atmospheric pollution data obtained from a multi-model inter-comparison project, Hemispheric Transport of Air Pollution (HEMITAP), and to develop a web-based portal under the Goddard Earth Sciences Data and Information Services and Interactive Online Visualization and analysis Infrastructure (Giovanni) to disseminate this information to the atmospheric chemistry and air pollution modeling user community. An additional activity included contributions to enhance Giovanni's Goddard Hurricane portal with satellite and atmospheric forecast model data and analysis. Moreover, ongoing projects continued on retrieval, observational analysis, and modeling of precipitation with the focus on Gulf of Mexico - Caribbean Sea (GM-CS) basin and Mediterranean basin (Med).

Accomplishments in FY 08-09

The United Nations Economic Commission for Europe (UNECE) established the Hemispheric Transport of Air Pollution (HEMITAP) to examine Long-range Trans-boundary, Air Pollution (LRTAP-http://www.unece.org/env/lrtap) to study inter-continental transport of pollutants (http://www.htap.org). Approximately 43 atmospheric models participated in this program and a large number of sensitivity experiments to study relationship between atmospheric chemistry and circulation. This project resulted in a voluminous database of air pollutants and atmospheric dynamic and thermodynamic data, difficult to download and analyze by user community. To facilitate the study of HEMITAP air pollution, the Giovanni team initiated a new project for the development of a web-based data analysis and visualization facility. Under the current JCET Task 109, a prototype version of the HEMITAP-Giovanni web instance was created to conduct statistical analysis and inter-comparison of the HEMITAP data. A presentation about this instance was made in the 'Workshop on Linkages Between Regional and Global Modeling and Air Quality and Climate Change' held in France from June 17-19, 2009. Various issues with the HEMITAP data are currently being discussed and an operational HEMITAP-Giovanni instance will soon be available. In addition, an inter-comparison of the HEMITAP model data with surface measurements of SO_2, NOx, and $PM_{2.5}$ out over South Asia was initiated.

Under an ongoing project of Cloud Dynamics and Radiation data base (CDRD) for improved rain retrievals from future microwave radiometers, an experimental, Bayesian-type algorithm to retrieve precipitation was developed and is currently being tested over the Med region.

Objectives for FY 09-10

The main objective for the next year is to conclude the CDRD project by demonstrating its accuracy and usefulness in rain retrievals from microwave radiometers over the GM-CS and Med regions. In addition, two new projects will be commenced: first, a quantitative analysis of water budget over the Med basin using satellite and atmospheric re-analysis data, and second, a study of eye-wall replacement processes in hurricanes by using satellite and field experiment data. Mehta's additional goal is to help finalize the HEMITAP-Giovanni instance and also to participate in regional inter-comparisons of HEMITAP pollution data.

NASA Grant: Combined Radar/Radiometer Estimates of Precipitation and Latent Heating Profiles for Training Spaceborne Passive Microwave Radiometer Algorithms (NNX07AK46G)

Task 45: Global Retrieval of Precipitation and Latent Heating Distributions from Spaceborne Radiometer/Radar Observations *(Sponsor: M. Schoeberl)*

NASA Grant: Retrieval Algorithm Development for Precipitating Snow Detection and Estimation Using High Frequency Observations (06-PMM06-0045)

NASA Grant: Multi-frequency Polarimetric Radar, Profiler, and Space-Borne Studies of Particle Size Distributions and Mixed Phase Processes in Cold and Warm Season Precipitation (NNX07AK39G)

NASA Grant: Calibration and Analysis of Global Latent Heating Estimates Using Passive and Active Microwave Sensor Data (NNG06GC99G)

NASA Grant: A Long-Term Precipitation Dataset with Uncertainty Information (NNX08AT04A)

Investigators: William S. Olson, Research Associate Professor, Physics; Mircea Grecu, UMBC/GEST; Chung-Lin Shie, UMBC/GEST; Gail S. Jackson, GSFC, Code 614.6; Mei Han, UMBC/GEST; Lin Tian, UMBC/GEST; Arthur Hou, GSFC, Code 610.1; Christian Kummerow, Colorado State University.

Description of Research

The main emphasis of Olson's team's research is on the calibration of satellite passive microwave estimates of precipitation and latent heating using coincident, high-resolution estimates from spaceborne radar as a reference. Spaceborne radar methods for estimating precipitation/latent heating vertical structure are being developed and tested for applications to 14-GHz radar (Tropical Rainfall Measuring Mission; TRMM) and 14 and 36 GHz radar (Global Precipitation Measurement mission; GPM) and 94-GHz radar (CloudSat mission) in conjunction with a range of passive microwave multispectral observations. Regarding precipitation, their specific objectives are to improve the representations of ice and mixed-phase particles in combined radar/passive microwave algorithms. The remote sensing of latent heating vertical distributions using spaceborne radar and passive microwave observations is a related area of study, with implications for understanding the earth's water and energy cycles.

Accomplishments in FY 08-09

With an anticipated launch date midway through 2013, the GPM core mission observatory will include both spaceborne radar (14 and 36 GHz) as well as a range of

passive microwave radiometer channels (10-183 GHz). These channels will provide their "best" estimates of precipitation and latent heating vertical profiles, and these, in turn, will be used to cross-calibrate radiometer-only profile estimates from an international fleet of radiometers flying in complementary orbits. Prof. Hirohiko Masunaga (Nagoya University) and Olson co-lead a team to develop and implement a combined radar-radiometer algorithm that will be applied operationally to the GPM core instruments, and this past year, the radar-only and combined algorithm teams met at GSFC to begin assigning tasks for constructing the algorithms. Dr. Mircea Grecu and Olson are developing a combined radar-radiometer algorithm for satellite applications, based upon a method of ensemble filtering. This technique was successfully applied to TRMM Precipitation Radar and Microwave Imager data, and can be easily adapted to GPM radar and radiometer observations.

Also under GPM, the PI leads a working group to improve the representation of ice and mixed-phase precipitation physics in combined algorithms. Dr. Grecu and Olson developed a forward cloud/radiative model and optimization method that can be used by the working group to diagnose biases and uncertainties in ice/mixed-phase precipitation physics through comparisons to airborne remote sensing and *in situ* data from recent field campaigns. In a related investigation with Dr. Walter Petersen (University of Alabama-Huntsville), a thermodynamic/electromagnetic melting layer model was developed to help interpret radar and passive microwave remote sensing data from field observations.

A study with Dr. Mei Han to examine the consistency of model-simulated and TRMM-observed radar reflectivities and upwelling microwave radiances from a cold frontal rainband recently concluded; this study helped Olson's team quantify the strengths and weaknesses of different model microphysical parameterizations. The predominance of simulated graupel from some microphysical schemes led to excessive microwave bulk scattering, while the overabundance of snow in other schemes led to a surplus of radar backscatter, relative to TRMM observations. An adjustment of current bulk microphysical methods or the use of multiple-moment methods will be required to resolve the discrepancies between model simulations and observations.

Under NASA's Energy and Water cycle Study (NEWS), the latent heating estimation algorithm developed with Drs. Grecu and Chung-Lin Shie was applied to TRMM Microwave Imager observations and combined with estimates of radiative heating from Tristan L'Ecuyer (Colorado State University) to create a 10-year satellite-based record of total diabatic heating. The investigators also completed a preliminary study of the mean seasonal cycle of diabatic heating.

A new investigation under the direction of Dr. Christian Kummerow (Colorado State University) commenced during the reporting period, and preparatory work to process a consistently calibrated, long-term record of Special Sensor Microwave/Imager (SSM/I) rain rate estimates was completed. This work is supported by NASA's MEaSUREs program.

Objectives for FY 09-10

The GPM-combined radar-radiometer algorithm team will assemble precipitation algorithm components and develop a theoretical basis document to describe the current algorithm configuration. Olson's team will continue to test their ensemble filtering approach for combined algorithm applications. The ice/mixed-phase precipitation working group will begin evaluating physical parameterizations of precipitation, including their thermodynamic/electromagnetic melting parameterization, against field observations. Studies of the climatology of total diabatic heating and the extension of this climatology to over-land regions will also be performed. The long-term record of consistently calibrated rainfall estimates from SSM/I will be used to adjust Global Precipitation Climatology Project (GPCP) infrared rain estimates.

NASA Grant:	Measurements of the Hydrometeor Size Distribution through Surface-based Instruments (NNX 07AF45G)
NASA Grant:	Improved Ground Validation Rain Estimates at Kwajalein and Central Florida for Comparison to and Validation of TRMM and Other Satellite Estimates (NNX 07EJ50C)
Task 34:	A proposed Mid-Latitude Coastal Ground Validation Site for the NASA Precipitation Measurement Mission *(Sponsor: M. Schwaller)*
Investigator:	Ali Tokay, Research Associate Professor, Affiliated Associate Professor

Description of Research

The theme of the study is to improve the precipitation measurements under the umbrella of NASA's Precipitation Measurement Mission. The investigator takes four major avenues in improving precipitation measurements: first, the collocated measurements of disdrometers, profilers, and scanning radars have been employed to diagnose the measuremnt accuracy and error bars of each measurement; second, the variability of raindrop size distribution and rain parameters has been investigated within the radar pixel and satellite footprint; third, efforts have been made in determining precipitation microphysics in rain, mixed precipitation, and snow; and fourth, steps have been taken to evaluate the existing operational rainfall products that can be used to validate the satellite precipitation products.

Accomplishments for FY 08-09

A publication that appeared in a peer-reviewed journal was related to the time height ambiguity of the reflectivtity between collocated disdrometer and profiler measurements. The manuscript also included the vertical variation of radar rainfall relation in rain layer when profiler reflectivity and disdrometer rain rate is employed. The observations were taken through a 16-month-long field campaign at NASA Wallops Flight Facility (WFF) [Tokay *et al.* 2009a].

A manuscript on the performance of operational gauges submitted to a peer-reviewed journal has been conditionally acceped for publication. This study employed collocated dual or triple research and a single operational gauge in the Mid-Atlantic region. The research gauges were on the field for more than a year in each site and the study has been conducted for daily and monthy rainfall [Tokay *et al.* 2009b].

A manuscript has been submitted to a peer-reviewed journal on the variability of raindrop size distribution and rain parameters in radar pixel. This study was conducted employing three disdrometers at WFF. The statistics (correlation coefficent and

standard deviation) of four-month-long observations showed noticable differences in size distribition and rainfall parameters [Tokay *et al.* 2009c].

A study on the performance of Parsivel disdrometer in snow has been submitted and conditionally accepted in a peer-reviewed journal. The measuring principles of Parsivel have been revisited and its performance was evaluated through a comparative study of collocated Parivel and two-dimensional disdrometer measurements during a field campaign in Southern Ontario, Canada [Battaglia *et al.* 2009].

A study on the evaluation of the Multi-sensor Precipitation Estimate (MPE) was evaluated using a rain gauge network in the Mid-Atlantic region. Since the gauges are not part of the MPE, they provide an independent source of evaluation. The comparisons were done on hourly, three-hourly, six-hourly, daily, and monthly time scales. The results showed that the gauge adjustment is an important component for the accuracy of MPE product. Dr. Kurtulus Ozturk, visiting GEST fellow, led this effort.

A study on the variability of rainfall within a satellite footprint has been conducted through six dual rain gauge sites at WFF. The study focuses on the rainfall decoration distance and its dependency on the time integration and rainfall types. Tokay considered time integration between 5-minute and daily rainfall and stratified two years of observations by season, 6-month, and yearly periods. The observations were also stratified by frontal rain and tropical cyclones as well as uniform, variable, and highly variable rainfall. Dr. Kurtulus Ozturk, visiting GEST fellow, led this effort as well.

A study on the determination of the regime dependency of the raindrop size distribution has been conducted using disdrometer data in Southeast Texas. The size spectra in a tropical cyclone exhibited more small drops and less large drops at a given reflectivity. There were also noticeable differences in size distribution between cold and warm frontal events. Collin Lawrence, visiting summer student, led this effort.

Finally, a comparative study of radar-measured disdrometer-calculated reflectivity was also conducted in Southeast Texas. Two disdrometers were 19 and 80 km from the radar, and rainfall statistics showed considerable bias between the two measurements. Aaron Ferrel, visiting summer student, led this effort.

Objectives for FY 09-10

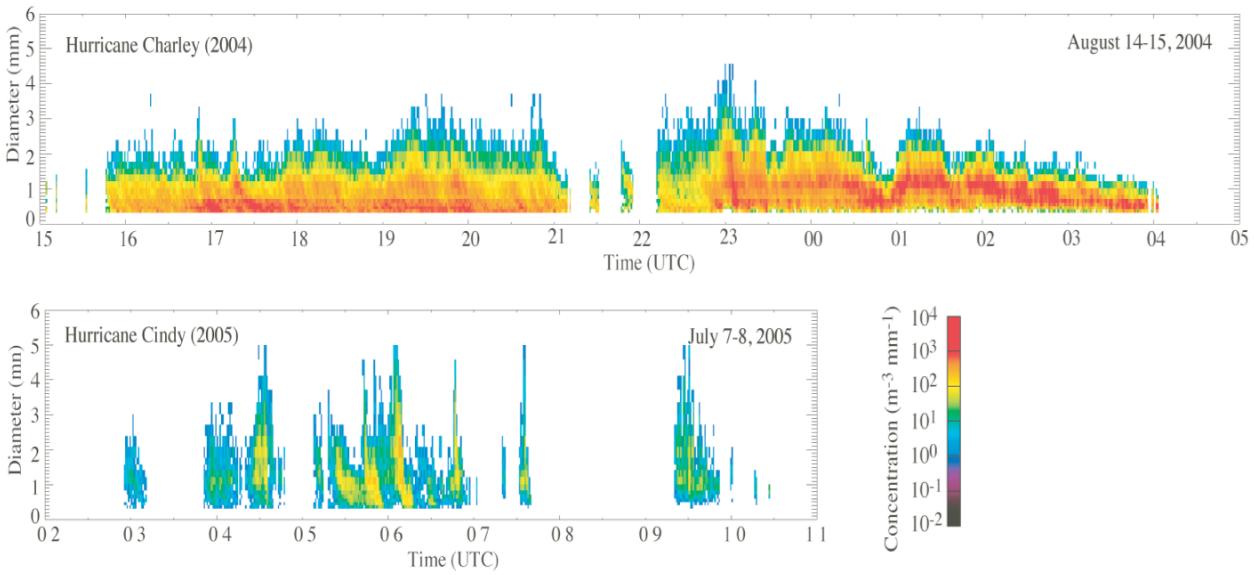
Tokay expects to complete ongoing studies and submit two manuscripts to peer-reviewed journals. A comparative study of Parsivel and and two-dimensional video disdrometers will be performed employing snow and rain events in Canada and rain events in Hunstsvile, AL. These disdrometers will be used in determining the characteristics of snowfall and the variability of raindrop size distribution and rain parameters in upcoming Global Precipitation Measurement (GPM) mission field campaigns in Finland and Oklahoma. The regime dependency of raindrop size distribution will be investigated by employing disdrometer data sets in WFF. This mid-latitude site receives precipitation from frontal systems, air mass thunderstorms, and remnants of tropical cyclones. The relations between the polarimetric radar observables and rainfall will be derived for different precipitation regimes, with NASA's S-band polarimetric radar in mind. A new precipitation validation site has been constructed

at the Howard University – Beltsville campus. Tokay plays a role in these efforts and will conduct the preliminary data analysis.

JCET Highlight: Raindrop Abundance and Intensity

Investigator: Ali Tokay

Through the use of disdrometers, Dr. Tokay examines the characteristics of raindrop size distribution in tropical cyclones before and after they merge with the frontal systems. Tropical cyclone is named as extra-tropical cyclone after it merged with frontal system. Extra-tropical cyclones develop raindrops that are larger in size and mass than those of tropical cyclones, while tropical cyclones that form over water tend to rain harder and have a greater amount of smaller raindrops. As Tokay stated on ScienceDaily.com, "Both rain intensity and reflectivity are integral products of raindrop size distrbution, but they are mathematically related to different powers of the drop size." Rainfall estimates using weather radar can assist forecasters to more accurately predict rain intensity and possibly flash flooding, which can lead to lives saved.



Reference: Tokay, A., P. Bashor, E. Habib, and T. Kasparis (2008), Raindrop Size Distribution Measurements in Tropical Cyclones, Monthly Weather Review, 136 (5), May 2008, pp. 1669-1685, doi: 10.1175/2007MWR2122.1

This page intentionally left blank

Climate and Radiation
(Code 613.2)

This page intentionally left blank

NASA Grant: Aerosol optical depth retrievals using reflectance ratios from MODIS data (NNX09AD55G)

DOE Grant: Use of the ARM measurements of spectral zenith radiance for better understanding of 3D cloud-radiatio processes and aerosol-cloud Interaction

Investigators: J.-Y. Christine Chiu, Assistant Research Professor, JCET, Physics; Alexander Marshak, JCET Fellow, NASA/GSFC, Code 613.2; Warren Wiscombe, NASA/GSFC, Code 613.2

Description of Research

Cloud optical depth is the most fundamental cloud property determining the Earth's radiative energy balance. However, cloud optical depth is poorly predicted by climate models and is very difficult to remotely sense from the surface using traditional methods. This project focuses on remote sensing clouds from the ARM measurements of spectral zenith radiance, including passive radiometers and active lidars. These measurements are used not only to retrieve cloud optical propertes, but also to study spectral behavior in the area around cloud edges. In addition, based on satellite observations, a number of studies have shown that aerosol optical depth increases with cloud cover. This positive correlation could be attributed to a number of reasons, such as humidification of aerosols, cloud contamination, and radiative transfer effects. To reduce retrieval error from the cloud-induced enhancement in clear sky reflectances (3D cloud radiative effects), a method proposed by Kassianov and Ovtchinnikov (2008) using reflectance ratios is tested on MODIS data.

Accomplishments for FY 08-09

Currently, cloud optical depth is one of the most poorly observed climate variables. While a number of satellites routinely observe clouds, measurements from ground-based networks are limited. Only two operational networks provide continuous cloud measurements: the Atmospheric Radiation Measurement (ARM) program and Cloudnet. The former has five sites, and the latter has three sites. Thus, there is a severe lack of ground-based cloud observation on a global scale.

The Aerosol Robotic Network (AERONET) is a ground-based network that is designed to measure microphysical and optical properties of aerosols. AERONET is comprised of sun/sky radiometers that measure radiance at wavelengths of 440, 500, 675, 870, 936 and 1020 nm. Direct sun measurements are mainly used to screen out clouds and to retrieve aerosol optical depth, while sky radiance measurements are mainly used to retrieve aerosol microphysical and optical properties such as aerosol size distribution, phase function and single scattering albedo. However, when clouds completely block the sun, neither direct sun nor sky measurements is are appropriate for retrieving aerosol optical properties. Therefore, in these situations, the radiometer is put into sleep mode. Some of the sleep-mode time is proposed to observe clouds. The traditional mode for monitoring aerosols is

called “normal aerosol mode”, and the new one for monitoring clouds, “cloud mode”. The new “cloud mode” in AERONET will increase cloud optical depth observations dramatically in both number and accuracy.

Cloud mode retrievals were tested at the Atmospheric Radiation Measurement program’s Oklahoma site for a variety of situations, ranging from broken clouds to overcast. For overcast cases, AERONET1.5-min average cloud-mode cloud optical depth retrievals agreed to better than 10% with those from a standard ground-based flux method. For broken clouds, AERONET retrievals could capture the rapid variations revealed by the microwave radiometer. A three-year climatology of (daytime) cloud-mode retrievals agreed reasonably well with lidar-radar retrievals both in seasonal variation and probability distribution of optical depth. However, Chiu’s monthly mean cloud optical depths are generally larger than lidar-radar retrievals, mainly due to the current observation strategy of cloud mode, which excludes optically thin clouds. Cloud products from AERONET not only demonstrate a unique approach to acquire cloud and aerosol properties using a single instrument, but also greatly enhance current cloud observations and expand them to a global scale.

Work on the transition zone between cloudy and cloud-free regions continues. To the naked eye, clouds appear to have sharp boundaries, but this is merely an illusion. Cloud boundaries are actually somewhat fuzzy, with the transition from cloud to clear stretching over as little as 50-m to as much as several hundred meters. Within this transition zone, strong but poorly understood aerosol-cloud interactions are taking place. One-second-resolution zenith radiance measurements from the ARM program's new shortwave spectrometer (SWS) provide a unique opportunity to analyze the transition zone. The SWS points straight up and measures zenith radiance at 418 wavelengths between 350 and 2200 nm. A surprising spectral invariant behavior was found between ratios of zenith radiance spectra in the transition zone. This behavior suggests that the spectral signature of the transition zone is a linear mixture between the two extremes (definitely cloudy and definitely clear).

Cloud optical depths retrieved from the ARM’s deployment at Pt. Reyes, California in 2005 were used to provide statistical measures of aerosol-cloud interactions (ACI) and to characterize measures’ variability in environmental conditions and observational approaches. The measure of ACI varies, depending on the assumption of constant cloud liquid water path (LWP), the relative value of cloud LWP, aerosol size distribution, updraft velocity, and the scale and resolution of observations.

Objectives for FY 09-10

Learning about spectral behaviors in the transition zone between cloudy and cloud-free regions will continue. First, a 1D SBDART radiative transfer model will be used to simulate spectral radiance. This will help the investigators to better understand how spectral invariant behavior varies with solar zenith angle, surface albedo, aerosol loading, etc. Second, a 3D radiative transfer model will be used to better understand the effects of 3D cloud structures and the field-of-view on zenith radiance measurements. Third, Chiu will revisit 2NFOV data from the Pt. Reyes campaign to investigate radiative signature in the transition zone.

The ARM Clouds with Low Optical Water Depths (CLOWD) Optical Radiative Observations (RACORO) field campaign has made routine flights to observe low-altitude liquid-water clouds in the boundary layer during January – May 2009. The goal of the campaign is to collect representative statistics of cloud microphysical properties and to help validate ground-based retrieval methods. Airborne flux and radiance measurements will be analyzed and used to validate retrieved cloud optical depth from the "REDvsNIR" and the "COUPLED" methods.

Chiu and her team will continue analyzing data collected from the ARM two-channel narrow-field-of-view radiometer (2NFOV) during the China campaign. The intercomparison of preliminary retrievals to those from flux measurements shows reasonable results. More comparisons with retrievals from the ARM micropulse lidar and microwave radiometer will be conducted and reported.

Task 18:	**Studies of Aerosol Particles from Biomass Burning and its Radiative Effects *(Sponsor: L. Remer)***
NASA Grant:	**Climate Effect of Black Carbon Aerosol on Tropical Convective Clouds and Precipitation**
NASA Grant:	**Remote Sensing Measurements of Aerosol Absorption and its Effects on Climate Forcing**
NASA Grant:	**Investigation of Aerosol Spectral Absorption Properties from UV to NIR**
NASA Grant:	**Rainbow and Cloud Side Remote Sensing: A Novel Look at Cloud-Aerosol Interaction and its Effect on Cloud Evolution**
Investigators:	J. Vanderlei Martins, Associate Professor, Physics; Roberto Fernandez Borda, Assistant Research Scientist, Research Faculty; Tianle Yuan, Post-Doc; Dominik Cieslak, Engineer
Students:	Steven Buczkowski, PhD Student; Gergely Dolgos, PhD Student; Li Zhu, PhD Student; Adriana Rocha Lima, PhD Student

Description of Research

The optical properties of aerosol particles and its effects on the radiative balance of the atmosphere and on cloud microphysics constitute major uncertainties in determining the anthropogenic impact on Earth's climate and weather. These two issues are addressed in this task with a variety of new techniques and methodologies that cover instrument development, laboratory and field measurements from the ground and aircraft, algorithm development, satellite remote sensing, and model calculations. One of the novel spectral absorption techniques applied in this project provides detailed information on wide wavelength range (350-2500nm) for samples from several regions in the globe, including India, China, Brazil, Israel, USA, Mexico, UAE, Chad, etc. The impact of aerosol in clouds and precipitation is another very important topic in aerosol research addressed in this task via the study of aerosol microphysical properties and via the measurement of cloud spectral properties using novel instrumentation developed in our laboratory. Major efforts in this task are also devoted to the development of new ground based, airborne, and satellite techniques to measure aerosol, clouds, its interactions and consequences. Prototype instruments were built and are being applied to the measurement of cloud properties from the ground and from aircraft. These instruments are also being studied as prototypes for future satellite measurements, including the PACS (Passive Aerosol and Cloud Suite) that is part of the ACE Mission, which is included in the National Academy of Sciences Decadal Survey. Recent efforts have also being devoted to the development of Pico-satellites for the measurement of aerosol and cloud properties.

Accomplishments for FY 08-09

In FY09 Martins and his team have continued their efforts on the development of

algorithms, instrumentation and methods for the measurement of aerosol absorption and scattering properties via remote sensing and *in situ* techniques, on the development and application of instrumentation for the measurement of the effect of aerosols on the vertical profile of cloud effective radii and thermodynamics, and on the development of instrumentation and methods for the measurement of polarized radiances for the retrievals of aerosol and cloud microphysical and thermodynamic properties. They also continued the collection and analysis of *in situ* data from several field campaigns and ground stations. Significant efforts were spent toward the development of new remote sensing measurement concepts from aircraft and space. Important efforts were also dedicated to the understanding of the effect of aerosol particles on cloud formation, evolution, and lifetime. In this fiscal year, they continued the design and began to build a new version of the PACS polarimeter to be proposed as part of the Decadal Survey ACE Mission.

There were several significant and specific developments over the past year, such as the development of a tethered balloon sonde for the measurement of the vertical profile of scattering and absorption properties of aerosols. This sonde was used for the first time in China in July 2008. They also developed the PACS Polarimeter prototype for the ACE Mission proposal, as well as algorithms and methods for the measurement of cloud microphysical properties using the cloud-bow. Martins' team participated in the VOCALS aircraft experiment in Chile, October/November 2008 for the measurement of cloud bows in stratiform clouds. They developed dry and wet aerosol generators for the production and measurement of various types of aerosols in the laboratory, and they developed instrumentation for the measurement of aerosol phase function. Additionally, they developed and applied techniques for the measurement of the spectral absorption properties of aerosols from 200-2500nm. And, the team developed a concept for measurements of cloud microphysical properties using Pico Satellites.

Objectives for FY 09-10

In the coming year, the investigators intend to finish the first prototype of the ACE/PACS imaging polarimeter and perform its first field/aircraft tests. They will continue the development of new *in situ* instrumentation for aerosol sampling and for the measurement of aerosol scattering and absorption properties, as well as the development of remote sensing techniques for the measurement of aerosol absorption and direct radiative forcing, and the development of polarization algorithms for the detailed retrieval of aerosol and cloud particles. Also they intend to implement the cryogenic component of their laboratory aerosol generator, allowing for the study of phase transitions between water and ice, detailed properties of cloud ice particles, and their interaction with several aerosol types including dust, smoke, etc.

Task 72: **Retrieval of cloud and sea ice properties from THOR lidar measurements** ***(Sponsor: R. Cahalan)***

DOE Grant: **Parameterization and analysis of 3D solar radiative transfer in clouds**

Investigators: Tamás Várnai, Research Assistant Professor, Physics; Alexander Marshak, JCET fellow, NASA GSFC Code 613.2; Robert F. Cahalan, JCET fellow, NASA GSFC Code 613.2; Stefani Huang, SSAI.

Description of Research

The overall goal of this research is to improve the understanding of 3D radiative processes that occur in clouds, snow and sea ice. Várnai's work focuses on four areas in particular. First, it examines the influence of 3D radiative interactions on radiative heating in clouds and cloud development. Second, it investigates the uncertainties 3D radiative processes cause in satellite retrievals of cloud optical thickness and aerosol properties near clouds. Third, it explores a new retrieval technique that determines the structure of snow, sea ice, and highly opaque clouds by observing the way 3D multiple scattering spreads out the returning lidar pulses. Fourth, it brings improvements to the 3D radiative transfer tools available to the research community by coordinating model intercomparisons, providing on-line resources, and organizing workshops on 3D radiative transfer.

Accomplishments for FY 08-09

This year Várnai and his team expanded their research on 3D radiative processes by considering not only the implications for satellite remote sensing but also for cloud development. In order to enable dynamical cloud simulations to consider the 3D nature of radiative heating, they started developing a new radiation parameterization. As a first step toward training this parameterization, they created a large database of cloud structures at two sites of the Department of Energy Atmospheric Radiation Measurement program and performed radiative simulations for them. Initial results (presented at a recent conference) indicated that 3D effects change both radiative heating and satellite radiances especially in cumuloform clouds.

The investigators also continued to research 3D radiative processes that affect satellite retrievals of aerosol properties in the vicinity of clouds. They completed a statistical analysis of MODIS observations over clear areas near clouds, which can be influenced by 3D effects [Várnai and Marshak, 2009], and also analyzed CALIPSO lidar data that are not influenced by 3D processes. The results indicated that the 3D process of clouds scattering sunlight toward nearby cloud-free areas significantly increases the brightness of MODIS images near clouds. Next, they plan to explore the potentially large implications of this finding on satellite measurements of aerosol properties.

They also continued exploring the benefits of offbeam multiview lidars that can detect photons returning from increasingly wide rings around a spot illuminated by a laser beam. This year they further analyzed and published in a peer-reviewed conference paper the

ground-based observations taken last year in Maryland and Pennsylvania [Várnai and Cahalan, 2009]. The results suggest that despite the large amount of absorbing aerosol embedded in the snow in this region, halo-observations can still reveal the thickness of thin and moderately thick snow covers, which in turn suggests that fairly minor upgrades could enable their cloud-observing instrument to provide valuable airborne snow thickness measurements. They also started exploring the potential for obtaining cloud microphysical information from ground-based dual-view micropulse lidars.

Finally, Várnai and his team further advanced the third phase of the I3RC (Intercomparison of 3D Radiative Codes) project. In particular, the results of their most recent intercomparisons were published in a peer-reviewed conference paper [Várnai and Cahalan, 2009] and posted at the I3RC website (http://i3rc.gsfc.nasa.gov). They also improved the user friendliness of the I3RC community model of 3D radiative transfer and made other improvements to the I3RC website.

Objectives for FY 09-10

Next year, the investigators plan to use their new dataset to develop a parameterization that is fast enough to allow 3D radiative calculations even in high-resolution dynamical models of cloud development. This will be an important step toward examining the influence of 3D radiative processes on cloud development.

In addition, they plan to continue exploring the 3D radiative effects through which clouds influence aerosol measurements near them. In particular, they plan to combine observation statistics with radiative simulations in order to estimate the effects on aerosol optical thickness and particle size retrievals.

They also intend to utilize their new dataset of cloud structures at DOE sites to examine the implications of simulated 3D radiative effects for satellite measurements of cloud properties. Their ultimate goal is to help improve these measurements by establishing statistical relationships between easily observable features such as cloud texture and 3D influences on cloud optical thickness retrievals.

Further, the investigators intend to expand the scope of multiview lidar measurements by exploring the potential for measuring vertical profiles of optical properties in stratiform clouds.

Finally, Várnai and his team plan to make additional improvements to the I3RC website so that it provides additional resources for the 3D community. The planned upgrades include an online 3D radiative transfer calculator and an online test bed suitable for future model evaluation.

This page intentionally left blank

Atmospheric Chemistry and Dynamics (Code 613.3)

This page intentionally left blank

NASA IPA: Intergovernmental Personnel Act (IPA) Assignment to the NASA HQ Science Mission Directorate's Research and Analysis Program, Program Manager and Scientist

Investigator: Ernest Hilsenrath, Professor of Practice

Description of Research

Hilsenrath is an IPA detailed to NASA Headquarters. He participates in the formulation and implementation of various elements of NASA's Science Mission Directorate's (SMD) Earth Science Division to include the Atmospheric Composition Focus Group in collaboration with the Atmospheric Composition Modeling and Analysis Program, Upper Atmosphere Research Program, Tropospheric Chemistry Program (ACMAP) and the SMD Applications Division. He participates in scientific research solicitation and selection through the ROSES program and the initiation of research grants with selected principal investigators. Through CEOS (Committee for Earth Observing Satellites), he coordinates and participates with international groups consisting of representatives of international space agencies and represents NASA interests in international forums and collaborating flight missions and research programs. He is the EOS-Aura Program Scientist.

Accomplishments for FY 08-09

In the past year, Hilsenrath chaired the CEOS Constellation effort for international collaboration and coordination of Atmospheric Composition satellite missions. He also conducted two workshops; the first on "Data Gaps and Impact on Atmospheric-Chemistry Models and the second on "Air Quality Measurement Capabilities from Satellites". Peer review reports were prepared and submitted to the CEOS space agencies (posted at www.ceos.org).

Hilsenrath initiated the development of the Atmospheric Composition Portal to service the CEOS and GEO communities, and he provided programmatic support for the Aura mission by dealing with the Senior Review proposal for continued mission operations and data analysis and budget distributions.

He also participated in the development of the ACMAP ROSES 09 solicitation and reviewer selection. Additionally, he tracked the progress of NASA-selected Atmospheric Composition Principal Investigators and service of their grants.

Objectives for FY 09-10

Going forward, Hilsenrath plans to continue the development of CEOS Atmospheric Composition Constellation efforts by engaging international partners through the development of projects. He will oversee the demonstration of a CEOS-sponsored Atmospheric Composition portal. He will also provide programmatic support for the upcoming atmospheric composition Decadal Survey missions: GEO-CAPE and GACM. Hilsenrath will also continue to support NASA's Atmospheric Composition Focus Area to the US Climate Change Science Program, continue as EOS-Aura Program Scientist representing the interests of mission science and budget allocations, continue ongoing support to the

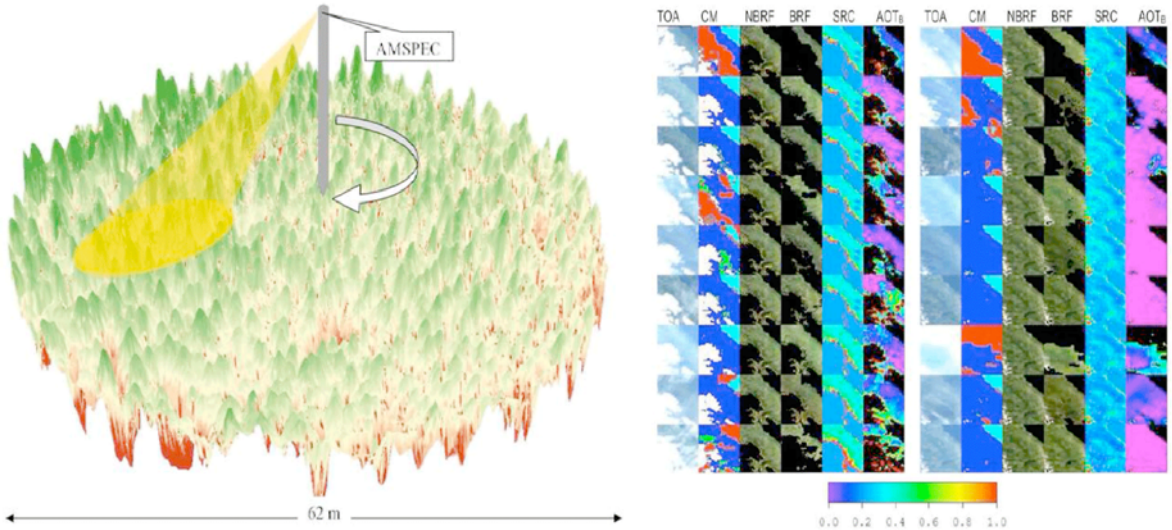
NASA SMD Earth Science program for Congressional and Administration inquiries and NASA strategic planning. Finally, he plans to co-chair the ROSES 09 panel review and selection process for Atmospheric Composition Modeling and Data Analysis Program.

Hydrospheric and Biospheric Sciences (Code 614x)

JCET Highlight: Forest Light Use and Photosynthesis from MODIS

Investigators: Forrest Hall, Thomas Hilker, Alexei Lyapustin, K. Fred Huemmrich, Elizabeth Middleton, Hank Margolis, Guillame Drolet, and Andy Black

A breakthrough in the direct satellite measurement and validation of forest photosynthetic rate from the MODIS satellite sensor has resulted from a collaboration between UMBC/JCET, GEST, the University of British Columbia, Laval University, and the NASA Goddard Space Flight Center. The advance is a result in part of a novel tower-mounted spectro-radiometer (AMSPEC) and methodology for characterizing the complex diurnal angular reflectance patterns of a forest as measured throughout the day from a tower and a new multi-angular implementation of atmospheric correction (MAIAC). MAIAC characterizes and adjusts MODIS-observed forest angular reflectance patterns for the intervening cloud and aerosol properties at the time of a MODIS overpass.



TOWER-MOUNTED DIURNALSPECTROMETER MODIS/MAIAC

The tower-mounted spectrometer measures narrow waveband spectral properties of the forest at numerous view-angles every 15 minutes; the tower-mounted gas flux, radiation and wind sensors permit estimates of average light use efficiency during those periods; and on its overpass each day, MODIS measures the photochemical reflectance index (PRI), a vegetation index composed of MODIS bands 11 and 12. The investigators have shown in previous work PRI provides a direct measure of photosynthetic down-regulation when the forest is stressed because leaf and canopy reflectance changes in MODIS Band 11(531nm). By using MAIAC, a breakthrough technology, to relate the tower-mounted spectrometer measurements of PRI to the daily MODIS measurements of PRI under varying solar illumination, view angles, and atmospheric conditions, they can now measure changes in forest photosynthetic rate from MODIS.

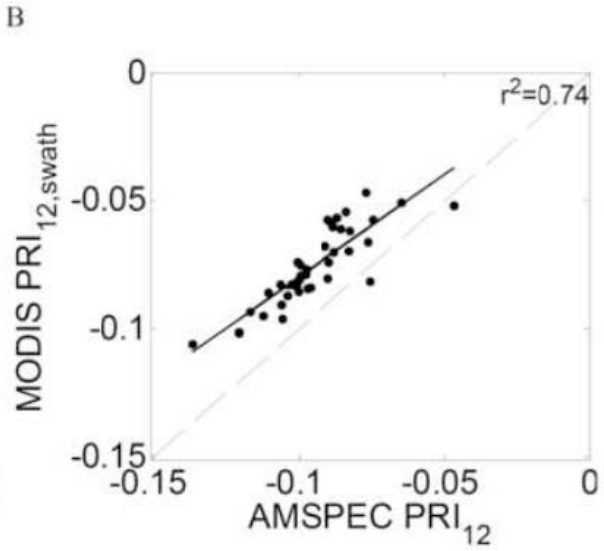


Figure 2 (above) demonstrates the high correspondence between the spectrometer and MODIS measurements for all MODIS acquisitions between April 1st and September 15th 2006.

This page intentionally left blank

Task 71: **NASA Terrestrial Ecosystems, Spectral Bio-Indicators of Ecosystem Photosynthetic Light Use Efficiency** ***(Sponsor: E. Middleton)***

Investigator: Petya K. E. Campbell, Ph.D.

NASA Grant: **EO1-Hyperion: Data analysis and product generation, in support of future satellite missions**

Investigators: P. Campbell; E. Middleton and S. Ungar, Biospheric Sciences Branch, Laboratory for Terrestrial Physics, NASA/Goddard Space Flight Center, Greenbelt, MD

NASA Grant: **Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency**

Investigators: P. Campbell; E. Middleton, Biospheric Sciences Branch, Laboratory for Terrestrial Physics, NASA/Goddard Space Flight Center, Greenbelt, MD

Description of Research

One of the most important issues facing scientists today focuses on balancing the global carbon cycle and determining the major carbon (C) sources and sinks within the Earth system. Current remote sensing methods do not provide accurate estimates of vegetation physiological status and C sequestration potential.

Within the EO1-Hyperion data intercalibration and analysis effort, the goal is to compare existing products and suggest new land cover products, addressing vegetation type and function. This effort was initiated in the spring of 2007 and will use the only available space borne spectrometer (EO1 Hyperion) to contribute toward the comparisons of current data products, generated by multiple and frequently disparate systems. Datasets and comparisons will be produced for core EOS sites and made available for use in calibrating long term data records, required for understanding climate dynamics and change. The development of new products assessing vegetation physiology would contribute toward the development of the recommended in the NRC Decadal Survey missions: HysplRI (Hyperspectral/IR Imagery) and GEO-CAPE (Geostationary Coastal and Air Pollution Events) missions.

Recent studies have demonstrated that superior results can be achieved with narrow band visible/near-infrared spectral reflectance analyses, as compared to results using traditional wide band (>20 nm) reflectance, for remote assessment of vegetation type and condition. To plan for future hyperspectral satellites, new studies are critical to define the optimal narrow band information required for monitoring ecosystem health from space. With this research, high spectral resolution reflectance data obtained for vegetation over a range of functional types, species, phenology, and stress conditions is evaluated to establish which

spectral algorithms perform rigorously with respect to the correlation to photosynthetic function and efficiency. Reflectance data having contemporaneous photosynthetic data is being assembled from various field measurement projects conducted by the participants and through collaborations with other investigators; this data set is then supplemented by additional focused data collections. In particular, the reduction or enhancement in photosynthetic efficiency resulting from environmentally induced physiologic stress and nitrogen application is being characterized. Researchers must consider the impact of how chlorophyll fluorescence contributes to the apparent red edge reflectance. A second tier of evaluation is being performed on flux and environmental data provided by AmeriFlux collaborators, from tower sites representing a range of ecosystems. High performance of candidate spectral bio-indices, ascertained from an *a priori* list compiled from previous research, are being evaluated for remote sensing application at ecosystem scales at the AmeriFlux and intensive sites using several radiative transfer modeling tools and atmospheric correction modules. The best performing spectral bio-indices would be applied to available hyperspectral remote sensing data over selected test sites. This project addresses one of NASA's programs on plant functional types and physiology, and supports research to justify missions currently under development by several agencies, including NASA (Flora, from EO-1 Hyperion heritage) and the European Space Agency (FLEX, Fluorescence Explorer).

The fluorescence research team's objective is to evaluate existing and emerging fluorescence technologies for use in determining vegetation photosynthetic function and carbon/nitrogen cycling dynamics in plants exposed to environmental stresses linked to alterations in the global nitrogen cycle. Improving the current understanding of the links between the global C and N cycles is essential to successfully interpret current and future feedbacks between the atmosphere and the terrestrial biome. This requires more study of the ways photosynthetic dysfunction due to environmental stresses can be measured and monitored, using new technologies and methods. Current strategies for monitoring the status of vegetation from satellites rely on spectral reflectance, which provide estimates of vegetation vigor related to chlorophyll content; however, fluorescence from vegetation can relate inversely to photosynthetic efficiency and directly to chlorophyll concentration. Fluorescence offers a non-destructive, fast alternative with diagnostic potential for early detection of changes in photosynthetic capacity, efficiency, rate, and to detect disturbances in the photosynthetic system. Campbell's team expects validate the use of active fluorescence for monitoring vegetation stress, and to demonstrate the use of passive fluorescence as an innovative remote sensing carbon sequestration monitoring capability.

Accomplishments for FY 08-09:

The contributions of fluorescence to reflectance of crop and tree species were assessed, on a range of C3 and C4 species under a full range of environmental stress regimes. The utility of spectral ratios computed from CF emission measurements and the reflectance ratios were compared for detecting vegetation at the leaf and canopy level. The research produced new algorithms and recommendations for cost-effective remote sensing

techniques for assessing vegetation physiological condition.

Campbell and her collaborators processed and analyzed 2008 and 2009 reflectance (R) and fluorescence (F) data, and also collected new 2008-9 spectral R, F and bio-physical data. They comparatively evaluated bio-physical measurements and the R and F trends in the datasets, and have drafted a manuscript for a peer-reviewed publication.

She also organized and participated in the CEOS/WGCV30 Plenary meetings. As the current Technical Secretariat of the Working Group on Calibration and Validation of the Committee on Earth Observation Satellites (CEOS/WGCV), under the chairmanship of Dr. C. Cao (NOAA), Campbell follows the plans for new satellite capabilities of various agencies and hopes to contribute to the efforts on data calibration, product development, validation and inter-comparison.

Additionally, outside of her research, Campbell conducted discussions at bi-weekly Science Team meetings and coordinated data processing and analyses activities, and also attended bi-weekly EO1-Hyperion Working Group meetings. She also participated in and presented research findings at professional meetings: IGARSS08, Ist HyspIRI Workshop, and 4th Global vegetation products workshop.

Objectives for FY 09-10

Campbell's specific interests and objectives include spectral analyses and assessments for the development of methods (algorithms, measurement techniques) for vegetation stress assessments and land cover change detection; the development of new EO1-Hyperion products assessing vegetation physiology; assessing the potential use of solar-induced ChlF to estimate vegetation photosynthetic efficiency for a number of vegetation species; and, considering the requirements for building a sensor to measure solar ChlF.

Regarding the future High Spectral Resolution satellite mission, Campbell will contribute to the discussions in determining the spectroscopy requirements for a future hyperspectral mission.

Within the Committee on Earth Observation Satellites, Working Group on Calibration and Validation (CEOS/WGCV), she will continue to operate as technical secretariat of the working group, facilitating the activities and meetings of the group and being an active participant. She hopes to contribute to the efforts on data calibration, product development, validation and inter-comparison.

Task 31:	**MODIS Light Use Efficiency *(Sponsor: J. Ranson)***
Investigator:	Forrest G. Hall, JCET; H. Margolis, PI of the major Canadian effort to study terrestrial ecosystems; Dr. Andy Black, Dr. Nicholas Coops and Thomas Hilker of the University of British Columbia; Dr. Caroline Nichole at the University of Edinburgh
Grant:	**Lidar and Passive Optical Project for Biophysical Parameter Estimation and Vegetation Photosynthetic Activity**
Investigator:	Forrest G. Hall
Task 91:	**DESDynI Mission Formulation Teams *(Sponsor: J. Piepmeier)***
Investigator:	Forrest G. Hall

Description of Research

Hall's research involved three general activities: a Lidar and Passive Optical Project for Biophysical Parameter Estimation and Vegetation Photosynthetic Activity; MODIS Light Use Efficiency; and DESDynI Mission Formulation Teams.

The focus of the Lidar and Passive Optical activity is to use Lidar, hyperspectral and multi-angle passive optical data to infer the 3-D structure and biophysical properties of vegetation. Lidar gives tree height and foliage vertical profiles; multi-angle and hyperspectral data provide crown diameter to height ratio, ground cover tree density and mean crown diameter. This is in collaboration with Ranga Myneni and Yuri Knyazikhin of Boston University.

The MODIS Light Use Efficiency effort is focused on the remote sensing of ecosystem primary production using narrow-band spectral sensors, specifically investigating the use of the Photochemical Reflectance Index to quantify vegetation light use efficiency. The effort is in collaboration with Dr. Nicholas Coops, Dr Thomas Hilker and Dr. Andy Black of the University of British Columbia and Dr. Caroline Nichole at the University of Edinburgh. This effort would expand the light use efficiency work to MODIS.

Hall is collaborating with the DESDynI mission formulation group, developing DESDynI mission requirements and participating in mission design exercises, including OSSEs and coordinating the field campaign to develop and evaluate DESDynI technology and algorithms.

Accomplishments in FY 08-09

Under a previous task related to the MODIS BIOPHYS project, an algorithm to retrieve biophysical parameters were developed, tested and validated for both Landsat and MODIS data, and subsequently publications were submitted. This portion of the task has concluded.

With regards to the MODIS Light Use Efficiency project under Task 31, Hall's research team has demonstrated that the MODIS 531 nm band is sensitive to variations in the photosynthetic uptake of carbon dioxide, thus demonstrating that MODIS can be used to measure plant light use efficiency, a major missing variable in satellite monitoring of the carbon water and energy cycle. They feel that demonstrating this capability from space is an important breakthrough, since scaling results previously were obtained only at the leaf and canopy level from aircraft. Several publications have resulted from this effort (Hall et al. 2008, Hilker et al. 2008a, Hilker et al. 2008b, Drolet et al. 2008, Hilker et al., in press).

The PI also participates in ICEsate and DESDynl Mission Formulation Teams. Hall attended one ICEsat II Science team meeting, and participated in regular telecoms and meetings with the DESdynI team to define mission science requirements, in support of global measurements of vegetation 3-D structure for global biomass surveys, forest disturbance and recovery to estimate global land carbon flux and for habitability and biodiversity surveys. He also participated in a joint US/Germany workshop at the German Aerospace center to discuss a joint mission to measure 3-D vegetation structure using L-band Interferometric SAR. He is also serving as coordinator of the 2009 DESDnyI field campaign in the US and Canada to acquire field, AC Lidar and SAR data in support of DESDynI algorithm development and validation.

Hall is co-editor on two special issues for DESDynI, one for *JGR* and the other for *RSE*. In addition, he has collaborated in the preparation of a draft DESDynI measurement requirement document and a paper articulating the measurement requirements, science justification and technology state of the art (Hall et al, in preparation). He has also co-authored two other DESDynI papers (Shugart et al., in press; Houghton et al., in press).

Objectives for FY 09-10

The three main activities for FY10 will be the continuation of algorithm development for biophysical variable retrievals and development of the DESDynI mission. The focus of this new effort is to include lidar data, along with multi-angle MISR data and hyperspectral data, to improve the retrievals of vegetation biophysical parameters. Hall has been funded by the GSFC mission formulation team to support the development of the DESDynI mission.

Task 79: Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency *(Sponsor: J. Ranson)*

Investigators: K. F. Huemmrich, Research Assistant Professor, JCET; E. Middleton, PI, GSFC Code 614.1; P. Entcheva-Campbell, JCET; C. Daughtry, USDA/ARS; G. Parker, Smithsonian Environmental Research Center; L. Corp, Science Systems and Applications, Inc.

Task 86: North American Forest Disturbance and Regrowth Since 1972 *(Sponsor: J. Ranson)*

Investigators: K. F. Huemmrich, Research Assistant Professor, JCET; J. Masek, PI, GSFC Code 614.1

Description of Research

The focus of Huemmrich's research is to develop methods of using multispectral and hyperspectral remote sensing data of landscapes to determine biophysical characteristics of vegetation, and to link those characteristics to carbon fluxes, plant growth, biodiversity, and disturbance. This work includes studies of data from a variety of ecosystems, including boreal forests, arctic tundra, cropland, prairie, and temperate forests.

Canopy reflectance models take vegetation structural information (*e.g.* leaf area index and tree crown shape) and optical properties (*e.g.* leaf spectral reflectance and transmittance) and use them to calculate the observed reflectance for a given viewing direction and solar illumination conditions. Model results provide a physical basis to infer biophysical characteristics of vegetation.

Hyperspectral and narrow-band multispectral data can detect changes in apparent leaf spectral reflectance associated with plant stress. Combining reflectance data with measurements of carbon flux provides the opportunity to see if these stress effects can be observed and used to monitor ecosystem carbon exchange. Measurements made at a leaf level can be used in models combining canopy reflectance models with photosynthesis models to simulate the relationship between canopy reflectance and photosynthesis. These relationships can also be explored at a canopy level using canopy-level reflectance measurements combined with ecosystem carbon flux measurements from flux towers.

Accomplishments for FY 08-09

To determine landscape characteristics for the North American Forest Disturbance project, a canopy reflectance model is run in the forward mode multiple times varying the inputs over the range of possible values. In this approach the model is run millions of times with different combinations of inputs. The reflectance values output by the model along with all of the input values are stored in look up tables (LUT). Given observed reflectance values, the LUT is searched to find modeled reflectance values that match. Associated with the modeled reflectances are the inputs that describe the

vegetation characteristics along with a measure of uncertainty. The derived vegetation characteristic data are used to study spatial and temporal patterns of disturbance and regrowth. Tests have been performed comparing the model results with ground observations made by the Forest Service.

Studies using ground- and satellite-based observations for a number of different ecosystem types are being performed to study the use of narrow spectral bands to detect plant stress and relate that to ecosystem carbon exchange. The satellite approach uses data from the Hyperion sensor on the EO-1 satellite and narrow MODIS spectral bands intended for ocean studies over land. Huemmrich's team has shown that an index using two narrow spectral bands is related to the light use efficiency, the rate of carbon dioxide taken up by plants for photosynthesis per unit of light absorbed by the canopy. However, they have also found that the amount of shadows in the field of view of the sensor can affect the interpretation of the reflectance index.

To further examine vegetation spectral reflectance changes associated with stress in a more detailed manner, the researchers conducted field experiments where they measured leaf level reflectance and carbon exchange in conjunction with measurements of whole canopy reflectance and carbon exchange. This fieldwork is being performed on tulip poplar trees and in a cornfield in conjunction with Smithsonian and Department of Agriculture scientists. Hyperspectral reflectance data has been collected at multiple times diurnally in a cornfield, and the researchers compared these observations with carbon fluxes measured in the same field. Preliminary results indicate that short-term changes in apparent spectral reflectance are associated with photosynthetic down-regulation and the reduction of carbon uptake by the corn. To measure at multiple levels in the tulip poplar forest the researchers are lifted up in a basket suspended from a crane. Their studies have shown that canopy structure is important in determining the light environment of plant canopies, and has an effect on the overall productivity of vegetation and the manner it responds to stress conditions.

In addition to his research activities, Huemmrich is on the committees for four PhD students, two in the Forestry Department at Virginia Tech, one in the Geography Department at UMCP, and one in the Forestry Department at Laval University.

Objectives for FY 09-10

In the coming year, the PI plans to continue the work on remote sensing of plant stress and publish his analysis using MODIS data to detect light use efficiency for multiple forest types. He also plans to create models of vegetation canopy radiative transfer dynamically linked to leaf level photosynthesis and stress response. Such a model will provide a physical link between the leaf- and canopy-level observations. Additionally, the PI plans to expand the use of multiple forward-mode modeling of canopies to detect vegetation biophysical characteristics, using this technique for the detection of vegetation disturbance over all of North America. Huemmrich will continue to work on developing research activities on monitoring high latitude ecosystem change, and examine the use of high temporal frequency reflectance data in describing vegetation seasonality and temporal patterns of carbon flux.

Task 87:	**Passive and active microwave retrievals of frozen and melting precipitation hydrometeors *(Sponsor: G. Jackson)***
NASA Grant:	**Retrieval Algorithm Development for Precipitating Snow Detection and Estimation using High Frequency Observations NASA (NNH06ZDA001N-PMM / WBS 573945.04.01.06)**
NASA Grant:	**Retrievals of Precipitating Snow and Light Rain Using Synergistic Multi-Sensor Active and Passive Observations (NNH05ZDA001N-CCST)**
Investigators:	Benjamin T. Johnson (Co-I), JCET & University of Wisconsin; Gail Skofronick-Jackson (PI), NASA GSFC; James W. Wang, NASA GSFC; William Olson, NASA GSFC; Mircea Grecu, GEST.

Description of Research

Johnson's research has focused primarily on improving multi-sensor microwave (passive and active) retrievals of cold-cloud and mixed phase precipitation. The primary goal is to obtain a higher quality retrieval of precipitation properties such as particle size distribution, particle density, precipitation rate, and particle shape.

Accomplishments for FY 08-09

The primary accomplishments involve refinements to an existing combined radar-radiometer retrieval algorithm, and the development of a Bayesian radiometer-only precipitation retrieval algorithm. The primary feature of the Bayesian algorithm is that it not only provides a retrieved quantity but also characterizes the known error in the retrieval -- an important step toward understanding the uncertainties in precipitation retrieval.

Johnson has improved his snowflake growth model: through the use of two parameters, the model can simulate nearly all of the 2-D snowflake shapes ranging from sector plates to dendrites. Using these shapes, more complex aggregates can be constructed, which are representative of commonly observed falling snow particles. He also developed a model to simulate the melting of these aggregates, and is currently collaborating with Dr. William Olson (JCET) on incorporating these into a melting-layer model for use in retrieval algorithms.

Other research topics involved estimating retrieval sensitivity to variations in land surface emissivity and particles shape for precipitation retrievals over land. This is also operating in conjunction with the Centre for Atmospheric Research Experiments (CARE) CloudSat/Calipso validation program C3VP field experiment research.

During this past year, Johnson has also supervised a master's student, Anne Kramer, who is working in his group on field campaign data and on snowflake shape properties. She continues to provide support on a number of tasks, focusing this year on the C3VP

experiment.

In addition to his research, the PI is a member of the Global Precipitation Mission (GPM) combined radar/radiometer algorithm development team. As a member of this team, he is tasked with developing the standard GPM algorithm for combined retrievals. Johnson is also an active member of the ice/mixed phase working group, land surface emissivity working group, and the precipitation detection working group, all of which operate in support of the GPM project.

Johnson also served as the Dean's Representative on Andrew Rickert's Master's Thesis committee, which he successfully defended on June 10, 2009.

As for his professional obligations, he has been an active reviewer for the *Journal of Applied Meteorology and Climatology (JAMC),* and *Journal of Geophysical Research (JGR)*. Additionally, he served as the Chairman for the research group during the Fourth Workshop of the International Precipitation Working Group (IPWG), Beijing, China in October 2008.

His research work as a Co-I on two funded proposals continues, and they are in the process of writing papers highlighting their research results.

Objectives for FY 09-10

Going forward, Johnson plans to compare spherical particles with more realistic shape model & properties (*e.g.,* using the discrete dipole approximation) and simulate melting particles more realistically for use in the melting layer of the forward model. Regarding over-land retrievals, he plans to improve land surface emissivity and radar cross-sections, and understand terrain influences on the retrievals. His primary objective is to develop GPM-era combined GMI/PR2 radar retrieval algorithm(s) for light rain and snow over both land and ocean. Johnson's primary direction is toward a working algorithm for GPM which will combine all aspects of the aforementioned research: realistically shaped melting particles, improved retrieval capability, improved forward modeling capability, retrieval over land and ocean of both rain and snowfall. He plans to submit papers for publication describing techniques and results for precipitation retrieval.

This page intentionally left blank

Heliophysics & Solar System Divisions (Code 660-699)

JCET Highlight: Laser Scan Data in the Mojave Desert

Investigator: Mark Bulmer

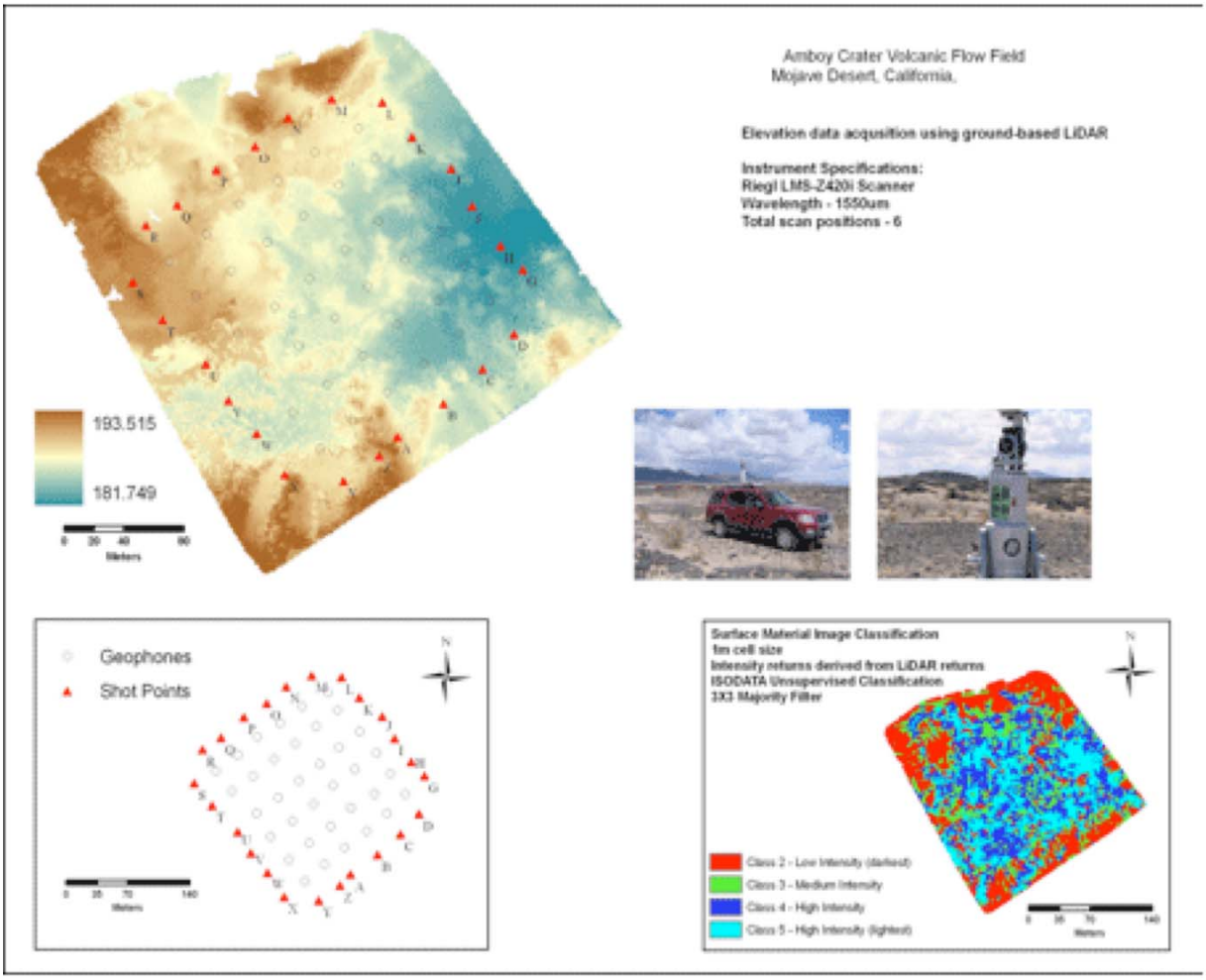


Figure 1. Ground-based laser scan data acquired at Amboy Crater in the Mojave Desert. The top left shows the digital elevation model from the combined scan locations shown as red triangles. The two photos in the center right show the scanner and how it was mounted onto a vehicle. Lower right shows a map of intensity returns displayed as an unsupervised classification.

USRA Subcontract: Olympus Mons – NASA Mars Data Analysis Program, (2094-03)

NASA MFR: Topography Data on Mars: Optimizing its Collection and Application Using Laser Scanning (NNX08AT15G)

World Bank Grant: Vilcanota Valley Slope Monitoring for Flash Floods and Other Natural Hazards (0000002683)

Investigator: Mark Bulmer, Research Associate Professor, Geography and Environmental Systems

Description of Research

Bulmer's current research interests include remote sensing applications to the Earth; terrestrial planets and icy satellites; mechanics and landslide hazard and risk assessment; integrating spaceborne, airborne, surface and sub-surface data; configuring Unmanned Aerial Vehicles (fixed wing, rotor and lighter-than-air) and sensors (cameras), and designing data collection devices. In addition, he is involved in Resilience Planning in the UK and has provided assistance during civil emergencies. In the past year, the Geophysical Flow Observatory and the Landslide Mitigation Group have worked with National and International funding agencies, the NGO community and commercial enterprises. Increased experience has been acquired in emergency management planning, response and management, which led to an improved focus on the type, nature and extent of information about the natural world that currently resides within many emergency response agencies and organizations. The PI's association has continued with the Planetary Geodynamics and Geodesy Group at NASA Goddard through funding of a new NASA project. His time has been divided between pure and applied research, plus teaching and mentoring. Undergraduate classes taught have included Planetary Geology, Natural Hazards and Process Geomorphology. He taught Process Geomorphology at UMBC as a 300-level course in the Department of Geography and Environmental Systems. Also, one of the two graduate students in UMBC's Department of Mechanical Engineering who Bulmer is currently supervising assisted in fieldwork in Peru, and is now moving toward completion of his thesis.

Accomplishments in FY 08-09

As part of ongoing research as a Co-I on the NASA Mars Data Analysis Program grant, new image and topography data over Olympus Mons and the surrounding aureoles has continued to be compiled into a GIS environment and assigned a common coordinate system. Shaded relief, color- coded elevation and slope gradient maps have been amended continually to include new data from which geomorphologic mapping of the aureoles and volcanic edifice has continued. Results were presented at the 2008 Lunar and Planetary Conference, 2008 LPI Workshop on Martian Gullies and 2009 Geochemistry, Geophysics and Remote Conference in Italy.

Regarding the World Bank grant, GFLO's second mission to Machu Picchu Pueblo (MPP) was identified as `*Mission Two*' in the terms of reference for Contract 7145926 between the UMBC and The World Bank Group[1]. Consistent with an approved Plan[2], GFLO performed a specialized terrain survey and evaluated a number of candidate early warning technologies on-site in the midst of the wet season (*i.e.,* 21st Feb to 8th March 2009). On this basis, a set of suitable sensor and communication technologies was identified and configured as a working prototype. The resulting prototype was demonstrated and conveyed to the community on 6th March 2009, and a local team has continued to operate it on an intermittent basis since that time. The second mission was successful in the sense that it proved the basic feasibility of technology-based hazard monitoring under local conditions. GFLO has now completed a series of technical studies to define the recommended approach to further develop a permanent warning system in MPP. Results have been presented in two GFLO technical reports, which have been disseminated by The World Bank Group.

Work in year one of Bulmer's grant on the Topography Data on Mars has yielded significant advances in the investigators' ability to identify the optimal collection parameters, analytical protocols, and additional data needed to resolve features on a terrestrial rocky surface of interest. Using airborne and ground-based laser scanning techniques, terrestrial data has been acquired at six sites, including rock avalanches, lava flows and fluvial outwash plains using airborne and ground-based scanning instruments. All data has been processed to level one, and point clouds used to generate DEM's. Initial results relating terrestrial and MOLA-derived LiDAR have been presented at two conferences. The PI spent time at CRREL with Co-I Finnegan, during which time laser-scanning techniques, protocols, and controlled experiments using selected rock characteristics were reviewed. In addition, areas were identified where laser-scanning systems could be developed.

Additionally, Bulmer attended workshops and conferences at the Royal United Services Institute where he is an Associate Fellow. Current collaborations are with UMBC Department of Mechanical Engineering, Lunar and Planetary Institute, University of Northern Colorado, Cold Regions Research Laboratory Army Corp of Engineers, InvisiTrack, and Baltimore County Department of Public Works. One invention disclosure has been filed with UMBC. Research results have been submitted and accepted for publication in a range of peer reviewed journals. Technical reports related to specific projects and topics have been produced as Geophysical Flow Observatory Open File Reports.

Objectives for FY 09-10

Proposals will be submitted to NASA Mars Data Analysis and Army Research Programs related to the manipulations of point cloud data.

[1] Change Order 7145926 Vilcanota Valley Slope Monitoring of Flash Floods and Other Natural Hazards (PO82625). University of Maryland Baltimore County and The World Bank Group, Washington, D.C. 20433. Signed 10/22/2008.

[2] Plan for Second Mission: Vilcanota Valley Slope Monitoring of Flash Floods and Other Natural Hazards (P082625). Submitted to The World Bank, January 2009, pp3.

Task 84: Numerical Modeling Historical Martian Dynamo *(Sponsor: W. Kuang)*

Investigators: Weiyuan Jiang, Research Assistant Professor, JCET/UMBC; Weijia Kuang, JCET Fellow, Code 698, GSFC

Description of Research

One of the most important findings of the Mars Global Surveyor (MGS) mission is the strong crustal magnetization in the highland crust of the Martian southern hemisphere (*e.g.* Acuña *et al* 1998, 2001). Now it is believed that Mars once had an active strong field dynamo in its early evolution stage, a dynamo that terminated about 4 Gyr ago. To understand why and how the Martian dynamo stopped operating, Jiang and Kuang used the MoSST numerical model to simulate the dynamo process in order to determine the following: the amount of gravitational energy that could be released in the core in the secular cooling of the Mars; the minimum gravitational energy for an active core dynamo; the effects of the size of the solid inner core on the Martian dynamo; the effect of the giant impacts on the Martian dynamo; and, the properties of the generated magnetic fields before termination.

Accomplishments in FY 08-09

After Jiang and Kuang carried out the numerical simulations for different sizes of the inner core r_{icb} = 0.1, 0.2, 0.3, the results showed that a sub-critical dynamo (a dynamo state maintained by less power than required for the onset of the dynamo action) exists for a small inner core. The smaller inner core requires more energy to maintain and support the strong field dynamo.

The numerical results show that, for different sizes of the inner core, the dynamo volume also changes dramatically around the sub-critical domain, while the deviation from the mean dynamo volume is relatively small at the super-critical domain. The numerical results also show that even for a relatively small Rayleigh number, the polar reversal happens frequently in the sub-critical dynamo domain.

Objectives for FY 09-10

Recent studies on the retention and absolute age of large impact basins (basin diameters D > 1000 km) indicate that Mars experienced as many as 20 giant impacts during the early to mid-Noachian. From remanent magnetic field data, Lillis *et al.* suggest that the Martian dynamo terminated during the same period. In particular, they indicate that the Martian dynamo may have terminated between the two super giant impacts Acidalia (D ~ 3087 km) and Utopia (D ~ 3380 km) that are separated approximately by 20 Myr. Is this simply a time coincidence, or did the giant impacts indeed cause the termination of the dynamo? Could this time correlation provide insights to poorly understood geophysical processes in the deep interior? Jiang will focus on the existence and conditions of a subcritical dynamo with heterogeneous heat fluxes across the CMB that were created by the three impacts; the properties of the dynamo-generated magnetic field through the three impacts; and, geophysical implications for Martian crustal remagnetization after the impacts, and possible magnetic constraints to post-dynamo geophysical processes, such as paleo-polar motion.

NASA Grant:	Dynamics of eastern Mediterranean, Sea Level and altimetry Calibration-validation (DynMSLaC) (NNG05GO31G)
NASA Grant:	Global Sea Level in a Changing Climate: Reference Frames, Data Analysis, and Interpretation (NRA-03-OES-03)
NASA Grant:	GRACE Applications for TRF developments and fundamental physics tests (NNH06ZDA001N-GRACE)
NASA Grant:	NEastern Mediterranean Altimetry Calibration Network (e-MACnet) (NNX08AR50G)
Task 33:	Space Geodesy Applications to Earth Sciences *(Sponsor: R. Ray)*
Task 105:	Design and Optimization of NASA's Future Space Geodetic Networks in Support of GGOS *(Sponsor: R. Ray)*
Investigators:	Erricos C. Pavlis, JCET, Res. Assoc. Professor, Physics; Magdalena Kuzmicz-Cieslak, JCET, Res. Associate; Keith Evans, JCET, Res. Analyst, Peter Hinkey, Abhijit Patil, and Bhushan Sonawane, undergraduate student assistants.

Description of Research

The research of Pavlis and his team focuses on the application of SLR, VLBI, GPS, and altimetry in Earth science covering many, often overlapping areas. They excel in the analysis of SLR, VLBI and GPS data for the development and maintenance of global terrestrial reference frames and mean sea level time series. They lead an international team to design NASA's future space geodetic tracking networks and now spend more than half of their effort on this subject alone. In the Aegean area, Pavlis and his team have established and operate six facilities for sea level monitoring, altimeter calibration and environmental observation for weather, oceanography and climate research, contributing to GLOSS and MedGLOSS.

Accomplishments in FY 08-09

Pavlis chairs the International Laser Ranging Service's (ILRS) Analysis Working Group and Refraction Study Group. He is also a member of the Steering Committee for IAG's (Int. Assoc. of Geodesy) Global Geodetic Observing System (GGOS), the ILRS Governing Board and Central Bureau, the Int. Earth Rotation and Reference Frame Service (IERS) Directing Board, as well as Science Coordinator for the GGOS Bureau of Networks and Communications and Associate Editor of the journal *Celestial Mechanics and Dynamical Astronomy*.

During the past year, the focus of SLR data analysis was on the development of an improved product that would support the development of the new International Terrestrial Reference Frame 2008 (ITRF2008). This was completed successfully and submitted to ILRS

and IERS in June 2009. They have continued the weekly and daily operational product series and have completely redesigned the web service for the evaluation and validation of the ILRS Analysis products and the quality control of the ILRS Data.

Pavlis and his team continue their collaboration with an international group of scientists and engineers seeking an improved measurement of the relativistic "frame-dragging" effect using a third cannonball satellite (LARES) that the group designed for the Italian Space Agency (ASI). They won a 5-year NASA grant for studies associated with LARES and Pavlis is now officially the US-side co-PI of the LARES mission. LARES is nearly completed now with a tentative launch date in late 2010.

Under the OSTM program, they continued with full operations at the KASTELI facilty, including the connection to METEOSAT and the EUMETSAT web-based database. They have now instrumented four more sites in the eastern Mediterranean area, with only one left to complete the Eastern Mediterranean Altimetry Calibration Network (*e*-MACnet).

Work on the Mean Sea Level (MSL) project focused on the accuracy assessment of their knowledge of the geocenter and quantified the implications in terms of MSL variability. Simulations focused on the development of a strategy that will use SLR-tracked GPS satellites to improve reference frame stability and disseminate the ITRF with sufficient accuracy to meet the requirements for MSL and climate change studies. Results were presented at the GGEO2008 IAG Symposium, the Fall 2008 AGU meeting, the 2009 European Geosciences Union general assembly, and several other meetings and seminars. Work now focuses on the development of simulation techniques for further validation and study of the error budget associated with MSL determination and its long- and short-term variations. Pavlis' team contributed in the authorship of chapters of two international publications [Pavlis *et al.*, 2009] that focus on GGOS and its role in MSL monitoring and studies of climate change.

Objectives for FY 09-10

As an ILRS Analysis Center, Pavlis and his investigators will continue to operate their automated weekly and daily data analysis and quality control, and generate annual contributions. Addtionally, they will extend their solutions to include the new SLR targets that they re-processed from historical data, extending the record to the early years of SLR tracking (ca. mid-1970s). This product will be submitted to ILRS and IERS for evaluation. They will continue to extend their analysis of GRACE data for temporal variations of gravity and test them in the reanalysis of SLR data in preparation for a new reanalysis.

They will continue their project eMACnet/GAVDOS collaboration with their European partners, and the routine operation of their six facilities. A paper detailing the results is in preparation for a special 2010 issue of *Marine Geodesy*. The final site will be deployed in late 2009 and all communication packages will be upgraded in 2009/2010.

In the coming year, Pavlis will organize two workshops, the first associated with the LARES mission and a second one focused on the SLR tracking of GNSS targets for reference frame development.

This page intentionally left blank

III. Supporting Information

This page intentionally left blank

III.1 References

Bae, H., et al. (2008), The drought response of Theobroma cacao (cacao) and the regulation of genes involved in polyamine biosynthesis by drought and other stresses, *Plant Physiology and Biochemistry*, 46(2), 174-188.

Bell, T.L., and P.K. Kundu (2003), Comparing satellite rainfall estimates with rain gauge data: Optimal strategies suggested by a spectral model, *J. Geophys. Res.,* 108, D3, 4121 doi:10.1029/2002JD002641.

Brown, M. E., et al. (2008), Neural networks as a tool for constructing continuous NDVI time series from AVHRR and MODIS, *International Journal of Remote Sensing*, *29*(24), 7141-7158.

Chu, D. A., Y. J. Kaufman, et al. (2003), Global monitoring of air pollution over land from the Earth observing system-Terra Moderate imaging spectroradiometer (MODIS), *J. Geophys. Res.,* 108(D21), 4661.

De Almeida Castanho, A. D., R. Prinn, V. Martins, M. Herold, C. Ichoku, and L. T. Molina (2007), Urban Visible/SWIR surface reflectance ratios from satellite and sun photometer measurements in Mexico City, *Atmos. Chem. Phys. Discuss.*, 7, 8113-8139.

Delgado, R., L. Zhu, P. Schou, M. Weldegaber, M. Woodman, M. Seybold, B. Demoz, K. J. McCann, and R. M. Hoff (2008), Low Level Jet Events over Baltimore, 2008 *CREST Technical Meeting*, Mayaguez, Puerto Rico, February 21-23.

Deuzé, J.-L., F.-M., Bréon, C. Devaux, P. Goloub, M. Herman, B. Lafrance, F. Maignan, A. Marchand, F. Nadal, G. Perry, and D. Tanré (2001), Remote sensing of aerosols over land surfaces from POLDER-ADEOS-1 polarized measurements, *J. Geophys. Res.*, 106, 4913–4926.

Diner, D., *et al.* (1998), Multi-angle Imaging Spectroradiometer (MISR) instrument description and experiment overview, *IEEE Trans. Geosci. Remote Sens.*, 36(4), 1072-1087.

Dixon, R., (2009), Forcing Mechanisms for Heavy Precipitation in the Extratropical Transition of Atlantic Hurricanes, MS Thesis, University of Maryland, Baltimore County, August 2009.

Engel-Cox, J. A., C. H. Holloman, B. W. Coutant, and R. M. Hoff (2004), Qualitative and quantitative evaluation of MODIS satellite sensor data for regional and urban scale air quality, *Atmos. Environ.*, 38, 2495–2509, doi:10.1016/j.atmosenv.2004.01.039.

Engel-Cox, J. A., R. M. Hoff, R. Rogers, F. Dimmick, A. C. Rush, J. J. Szykman, J. Al-Saadi, D. A. Chu, and E. R. Zell (2006), Integrating Lidar and Satellite Optical Depth with Ambient Monitoring for 3- Dimensional Particulate Characterization, *Atmos. Environ.,* 40, 8056-8067.

Fisher, J. A., D. J. Jacob, M. T. Purdy, M. Kopacz, P. Le Sager, C. Carouge, C. D. Holmes, R. M. Yantosca, R. L. Batchelor, K. Strong, G. S. Diskin, H. E. Fuelberg, J. S. Holloway, E. J. Hyer, W. W. McMillan, J. Warner, D. G. Streets, Q. Zhang, Y. Wang, and S. Wu (2009), Source attribution and interannual variability of Arctic pollution in spring constrained by aircraft (ARCTAS, ARCPAC) and satellite (AIRS) observations of carbon monoxide, *Atmos. Chem. Phys.* (submitted).

George, M., C. Clerbaux, D. Hurtmans, S. Turquety, P. F. Coheur, M. Pommier, J. Hadji-Lazaro, D. Edward, H. Worden, M. Luo, C. Rinsland, and W. McMillan (2009), Carbon monoxide distributions from the IASA/METOP mission: evaluation with other spaceborne remote sensors, *Atmos. Chem. Phys. Discuss.*, 9, 9793-9822.

Gupta, P., and S. A. Christopher (2008), Seven year particulate matter air quality assessment from surface and satellite measurements, *Atmos. Chem. Phys.,* 8, 3311–3324.

Hodzic, A., R. Vautard, B. Bessagnet, M. Lattuati, and F. Moreto (2005), Long-term urban aerosol simulation versus routine particulate matter observations, *Atmos. Environ.*, 5851–5864.

Hoff, R., F. Moshary, S. Ahmed, B. Gross, P. McCormick, and H. Parsiani (2009), *CREST Lidar Network (CLN)*, CREST Publication Series, **7**, Number 09-01, NOAA-CREST Technical Report Series, Steinman Hall, City College of New York, New York, NY, 32 pp.

Hopkins, P. E., V. S. Connors, W. W. McMillan, H. G. Reichle, and R. J. Ribando (2009), Feasibility of determining carbon monoxide mixing ratios from the MicroMAPS instrument on an airborne platform, *J. Atmos. Oceanic Tech*. (submitted).

Hughes, E. J., L. C. Sparling, S. Carn, A. Krueger, M. Schoeberl (2008a), Using Horizontal Transport Characteristics to Infer an Emission Height Timeseries of Volcanic SO2, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract A23A-0270.

Hughes, E. J., Using Horizontal Transport Characteristics to Infer an Emission Height Timeseries of Volcanic SO2, MS Thesis, University of Maryland Baltimore County, May 2009.

Joshi, A., J. Caban, P. Rheingans and L. Sparling (2009), Case Study on Visualizing Hurricanes Using Illustration-Inspired Techniques, *IEEE Transactions on Visualization and Computer Graphics*, 15, doi:10.1109/TVCG.2008.105.

Kacenelenbogen, M., J.-F. Léon, I. Chiapello, and D. Tanré (2006), Characterization of aerosol pollution events in France using ground-based and POLDER-2 satellite data, *Atmos. Chem. Phys.,* 6, 4851-4866.

Kassianov, E. I., and M. Ovtchinnikov (2008), On reflectance ratios and aerosol optical depth retrieval in the presence of cumulus clouds, *Geophys. Res. Lett.*, 35, L06807, doi:10.1029/2008GL033231.

Kaufman, Y. J., and D. Tanré (1998), Algorithm for remote sensing of tropospheric aerosol from MODIS, Product ID: MOD04, 85 pp.

Kaufman, Y. J., D. Tanré, and O. Boucher (2002), A satellite view of aerosols in the climate system, *Nature*, 419, 215–223.

Koelemeijer, R.B.A., C.D. Homan, and J. Matthijsen (2006), Comparison of spatial and temporal variations of aerosol optical thickness and particulate matter over Europe, *Atmos. Environ.,* 40, 5304–5315.

Kopacz, M., D. J. Jacob, J. A. Fisher, J. A. Logan, L. Zhang, I. A. Megretskaia, R. M. Yantosca, K. Singh, D. K. Henze, J. P. Burrows, M. Buchwitz, I. Khlystova, W. W. McMillan, J. C. Gille, D. P. Edwards, A. Eldering, V. Thouret and P. Nedelec (2009), Global estimates of CO sources with high resolution by adjoint inversion of multiple satellite datasets (MOPITT, AIRS, SCIAMACHY, TES), *Atmos. Chem. Phys.* (in preparation).

Kuang, W., A. Tangborn, and Z. Wei (2009), Constraining a numerical dynamo model with 100 years of surface observations, *Geophys. J. International* (revision submitted).

Kundu, P. K., and R.K. Siddani (2007), A new class of probability distributions for describing the spatial statistics of area-averaged rainfall, *J. Geophys. Res.* 112, D18113, doi:10.1029/2006JD008042.

Kurtz, N. T., T. Markus, D. J. Cavalieri, L. C. Sparling, W. B. Krabill, A. J. Gasiewski, and J. G. Sonntag (2009), Estimation of sea ice thickness distributions through the combination of snow depth and satellite laser altimetry data, *J. Geophys. Res.*, doi:10.1029/2009JC005292.

Lary, D. J. (2008), Objectively Optimized Earth Observing Systems, in *Intelligent Aerial Vehicles*, edited by T. M. Lam.

Lary, D. J., and O. Aulov (2008), Space-based measurements of HCl: Intercomparison and historical context, *Journal of Geophysical Research-Atmospheres*, *113*(D15).

Lary, D. J. (2009a), Artificial Intelligence in Geoscience and Remote Sensing, in *Aerospace Technologies Advancements*, edited.

Lary, D. J. (2009b), Artificial Intelligence in Geoscience and Remote Sensing, in *Geoscience and Remote Sensing*, edited.

Li, C., A. K. Lau, J. Mao, and D. A. Chu (2005), Retrieval, validation, and application of the 1-Km aerosol optical depth From MODIS measurements over Hong Kong, *EEE Trans. Geosci. Remote Sens.,* 43(11), 2650–2658.

Lightner, K. J., W. W. McMillan, K. J. McCann, R. M. Hoff, M. J. Newchurch, J. Song, E. Hintsa, and C. D Barnet (2009), Detection of a tropospheric ozone anomaly using the Kurt Lightner Ozone BaBaEri Retrieval (KLOBBER) algorithm on 2 June 2003 at the Chesapeake Light lighthouse, *J. Geophys. Res.*, 114, D06304, doi:10.1029/2008JD010270.

Liu, Y., R. J. Park, D. J. Jacob, Q. Li, V. Kilaru, and J. A. Sarnat (2004), Mapping annual mean ground-level PM2.5 concentrations using Multiangle Imaging Spectroradiometer aerosol optical thickness over the contiguous United States, *J. Geophys. Res.*, 109, D22206, doi:10.1029/2004JD005025.

McMillan, W. W., J. X. Warner, M. M. Comer, E. Maddy, A. Chu, L. Sparling, E. W. Eloranta, R. M. Hoff, G. Sachse, C. Barnet, I. A. Razenkov, and W. Wolf (2008), AIRS views of transport from 12-22 July 2004 Alaskan/Canadian fires: Correlation of AIRS CO and MODIS AOD with forward trajectories and

comparison of AIRS CO retrievals with DC-8 in situ measurements during INTEX-A/ICARTT, *J. Geophys. Res.*, doi:10.1029/2007JD009711.

McMillan, W. W., R. Pierce, L. C. Sparling, G. Osterman, K. McCann, M. L. Fischer, B. Rappenglück, R. Newsom, D. Turner, C. Kittaka, K. Evans, S. Biraud, B. Lefer, A. Andrews and S. Oltmans (2009), An Observational and modeling strategy to investigate the impact of remote sources on local air quality: A Houston, Texas case study from TEXAQS II, *J. Geophys. Res.* (in press).

Noelle, A., et al. (2008), UV/Vis Spectra Data Base, edited by A. Noelle, et al., science-softCon.

Pavlis, E. C. et al., (2009), "Observing Systems Needed to Address Sea-level Rise and Variability", in *Understanding Sea-level Rise and Variability*, Aarup, T., J. Church, S. Wilson, and P. Woodworth (eds.), Blackwell, Oxford (*in press*).

Pavlis, E. C. et al., (2009), "The goals, achievements, and tools of modern geodesy", in *GGOS2020: The Global Geodetic Observing System,* H.- P. Plag and M. Pearlman (eds.) Chapter 2*,* pp. 24-62, GGOS/IAG, Springer-Verlag, New York.

Rickert, A. (2009), Neural Networks in Atmospheric Scattering Calculations, MS Thesis, University of Maryland, Baltimore County, August 2009.

Schoeberl, M. R., et al. (2008), QBO and annual cycle variations in tropical lower stratosphere trace gases from HALOE and Aura MLS observations, *Journal of Geophysical Research-Atmospheres*, *113*(D5).

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, W. Wang, and J. G. Powers (2005), A description of the advanced research WRF version 2. NCAR Tech. Note NCAR/TN-468_STR, 88 pp.

Tangborn, A., I. Stajner, M. Buchwitz, I. Khlystova, J. Burrows, S. Pawson, R. Hudman and P. Nedelec (2009), Assimilation of SCIAMACHY total column CO observations: Regional analysis of data impact, *J. Geophys Res. - Atmo.*, 114, DOI: 10.1029/2008JD010781.

Tokay, A., and P. G. Bashor (2009), An experimental study of small-scale variability of raindrop size distribution, *J. Appl. Meteor. Climatol.* (submitted).

Tokay, A., P. G. Bashor, and V. L. McDowell (2009), Comparison of rain gauge

measurements in mid-Atlantic region, *J. Hydrometeor. (*conditionally accepted).

Tokay, A., P. Hartmann, A. Battaliga, K. S. Gage, W. L. Clark, and C. R. Williams (2009), A field study of reflectivity and Z-R relations using vertically pointing radars and disdrometers, *J. Atmos. and Oceanic Technol.,* 26, 1120-1134.

Várnai, T., and A. Marshak (2009), MODIS observations of enhanced clear sky reflectance near clouds, *Geophys. Res. Letters*, 36, L06807, doi:10.1029/2008GL037089.

Várnai, T., and R. F. Cahalan (2009), Modeling and analysis of offbeam lidar returns from thick clouds, snow, and sea ice", paper #201770 at *2009 International Conference on Advances in Mathematics, Computational Methods, and Reactor Physics*, American Nuclear Society, Inc., ISBN: 978-0-89448-069-0. Saratoga Springs, NY.

Wang, J., and S. A. Christopher (2003), Intercomparison between satellite-derived aerosol optical thickness and PM2.5 mass: Implications or air quality studies, *Geophys. Res. Lett.*, 30(21), 2095, doi:10.1029/2003GL018174.

Weldegaber, M. H., *Investigation of Stable and Unstable Boundary Layer Phenomena using Observations and a Numerical Weather Prediction Model*, PhD Dissertation, University of Maryland Baltimore County, May 2009.

Yurganov, L. N., W. W. McMillan, A. V. Dzhola, E. I. Grechko, N. B. Jones, and G. R. van der Werf (2008), Global AIRS and MOPITT CO Measurements: Validation, Comparison, and Links to Biomass Burning Variations and Carbon Cycle, *J. Geophys. Res.*, 113, D09301, doi:10.1029/2007JD009229.

Zhang, D. L., S. Zhang and S. J. Weaver (2006), Low-level Jets over the Mid-Atlantic States: Warm-Season Climatology and a Case Study, *J. Appl. Meteor.*, 45, 194-209.

III.2 Peer-Reviewed Publications

Bulmer, M.H., T. Farquhar, and M. Roshan (2008), Effective use of Fiducial-based photogrammetry for tracking large scale outdoor motion, *J. Exp. Eng. Techs,* doi: 10.1111/j.1747-1567.2008.00474.

Campbell, P.K.E., E.M. Middleton, L.A. Corp and M.S. Kim (2008), Contribution of solar chlorophyll fluorescence to the apparent red/near-infrared reflectance of vegetation, *Science of the Total Environment,* 404, 433-439.

Carn, S.A., A.J. Krueger, N.A. Krotkov, K. Yang, and K. Evans (2009), Tracking volcanic sulfur dioxide clouds for aviation hazard mitigation, Natural Hazards, doi:10.1007/s11069-008-9228-4 (in press).

Carn, S.A., A.J. Krueger, N.A. Krotkov, S. Arellano, and K. Yang (2008), Daily monitoring of Ecuadorian volcanic degassing from space, *J. Volcanol. Geotherm. Res.,* doi:10.1016/j.jvolgeores.2008.01.029.

Carn, S.A., A.J. Prata, and S. Karlsdóttir (2008), Circumpolar transport of a volcanic cloud from Hekla (Iceland), *J. Geophys. Res.*, 113, D14311, doi:10.1029/2008JD009878.

Carn, S.A., J. S. Pallister, L. Lara, J. W. Ewert, S. Watt, A. J. Prata, R. J. Thomas, and G. Villarosa (2009), The unexpected awakening of Chaitén volcano, Chile, *EOS Trans. AGU*, 90(24), 205-206.

Chiu, J. C., A. Marshak, Y. Knyazikhin, P. Pilewskie, and W. J. Wiscombe (2009), Physical interpretation of the spectral radiative signatures in the transition zone between cloud-free and cloudy regions, *Atmos. Chem. Phys.*, 9, 1419-1430.

Ciufolini, I., E.C. Pavlis, et al., (2009), "Gravitomagnetism and its Measurement with Laser Ranging to the LAGEOS satellites and GRACE Earth Gravity Models", in *Lectures at the Wheeler school on relativity*, 2006 Erice Summer School Lecture series, (*in press*).

Ciufolini, I., E.C. Pavlis, et al., (2009), "Towards a One Percent Measurement of Frame Dragging by Spin with Satellite Laser Ranging to LAGEOS, LAGEOS 2 and LARES and GRACE gravity models", *Space Science Reviews*, (accepted).

Drolet, G., E. M. Middleton, K. F. Huemmrich, F. G. Hall, B. D. Amiro, A. G. Barr, T. A. Black, H. J. McCaughey, and H. A. Margolis (2008), Regional Mapping of Gross

Light-Use Efficiency Using MODIS Spectral Indices, *Remote Sensing of Environment*, 112, pp. 3064-3078.

Evans, K. F., A. Marshak, and T. Várnai (2008), The Potential for Improved Boundary Layer Cloud Optical Depth Retrievals from the Multiple Directions of MISR, *J. Atmos. Sci.*, 65, 3179-3196.

George, M., C. Clerbaux, D. Hurtmans, S. Turquety, P. F. Coheur, M. Pommier, J. Hadji-Lazaro, D. Edward, H. Worden, M. Luo, C. Rinsland, and W. McMillan (2009), Carbon monoxide distributions from the IASA/METOP mission: evaluation with other spaceborne remote sensors, *Atmos. Chem. Phys. Discuss.*, 9, 9793-9822.

Grecu, M., W. S. Olson, C.-L. Shie, T. S. L'Ecuyer, and W.-K. Tao (2009), Combining Satellite Microwave Radiometer and Radar Observations to Estimate Atmospheric Latent Heating Profiles, *Journal of Climate* (accepted).

Hall, F. G., T. Hilker, N. C. Coops, A. Lyapustin, K. F. Huemmrich, E. Middleton, H. Margolis, and G. Drolet (2008), Multi-Angle Remote Sensing of Forest Light Use Efficiency by Observing PRI Variation with Canopy Shadow Fraction, *Remote Sensing of Environment,* 112, pp. 3201–3211.

Hilker, T., N. C. Coops, F. G. Hall, T. A. Black, M. A. Wulder, Z. Nesic, and P. Krishnan (2008a), Separating physiologically and directionally induced changes in PRI using BRDF models, *Remote Sensing of Environment*, 112, pp. 2777–2788.

Hilker, T., N. C. Coops, F. G. Hall**,** T. A. Black, B. Chen, P. Krishnan, M. A. Wulder, P. J. Sellers, E. M. Middleton, and K. F. Huemmrich (2008b), A modeling approach for upscaling gross ecosystem production to the landscape scale using remote sensing data, *J. Geophys. Res.*, 113, G03006, doi:10.1029/2007JG000666.

Hilker, T., N. C. Coops, F. G. Hall, and T. A. Black (2009), Towards an assessment of photosynthetic light use efficiency from space: Modeling the atmospheric and directional impacts on PRI reflectance, *Remote Sensing of Environment* (in press).

Hilker, T., N.C. Coops, F.G. Hall, T.A. Black, B. Chen, P. Krishnan, M.A. Wulder, P.J. Sellers, E.M. Middleton, and K.F. Huemmrich (2008), A Modeling Approach for Upscaling Gross Ecosystem Production to the Landscape Scale Using Remote Sensing Data Source, *Journal of Geophysical Research-Biogeosciences,* 113, G03006.

Hoff, R. M., and S. A. Christopher (2009), The 34th AWMA Critical Review: Remote Sensing of Particulate Pollution from Space: Have We Reached the Promised

Land? *J. Air & Waste Manage. Assoc,.* 59, 645–675, doi:10.3155/1047-3289.59.6.645.

Hoff, R., H. Zhang, N. Jordan, A. Prados, J. Engel-Cox, A. Huff, S. Weber, E. Zell, S. Kondragunta, J. Szykman, B. Johns, F. Dimmick, A. Wimmers, J. Al-Saadi, and C. Kittaka (2009), Applications of the Three-Dimensional Air Quality System (3D-AQS) to Western U.S. Air Quality: IDEA, Smog Blog, Smog Stories, AirQuest, and the Remote Sensing Information Gateway, *J. Air & Waste Manage. Assoc.,* 59, 980–989, doi:10.3155/1047-3289.59.8.980.

Houghton, R.A., F. Hall, and S. J. Goetz (2009), The Importance of Biomass in the Global Carbon Cycle, *Journal of Geophysical Research Atmospheres* (in press).

Hu, J. C., W. J. Chen, J. C. Chiu, J. L. Wang, and G. R. Liu (2009), Quantitative precipitation estimation over ocean using Bayesian approach from microwave observations during the typhoon season, *Terr. Atmos. Oceanic Sci*. (in press).

Hughes, Eric (2009), Using Horizontal Transport Characteristics to Infer an Emission Height Time Series of Volcanic SO_2, M.S. Thesis, Physics Program, UMBC, May 2009.

Jiang, W., and W. Kuang (2008), An MPI-based MoSST core dynamics model, *Physics of the Earth and Planetary Interiors*, 170 (1-2), 46-51, doi:10.1016/j.pepi.2008.07.020.

Jiang, X., D. E. Waliser, W. S. Olson, W.-K. Tao, T. S. L'Ecuyer, J.-L. Li, B. Tian, Y. L. Yung, A. M. Tompkins, S. E. Lang, and M. Grecu (2009), Vertical Heating Structures Associated with the MJO as Characterized by TRMM Estimates, ECMWF Reanalyses and Forecasts: A Case Study During 1998-99 Winter, *Journal of Climate* (accepted).

Jordan, Nikisa S. (2009), Validation of the Version 5 Goddard Earth Observing System (GEOS-5) using Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), Ph.D. Thesis, Marine Estuarine and Environmental Science Program, UMBC, May 2009.

Joshi, A., J. Caban, P. Rheingans and L. Sparling, Case Study on Visualizing Hurricanes Using Illustration-Inspired Techniques, *IEEE Transactions on Visualization and Computer Graphics*, 15, doi:10.1109/TVCG.2008.105, 2009.

Kopeikin, S.M., E. C. Pavlis, D. E. Pavlis, V.A. Brumberg, A. Escapa, J. Getino, A. Gusev, J. Müller, W.-T. Ni, N. Petrova, (2008), Prospects in the orbital and

rotational dynamics of the Moon with the advent of sub-centimeter lunar laser ranging, *J. Adv. Space Res., 42, pp.1378–1390, doi:10.1016/j.asr.2008.02.014.*

Koren, I., J. V. Martins, L. A. Remer, and H. Afargan (2008), Smoke Invigoration Versus Inhibition of Clouds over the Amazon, *Science*, 321 (946), doi: 10.1126/science.1159185.

Krotkov, N. A., B. McClure, R.R. Dickerson, S.A. Carn, C. Li, P.K. Bhartia, K. Yang, A.J. Krueger, Z. Li, P. Levelt, H. Chen, P. Wang, and D.R. Lu (2008), Validation of SO_2 retrievals from the Ozone Monitoring Instrument (OMI) over NE China, *J. Geophys. Res.,* 113, D16S40, doi:10.1029/2007JD008818.

Kuang, W., W. Jiang, and T. Wang (2008), Sudden termination of Martian dynamo?: Implications from subcritical dynamo simulations, *Geophysical Research Letter*, 35, L14204, doi:10.1029/2008GL034183.

Kundu, P. K. and R. K. Siddani (2009), Long-range memory effect and generalized scaling in the distribution of dry intervals in gauge-derived rainfall time series, *Geophysical Research Abstracts,* 11, EGU2009-2631.

Kurtz, N. T., T. Markus, D. J. Cavalieri, L. C. Sparling, W. B. Krabill, A. J. Gasiewski, and J. G. Sonntag (2009, Estimation of sea ice thickness distributions through the combination of snow depth and satellite laser altimetry data, *J. Geophys. Res.*, doi:10.1029/2009JC005292.

Lightner, K. J., W. W., McMillan, K. J McCann, R. M Hoff, M. J Newchurch, J., Song, E. Hintsa, and C. D Barnet (2009), Detection of a tropospheric ozone anomaly using the Kurt Lightner Ozone BBAERI Retrieval (KLOBBER) algorithm on 2 June 2003 at the Chesapeake Light lighthouse, *J. Geophys. Res.*, 114, D06304, doi:10.1029/2008JD010270.

Liu, D., W. Kuang, and A. Tangborn (2009), High-order compact difference implicit methods for a paraboloic equation in geodynamo simulation, *Advances in Mathematical Physics*, Vol. 2009, doi:10.1155/2009/568296.

Marks, D. A., D. B. Wolff, D. S. Silberstein, A. Tokay, J. L. Pippitt, and J. Wang (2009), Availability of high quality TRMM ground validation data from Kwajalein, RMI: A practical application of the relative calibration adjustment technique, *J. Atmos. Oceanic Technol.,* 26, 413-429.

Martins, J. V., P. Artaxo, Y. J. Kaufman, A. D. Castanho, and L. A. Remer (2009), Spectral absorption properties of aerosol particles from 350–2500nm,

Geophysical Research Letters (accepted).

Matsui, T., X. Zeng, W.-K. Tao, H. Masunaga, W. S. Olson, and S. Lang (2009), Evaluation of Long-Term Cloud-Resolving Model Simulations Using Satellite Radiance Observations and Multi-Frequency Satellite Simulators, *J. Atmos. Oceanic Tech.*, 26, 1261-1274.

McComiskey, A., G. Feingold, A. S. Frisch, D. D. Turner, M. A. Miller, J. C. Chiu, Q. Min, and J. A. Ogren (2009), An assessment of aerosol-cloud interactions in marine stratus clouds based on surface remote sensing, *J. Geophys. Res.*, 114, D09203, doi:10.1029/2008JD011006.

McMillan, W. W., J. X. Warner, M. M. Comer, E. Maddy, A. Chu, L. Sparling, E. W. Eloranta, R. M. Hoff, G. Sachse, C. Barnet, I. A. Razenkov, and W. Wolf (2008), AIRS views of transport from 12-22 July 2004 Alaskan/Canadian fires: Correlation of AIRS CO and MODIS AOD with forward trajectories and comparison of AIRS CO retrievals with DC-8 in situ measurements during INTEX-A/ICARTT, *J. Geophys. Res.*, 113, D20301, doi:10.1029/2007JD009711.

McMillan, W. W., R. Pierce, L. C. Sparling, G. Osterman, K. McCann, M. L. Fischer, B. Rappenglück, R. Newsom, D. Turner, C. Kittaka, K. Evans, S. Biraud, B. Lefer, A. Andrews, S. Oltmans (2009), An Observational and modeling strategy to investigate the impact of remote sources on local air quality: A Houston, Texas case study from TEXAQS II, *J. Geophys. Res.* (in press).

Mehta, A. V., and S. Yang (2008), Precipitation Climatology over Mediterranean Basin from TRMM, *Advances in Geosciences*, 17, 87-91.

Middleton, E. M., L. A. Corp, and P. K. E. Campbell (2008), Comparison of measurements and FluorMOD simulations for solar induced chlorophyll fluorescence and reflectance of a corn crop under nitrogen treatments, *International Journal of Remote Sensing*, 29 (17), 5193-5213.

Middleton, E. M., Y. B. Cheng, T. Hilker, T. A. Black, P. Krishnan, N. C. Coops, and K. F. Huemmrich (2009), Linking Foliage Spectral Responses to Canopy-Level Ecosystem Photosynthetic Light-Use Efficiency at a Douglas-Fir Forest in Canada, *Canadian Journal of Remote Sensing,* 35, 166-188.

Pavlis, E. C. et al., (2009), "Observing Systems Needed to Address Sea-level Rise and Variability", in *Understanding Sea-level Rise and Variability*, Aarup, T., J. Church, S. Wilson, and P. Woodworth (eds.), Blackwell, Oxford (*in press*).

Pavlis, E. C. et al., (2009), "The goals, achievements, and tools of modern geodesy", in *GGOS2020: The Global Geodetic Observing System,* H.- P. Plag and M. Pearlman (eds.), Chapter 2*,* pp. 24-62, GGOS/IAG, Springer-Verlag, New York.

Pearlman, M., C. Noll, J. McGarry, W. Gurtner, E. Pavlis, (2009), "The International Laser Ranging Service", AOGS 2007, Kenji Satake (ed.), *Adv. Geosciences*, v. 13, pp. 129-153, World Scientific.

Rancic, M., H. Zhang, and V. Savic-Jovcic (2008), Nonlinear advection schemes on the octagonal grid, *Mon. Wea. Rev.*, 136, 4668-4686.

Remer, L. A., R. G. Kleidman, R. C. Levy, Y. J. Kaufman, D. Tanre, S. Mattoo, J. V. Martins, C. Ichoku, I. Koren, H. Yu, and B. N. Holben (2008), Global aerosol climatology from the MODIS satellite sensors, *J. Geophys. Res.*, 113, D14S07, doi:10.1029/2007JD009661.

Ricklefs, R. L., C. Noll, J. Horvath, O. Brogdon, and E. C. Pavlis, (2009), Implementing the Consolidated Laser Ranging Data (CRD) Format throughout the ILRS Network, in *Proceedings of 16th Int. Laser Workshop*, S. Schillack (ed.), Poznan, Poland, (accepted).

Shie, C.-L., L. S. Chiu, R. Adler, P. Xie, I.-I. Lin, F.-C. Wang, E. Nelkin, R. Chokngamwong, W. S. Olson, and D. A. Chu (2009), A Note on Reviving the Goddard Satellite-Based Surface Turbulent Fluxes (GSSTF) Dataset, *Advances in Atmospheric Sciences* (in press).

Shugart, H.H., S. Saatchi, and F.G Hall (2009), A Primer on the Structure of Forest and its Measurement from Space, *Journal of Geophysical Research, Atmospheres* (in press).

Soenen, S.A., D.R. Peddle, C.A. Coburn, R.J. Hall and **F.G. Hall** (2009), Canopy Reflectance Model Inversion in Multiple Forward Mode: Forest Structural Information Retrieval from Solution Set Distribution, *Photogrammertic Engineering & Remote Sensing*, 75 (4), 361-374.

Tangborn, A., R. Cooper, S. Pawson and Z. Sun (2009) Chemical source inversion using assimilated constituent observations observations in an idealized two-dimensional system, *Mon. Wea. Review* (in press).

Tangborn**,** A., I. Stajner, M. Buchwitz, I. Khlystova, J. Burrows, S. Pawson, R. Hudman and P. Nedelec (2009), Assimilation of SCIAMACHY total column CO observations: Regional analysis of data impact, *J. Geophys. Res. – Atmo.,* 114, doi:

10.1029/2008JD010781.

Tokay, A., P. G. Bashor, and V. L. McDowell (2009), Comparison of rain gauge measurements in mid-Atlantic region, *J. Hydrometeor.* (conditionally accepted).

Tokay, A., P. Hartmann, A. Battaliga, K. S. Gage, W. L. Clark, and C. R. Williiams (2009), A field study of reflectivity and Z-R relations using vertically pointing radars and disdrometers, *J. Atmos. Oceanic Technol.*, 26, 1120-1134.

Várnai, T., and A. Marshak (2009), MODIS observations of enhanced clear sky reflectance near clouds, *Geophys. Res. Letters*, 36, L06807, doi:10.1029/2008GL037089.

Willis, P., J.C. Ries, N.P. Zelensky, L. Soudarin, H. Fagard, E. C. Pavlis, and F.G. Lemoine, (2009), "DPOD2005 : An extension of ITRF2005 for Precise Orbit Determination", *Advances in Space Res.*, 44 pp.535–544, Elsevier, The Netherlands, doi:10.1016/j.asr.2009.04.018.

Yang, K., N.A. Krotkov, A.J. Krueger, S.A. Carn, P.K. Bhartia, and P.F Levelt (2009), Improving retrieval of volcanic sulfur dioxide from backscattered UV satellite observations, *Geophys. Res. Lett.*, 36, L03102, doi:10.1029/2008GL036036.

Yang, K., X. Liu, N.A. Krotkov, A.J. Krueger and S.A. Carn (2009), Estimating the altitude of volcanic sulfur dioxide plumes from space- borne hyper-spectral UV measurements, *Geophys. Res. Lett.,* 36, L10803, doi:10.1029/2009GL038025.

Yang, Y., A. Marshak, T. Várnai, W. Wiscombe, and P. Yang (2009), Uncertainties in ice sheet altimetry measurements from a space-borne 1064 nm single channel lidar due to undetected thin clouds, *IEEE Trans. Geosci. Remote Sens*. (in press).

Zhang, H., R.M. Hoff, and J.A. Engel-Cox (2009), The relation between Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol optical depth and PM2.5 over the United States: a geographical comparison by EPA regions, *J.Air & Waste Manage. Assoc*. (in press).

Zinner, T., A. Marshak, S. Lang, J. V. Martins, and B. Mayer (2008), Remote sensing of cloud sides of deep convection: Towards a three-dimensional retrieval of cloud particle size profiles, *Atmos. Chem. Phys. Disc.*, 8, 4267-4308.

III.3 Publications Submitted for Review

Bulmer, M. H., S. W. Anderson, T. Gregg, L. S. Glaze, and P. McGovern (2009), Paradoxical Views of the Emplacement of Blocky Lava Flows at Sabancaya Volcano Provided by Petrologic and Morphological Characterizations, *J. Geophys. Res.* (in preparation).

Bulmer, M. H., T. Farquhar, and M. Roshan (2009), Monitoring the Failure of Ingate Road Using Low Level Aerial Imagery, *QJEG* (in preparation).

Ciufolini, I., A. Paolozzi, E. C. Pavlis, G. Sindoni, R. König, J. Ries, and R. Matzner, (2009), "The LARES space experiment: LARES orbit, error analysis and satellite structure", in *Lectures at the Wheeler school on relativity*, 2006 Erice Summer School Lecture series, (*in review*).

Correia, A., T. Yuan, J. V. Martins, L. A. Remer and H. Yu (2009), Cloud base height sensitivity to biomass burning smoke and cloud cover in the Amazon Basin, *Geophys. Res. Lett.* (submitted).

DeSouza-Machado, S. G., L. L. Strow, B. Imbiriba, K. McCann, R. M. Hoff, S. E. Hannon, and J. V. Martins (2009) Dust studies using AIRS infrared data: A comparison of infrared dust column optical depth and height retrievals from AIRS against PARASOL, MODIS, OMI and CALIPSO retrievals, *J. Geophys. Res.* (submitted).

Fan, J., T. Yuan, J. Comstock, S. Ghan, R. Leung, A. Khain, Z. Li, M. Ovchinnikov, and J.V. Martins (2009), Dominant Role by Vertical Wind Shear in Regulating Aerosol Effects on Deep Convective Clouds, *Journal of Geophysical Research* (submitted and accepted for publication).

Finnegan, D.C., S. A. Arcone, M. H. Bulmer, and S. W. Anderson (2009), Topographic Comparison of Rock Size Distributions Derived from High-Resolution Ground-Based LiDAR, *J. Geophys. Res.* (in preparation).

Fisher, J. A., J. A. , D. J. Jacob, M. T. Purdy, M. Kopacz1, P. Le Sager, C.Carouge, C. D. Holmes, R. M. Yantosca, R. L. Batchelor, K. Strong, G. S. Diskin, H. E. Fuelberg, J. S. Holloway, E. J. Hyer, W. W. McMillan, J. Warner, D. G. Streets, Q. Zhang, Y. Wang, S. Wu (2009), Source attribution and interannual variability of Arctic pollution in spring constrained by aircraft (ARCTAS, ARCPAC) and satellite (AIRS) observations of carbon monoxide, *Atmos. Chem. Phys.* (in preparation).

Han, M., S. A. Braun, W. S. Olson, P. O. G. Persson, J.-W. Bao (2009), Application of TRMM PR and TMI Measurements to Assess Cloud Microphysical Schemes in the MM5 Model for a Winter Storm, *J. Appl. Meteor. and Climatol.* (submitted).

Hopkins, P. E., V. S. Connors, W. W. McMillan, H. G. Reichle, and R. J. Ribando (2009), Feasibility of determining carbon monoxide mixing ratios from the MicroMAPS instrument on an airborne platform, *J. Atmos. Oceanic Tech*. (submitted).

Kopacz, M., D. J. Jacob, J. A. Fisher, J. A. Logan, L. Zhang, I. A. Megretskaia, R. M. Yantosca, K. Singh, D. K. Henze, J. P. Burrows, M. Buchwitz, I. Khlystova, W. W. McMillan, J. C. Gille, D. P. Edwards, A. Eldering, V. Thouret, P. Nedelec (2009), Global estimates of CO sources with high resolution by adjoint inversion of multiple satellite datasets (MOPITT, AIRS, SCIAMACHY, TES), *Atmos. Chem. Phys.* (in preparation).

Koren, I., L.A. Remer, O. Altaratz, J. V. Martins, and A. Davidi (2009), Aerosol induced change of convective clouds anvils and the outcome climate warming, *Science* (submitted).

Krueger, A.J., N.A. Krotkov, K. Yang, S. A. Carn, G. Vicente, and W. Schroeder (2009), Applications of Satellite-based Sulfur Dioxide Monitoring, *IEEE-JSTARS* (revision submitted).

Kuang, W., A. Tangborn and Z. Wei (2009), Constraining a numerical dynamo model with 100 years of surface observations, *Geophys. J. International,* (revision submitted).

Marshak, A., Y. Knyazikhin, J. C. Chiu, and W. J. Wiscombe (2009), Spectral invariant behavior of zenith radiance around cloud edges, *Geophys, Res. Lett.* (submitted).

McMillan, W. W., W. R. Pierce, L. C. Sparling, G. Osterman, K. McCann, M. L. Fischer, B. Rappengl¨uck, R. Newsom, D. Turner, C. Kittaka, K. Evans, S. Biraud, B. Lefer, A. Andrews, S. Oltmans (2009), An Observational and modeling strategy to investigate the impact of remote sources on local air quality: A Houston, Texas case study from TEXAQS II, *JGR*, (submitted).

Prados, A. I., G. Leptoukh, J. Johnson, H. Rui, C. Lynnes, A. Chen, and R. B. Husar (2009), Access, Visualization, and Interoperability of Air Quality Remote Sensing Data Sets Via the Giovanni Online Tool, *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing* (submitted).

Rabier, F., A. Bouchard, E. Brun, A. Doerenbecher, S. Guedj, V. Guidard, F. Karbou, V-H. Peuch, L. El Amroaoui, D. Puech, C. Genthon, G. Picard, M. Town, A. Hertzog, F. Vial, P. Cocquerez, S.A. Cohn, T. Hock, J. Fox, H. Cole, D. Parsons, J. Powers, K. Romberg, J. VanAndel, T. Deshler, J. Mercer, J. Haase, L. Avallone, L. Kalnajs, C.R. Mechoso, A. Tangborn, A. Pellegrini, Y. Frenot, J.-N. Thepaut, A. McNally and P. Steinle (2009), The Concordiasi project in Antarctica for the International Polar Year, *Bull. Amer. Meteorol. Soc.* (submitted).

Russo, F., D. N. Whiteman, D. D. Turner, B. B. Demoz, R. M. Hoff, I. Veselovskii (2009), 2008 Measurements of the Aerosol Indirect Effect using a Raman lidar. Part 1: cloud liquid water measurements, *J. Atmos. Ocean. Tech.* (submitted).

Stephanie, A. W., J. A. Engel-Cox, R. M. Hoff, A. Prados, and H. Zhang (2009), An improved method for estimating surface fine particle concentrations using seasonally-adjusted MODIS, MISR, and GASP aerosol optical depth values, *J.Air & Waste Manage. Assoc*. (submitted).

Tokay, A., and P. G. Bashor (2009), An experimental study of small-scale variability of raindrop size distribution, *J. Appl. Meteor. Climatol.* (submitted).

Warner, J., Z. Wei, J.-L. Attie, L. Sparling, G. Diskin, G. Sachse, M. Luo, L. El Amraoui, and M. Claeyman (2009), Tropospheric CO Profiling Capabilities by AIRS and TES on A-Train Satellites, *J. Geophys. Res.* (in preparation).

Weber, S. A., J. A. Engel-Cox, R. M. Hoff, A. Prados, and H. Zhang (2009), An improved method for estimating surface fine particle concentrations using seasonally-adjusted MODIS, MISR, and GASP aerosol optical depth values, *Air & Waste Manage. Assoc.* (submitted).

Weber, Stephanie A., J. A. Engel-Cox, R. M. Hoff, A. Prados, H. Zhang, R. Rogers, and C. Kittaka (2009), Evaluation of 3-D Air Quality System remotely-sensed aerosol optical depth for the Baltimore/Washington metropolitan air shed, Journal of the Air and Waste Management Association (submitted).

Yuan, T., and Z. Li (2009), General Micro- and Macro- physical properties of deep convective clouds as observed by MODIS, *J. Clim.* (in revision).

Yuan, T., L. A. Remer, and K.E. Pickering (2009), Aerosol increased lightning activity and its impact on atmospheric chemistry, *Nature Geoscience* (submitted).

III.4 Conference Presentations, Non-reviewed Publications and Technical Reports

Bösenberg, J., and R. M. Hoff (2008), Plan for the implementation of the GAW Aerosol Lidar Observation Network (GALION), World Meteorological Report #178, WMO, Geneva, Switzerland.

Boy, J.-P., P. Gegout, J. Hinderer, F. Lemoine, S. Luthcke, E. C. Pavlis, D. Rowlands, (2008), Atmospheric, oceanic and hydrological loading effects on time-variable gravity and surface displacements, *New Challenges in Earth's Dynamics, ETS2008*, 1-5 September, 2008, Jena, Germany.

Bulmer, M.H. (2008), Identifying appropriate monitoring strategies for landslide hazards in the Vilcanota Valley, Global Facility for Disaster Reduction and Recovery, Stage 2, Detailed Application for GFDRR Track II, p.5.

Bulmer, M.H. (2008), Lessons Identified from Recent Flooding in the UK, RMLY G3-300/1, p.7.

Bulmer, M.H. (2008), SGER: An investigation of progressive slope failure in landslides in the area affected by the 8th October 2005 Earthquake in Pakistan, Final Report 0628819, p. 27.

Bulmer, M.H. (2009), Annual Progress Report for Year 1 of NASA Grant NNX08AT15G, Topography Data on Mars: Optimizing its Collection and Application Using Laser Scanning, pp. 5.

Bulmer, M.H. (2009), Comments on the Executive Committee of the Army Board Direction and Guidance on the Development of the TA ECAB/P(09)32, RMLY G3-105/1, pp. 4.

Bulmer, M.H. (2009), Observations on Headquarters 143 (West Midlands) Brigade UK Ops Level 2 Training, RMLY G3-300, pp. 4.

Bulmer, M.H. (2009), RMLY CVR(T) Spartan L37 Operator and Firing at Lulworth 12-16 Nov 08, RMLY G3-800/02, pp. 6.

Bulmer, M.H. (2009), Second Report Peru: Vilcanota Valley Slope Monitoring of Flash Floods and Other Natural Hazards February 2009 in *Geophysical Flow Observatory/ Landslide Mitigation Group Open File Report 09-04.1*, pp. 4.

Bulmer, M.H. (2009), Shropshire Yeomanry Comrades Association: Meeting the Challenges of Current Operations 2009, RMLY G1-505, pp. 5.

Bulmer, M.H. (2009), The Value of Geospatial Data in Assisting Decision Making for Planning and Managing with the H1N1 Pandemic: UMBC Campus Operations 2209, Geophysical Flow Observatory / Landslide Mitigation Group Open File Report 09-06.1, pp. 5.

Bulmer, M.H. and T. Farquhar (2008), First Report Peru: Vilcanota Valley Slope Monitoring for Flash Flood Prevention, May 2008, Geophysical Flow Observatory/ Landslide Mitigation Group Open File Report 08-05.1, pp. 27.

Bulmer, M.H., and T. Farquhar (2008), Vilcanota Valley Slope Monitoring for Flash Flood Prevention - Part of the Vilcanota Valley Rehabilitation and Management Project - P082625 - Terms of Reference for World Bank, p. 3.

Bulmer, M.H., D. Beller, J. Griswold, and P. J. McGovern (2008), Granular Materials in the disrupted terrain of Olympus Mons Aureoles, 39th Lunar and Planetary Science Conference, Houston, TX, 1971.

Bulmer, M.H., D. Beller, J. Griswold, and P. J. McGovern (2008), Slope Streaks Emplacement in the Disrupted Terrain of Olympus Mons Aureoles, Workshop on Martian Gullies: Theories and Tests, Houston, TX, LPI Contribution 1301, 17-18.

Campbell, P. (2009), WGCV 29 and 30 Reports: Minutes, Actions and Recommendations.

Campbell, P.K.E., E.M. Middleton, L.A. Corp, K. F. Huemmrich, G. Parker, Y. Cheng, D. Nayak and Q. Yuan (2008), Foliar bio-physical and spectral properties associated with light environment in a mature poplar stand (*Lirodendron tulipifera* L.), Proceedings, International Geoscience and Remote Sensing Symposium (IGARSS), Boston, MA, 6-11 July.

Cao, C., S. Ungar, P. Lecomte, X. Xiong and P. Campbell (2008), The CEOS CalVal Portal: Pathway to GEOSS Data Compatability - Toward consistent satellite calibration using common practices and CalVal site, IGARSS'08, Boston, MA, 6-11 July (invited presentation).

Carn, S. A., N. A. Krotkov, V. Fioletov, K. Yang, A. J. Krueger, and D. Tarasick (2008), Emission, transport and validation of sulfur dioxide in the 2008 Okmok

and Kasatochi eruption clouds, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract A51J-07.

Carn, S.A., A.J. Krueger, N.A. Krotkov, and K. Yang (2008), Volcanic degassing flare-ups, IAVCEI, Reykjavik, Iceland, 18-23 August.

Carn, S.A., A.J. Prata, W.G. Read, C. Clerbaux, N.A. Krotkov, K. Yang, and A.J. Krueger (2008), Probing volcanic clouds with the A-Train, IAVCEI, Reykjavik, Iceland, 18-23 August.

Carn, S.A., N.A. Krotkov, K. Yang, A.J. Krueger, G. Mount, E. Spinei, V. Fioletov, D. Tarasick, J. Rimmer, M. Allaart, and H. De Backer (2008), A Summer of SO_2: OMI validation opportunities provided by Aleutian volcanic eruptions, Aura Science Team meeting, Columbia, MD, 27-30 October.

Chaudhry, Z., J. V. Martins, and Z. Li (2008), In Situ Measurements of Aerosol Scattering and Absorption Profiles by a Balloon-Borne Aerosol Sonde, poster presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Chiu, J. C., A. Marshak, E. J. Welton, and W. Wiscombe (2008), Using lidars to retrieve optical depth for thick clouds: examples from ARM and MPLNET, International Radiation Symposium, Foz do Iguacu, Brazil, 3–8 August.

Chiu, J. C., A. Marshak, W. Wiscombe, B. Holben, P. Pilewskie, and P. McBride (2008), Retrievals of cloud properties from ground - based zenith radiance measurement, International Radiation Symposium, Foz do Iguacu, Brazil, 3–8 August.

Chiu, J. C., and W. Wiscombe (2008), Climate observations from the Atmospheric Radiation Measurement (ARM) program, 2008 Japan-America Frontiers of Engineering Symposium, Kobe, Japan, 17–19 November (invited paper).

Ciufolini, I., A. Paolozzi, E. C. Pavlis, G. Sindoni, and C.Vendittozzi, (2008), "Error Analysis for the LARES Experiment I: Gravitational Uncertaintiesand Even ZonalHarmonics", *The Nature of Gravity: Confronting Theory and Experiment in Space*, Int. Space Science Institute, Bern, Switzerland, 6–10 October, 2008.

Ciufolini, I. and E. C. Pavlis, (2009), "Measurement of gravitomagnetism with Satellite Laser Ranging to LAGEOS, LAGEOS 2 and LARES satellites", INVITED, *Relativity in Fundamental Astronomy: Dynamics, Reference Frames, and Data Analysis*, IAU Symposium 261, 27 April - 1 May 2009, Virginia Beach, VA.

Corp, L.A., E. M. Middleton, C.S.T. Daughtry, P.K.E. Campbell, K.F. Huemmrich, and Y. B. Cheng (2008), Impact of Spectral Resolution on Solar Induced Fluorescence and Reflectance Indices for Monitoring Vegetation, Proceedings, International Geoscience and Remote Sensing Symposium (IGARSS), Boston, MA, 6-11 July.

Corp, L.A., E. M. Middleton, P. K. Entcheva Campbell, K. F. Huemmrich, Y. B. Cheng, and C. S. T. Daughtry (2008), Spectral Indices to Monitor Nitrogen Driven Carbon Sequestration in Vegetation, NASA Carbon Cycle & Ecosystems Joint Science Workshop, College Park, MD, April 2008.

Corp, L.A., E. M. Middleton, P.K.E. Campbell, K.F. Huemmrich, Y.B. Cheng, and C.S.T. Daughtry (2009), Remote Sensing techniques to monitor Nitrogen driven Carbon dynamics in vegetation, SPIE Optics Photonics, Optical Engineering plus Applications, Remote Sensing and Modeling of Ecosystems for Sustainability, San Diego, CA 2-6 August.

Correia, A. L., J. V. Martins, and R. Fernandez-Borda (2008), Experimental Measurements and Strategies for Quantifying Cloud-Aerosol Interactions, oral presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Correia, A. L., R. Fernandez-Borda, and J. V. Martins (2008), New results of the Cloud-Aerosol Interaction Measurements (CLAIM) 2007 Field Campaign on the Amazon Basin, Brazil, pPoster presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

De Souza-Machado, S., B. Imbiriba, L. L. Strow, S. E. Hannon, K. McCann, D. Tanre, J.-L. Deuze, and F. Ducos (2008), Retrieving dust optical depths using AIRS and CALIPSO, IRS 2008, Foz de Iguassu, Brazil, 3-8 August.

De Souza-Machado, S., K. McCann, L. Strow, and G. Aumann (2008), Tropopause penetration of Deep Convective Clouds using AIRS data, AGU, San Francisco, CA, 15-19 December.

De Souza-Machado, S., L. Strow, S. Hannon, and D. Tanre (2008), Validating dust layer heights and optical depths from AIRS data, AGU, San Francisco, CA, 15-19 December.

Delgado, R., M. Weldegaber, R. C. Wilson, W. McMillan K. J. McCann, M. Woodman, B. Demoz, M. Adam, R. Connell, D. Venable, E. Joseph, S. Rabenhorst, L. Twigg, T. McGee, D. N. Whiteman, and R. M. Hoff (2008), ELF and ALEX SURF WINTER WAVES: Lidar Intercomparison of Aerosol and Water Vapor Measurements in the

Baltimore-Washington Metropolitan Area During the Winter Water Vapor Validation Experiments (WAVES) 2008 campaign, AGU Fall Meeting, San Francisco, CA, 15-19 December.

Delgado, R., P. Schou, L. Zhu, M. Woodman, M. Seybold, K. J. McCann, and R. M. Hoff (2008), Identification of Aerosols Above the Planetary Boundary Layer: ELF and ALEX Ride the A-Train, Paper P2.25, Symposium on Recent Developments in Atmospheric Applications of Radar and Lidar, American Meteorological Society Annual Meeting, New Orleans, LA, 21-24 January.

Dolgos, G., J. V. Martins, A. L. Correia, and L. A. Remer (2008), New Instrumentation for the Detailed Characterization of Aerosol Light Absorption and Scattering Properties, poster presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Doraiswamy, P., C. Hogrefe, W. Hao, K. Civerolo, J.-Y. Ku, G. Sistla, and H. Zhang (2009), Comparison of Model-predicted PM2.5 concentrations with satellite-based aerosol optical depth measurements, AWMA meeting, extended abstract 2009-A-469-AWMA.

Engel-Cox, J., and R. M. Hoff (2008), Use of Satellite Remote Sensing Data for Air Quality: The NASA Three-Dimensional Air Quality System (3D-AQS) US EPA National Air Quality Conference, Marriott Portland Downtown Waterfront, Portland, OR, 6-9 April.

Farquhar, T., and M. H. Bulmer (2009), Second Report Peru: Vilcanota Valley Slope Monitoring for Flash Floods and Other Natural Hazards - Geophysical Flow Observatory / Landslide Mitigation Group, Confidential Report to the World Bank, GFLO#09.20-MPP, pp. 54.

Fernandez-Borda, R., J. V. Martins, R. Ferrare, and L. Remer (2008), Aerosol Profile Studies using Calipso-MODIS measurements, poster presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Grecu, M., and W. S. Olson (2009), Construction of dynamic databases to support satellite passive microwave rain estimation, presented at the 4th International Workshop on Precipitation Retrieval Algorithms Using Satellite Microwave Radiometer, Radar and IR Data, Tokyo, Japan, 16-18 February.

Griswold, J., M. H. Bulmer, D. Beller, and P. J. McGovern (2008), An examination of Olympus Mons aureoles, 39th Lunar and Planetary Science Conference, Houston, TX, 2239.

Hall, F. (2009), BIOPHYS: A Physically-Based Algorithm to Retrieve Vegetation Structural Parameters, Canadian Remote Sensing Society, 22-26 June.

Hall, F. (2009), Light Use Efficiency from Tower-Based Spectrometer Measurements, North American Carbon Cyce Meeting, San Diego, CA, 17-20 February.

Hall, F. (2009), The DESDynI Mission, Canadian Carbon Program Meeting, University of British Columbia, 27 February – 1 March.

Hilsenrath, E. (2008), Long Term AC Measurements and Climate Modeling, SPARC/SSG, Toronto, Canada, 14-17 November.

Hilsenrath, E. (2008), The CEOS Atmospheric Composition Constellation (ACC): An Example of an Integrated Earth Observing System for GEOSS, 2008 EUMETSAT Meteorological Satellite Conference, 11 September.

Hilsenrath, E. (2009), Air Quality from Space - From Provider to User, ESIP Federation Meeting Santa Barbara, CA, 7-10 July.

Hoff, R. (2009), Committee on Developing Mesoscale Meteorological Observational Capabilities to Meet Multiple Needs, Chapter 4 of *Weather and Climate from the Ground Up: A Nationwide Network of Networks*, National Research Council, The National Academies Press, Washington, D.C. ISBN-13 978-0-309-12986-2, 234pp.

Hoff, R. M., J. Boesenberg and G. Pappalardo (2008), The GAW Aerosol Lidar Observation Network (GALION), IGARSS '08, Boston, MA, 8 July.

Hoff, R. M. and J. Engel-Cox (2008), The Three Dimensional Air Quality System, IGARSS '08, Boston, MA, 10 July.

Hoff, R. M., A. I. Prados, H. Zhang, M. Kacenelenbogen, R. Delgado, S. Kondragunta, J. Szykman, F. Dimmick, B. Johns, C. Kittaka, J. A. Al-Saadi, J. Engel-Cox, S. Weber, A. Huff, A. Wimmers, and S. A. Ackerman (2009), Increased availability of satellite remote sensing data for model evaluation through 3D-AQS, 11th Conference on Atmospheric Chemistry, American Meteorological Society Annual Meeting, Phoenix, AZ, 12-15 January.

Hoff, R. M., G. Pappalardo, and J. Boesenberg (2008), The GAW Atmospheric Lidar Observations Network (GALION), Paper 5.2, Symposium on Recent Developments in Atmospheric Applications of Radar and Lidar, American

Meteorological Society Annual Meeting, New Orleans, LA, 21-24 January (invited).

Hoff, R. M., G. Pappalardo, and J. Boesenberg (2008), The GAW Atmospheric Lidar Observations Network (GALION), 2008 CREST Technical Meeting, Mayaguez, Puerto Rico, 21-23 February.

Hoff, R. M., and S. A. Christopher (2009), The 34th AWMA Critical Review: Remote Sensing of Particulate Pollution from Space: Have We Reached the Promised Land?, Air and Waste Management Association Annual Meeting, Detroit, MI, 17 June.

Hoff, R., F. Moshary, S. Ahmed, B. Gross, P. McCormick, and H. Parsiani (2009), *CREST Lidar Network (CLN)*, CREST Publication Series, 7, Number 09-01, NOAA-CREST Technical Report Series, Steinman Hall, City College of New York, New York, NY, 32 pp.

Hoff, R.M., H. Zhang, N. Jordan, A. I. Prados, J. Engel-Cox, A. Huff, S. Weber, E. Zell, S. Kondragunta, J. J. Szykman, B. Johns, F. Dimmick, A. Wimmers, J. Al-Saadi, and C. Kittaka (2008), The Three-Dimensional Air Quality System (3D-AQS) as a Data Synthesis Toolbox, Paper A21G-03, AGU Fall Meeting, San Francisco, CA, December.

Huemmrich, K.F. (2009), Remote Sensing and Vegetation Dynamics, Specnet Workshop, Lethbridge, AB, 22 June.

Huemmrich, K.F., E. M. Middleton, D. Landis, T. A. Black, A. Barr, J. H. McCaughey, and F.G. Hall (2009), Remote Sensing of Ecosystem Light Use Efficiency, Canadian Remote Sensing Society Symposium, Lethbridge, AB, 23-26 June.

Huemmrich, K.F., L. Corp, A. Russ, E.M. Middleton, W. Kustas, J. Prueger, and Y.B. Cheng (2008), Using Reflectance Measurements to Determine Light Use Efficiency in Corn, IEEE International Geoscience and Remote Sensing Symposium, Boston, MA, 7-11 July.

Huemmrich, K.F., L. Corp, A. Russ, E.M. Middleton, W. Kustas, J. Prueger, and Y.B. Cheng (2009) Using Spectral Reflectance to Determine Light Use Efficiency, North American Carbon Program Workshop, San Diego, CA, 17-20 February.

Huemmrich, K.F., L. Corp, A. Russ, E.M. Middleton, W. Kustas, J. Prueger, and Y.B. Cheng (2009), Using Spectral Reflectance to Determine Light Use Efficiency, Canadian Carbon Program Annual Meeting, Vancouver, BC, 27 Feb – 1 Mar.

Huff, A. K., J. Engel-Cox, and R. M. Hoff (2008), Use of NASA Three Dimensional Air Quality System (3D-AQS) Remote Sensing Data for Air Quality Forecasting, US EPA National Air Quality Conference, Marriott Portland Downtown Waterfront, Portland, OR, 6-9 April.

Hughes, E. J., L. C. Sparling, S. Carn, A. Krueger, and M. Schoeberl (2008a), Using horizontal transport characteristics to infer an emission height timeseries of volcanic SO_2, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract A23A-0270.

Hughes, E., and L. Sparling (2008b), Investigation of Tropospheric Transport from Backward Trajectory Modeling of Volcanic SO2, EOS AURA Science team meeting, Columbia, MD, 27-30 Oct.

Imbiriba, B., L. Strow, S. Hannon, and S. De Souza-Machado (2008), CO2 with AIRS, AGU, San Francisco, CA, 15-19 December.

Johnson, B.T. (2009), Global Precipitation Estimation Using Combined Radar and Radiometer Observations: An Overview, 4th GSMaP International Symposium, Tokyo, Japan, 16-20 February.

Johnson, B.T., G. Skofronick-Jackson, A. Kramer, and J. Wang (2009), Snowfall Retrieval Sensitivity to Land Emissivity and Particle Shape, European Geophysical Union (EGU), Vienna, Austria, 20-24 April.

Johnson, B.T., G. Skofronick-Jackson, and G.W. Petty (2008), Combined passive and active microwave retrieval of falling snow during the 2003 Wakasa Bay field experiment, Microwave Radiometry and Remote Sensing of the Environment, MICRORAD 2008.

Johnson, B.T., G. Skofronick-Jackson, and G.W. Petty (2008), Passive and Active Microwave Remote Sensing of Cold-Cloud Precipitation, Fourth Workshop of the International Precipitation Working Group (IPWG), Beijing, China, October 2008.

Jordan, N. S., R. M. Hoff, and J. T. Bacmeister (2009), CALIPSO Compared to the GEOS-5 Model, Am. Met. Soc. Annual Meeting, Phoenix, AZ, 12-15 January.

Kollonige, D. W., W. McMillan, L. Sparling, M. Avery, G. Sachse, G. Diskin, E. Browell, J. Hair (2008b), Study on the Spatial and Temporal Variability of Stratosphere-Troposphere Exchange with A-Train Observations, EOS AURA Science team meeting, Columbia, MD 27-30 Oct.

Kollonige, D., W. McMillan, L. Sparling, M. Avery, G. Diskin, G. Sachse, E. Browell, and J. W. Hair (2008), Study on the Spatial and Temporal Variability of Stratosphere-Troposphere Exchange with A-Train Observations, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract B31C-0301, San Francisco, CA, 15-19 December.

Kopeikin, S. E. C. Pavlis and D. E. Pavlis, (2008), Millimeter laser ranging to the Moon: prospects and challenges in improving the orbital and rotational dynamics, European Earth and Planetary Sciences Congress '08, Münster, Germany, 21-26 Sept 2008.

Koren, I., J. V. Martins, L. A. Remer, and H. Afargan (2008), A Smooth Transition from Microphysics to Absorption Effects of Smoke on Amazonian Clouds, oral presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Krotkov, N. A., M. Schoeberl, and S. A. Carn (2008), Trajectory modeling of Kasatochi eruption plume compared with OMI SO_2 observations, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract A53B-0266.

Krotkov, N., K. Yang, P. Bhartia, S. Carn, A. Krueger, K. Pickering, G. Vincente, G. Serafino, R. Dickerson, C. Li, J. Witte, and P. Levelt (2008), Global SO_2 sources detected in OMI operational data and improvements with a new iterative spectral fit SO_2/O_3 algorithm, Aura Science Team meeting, Columbia, MD, 27-30 October.

Krueger, A. (2009), OMI Sarychev SO2 image posted on the NASA Earth Observatory: http://earthobservatory.nasa.gov/IOTD/view.php?id=38975

Krueger, A. J., S. Carn, K. Yang, and N. Krotkov (2008), Advances in Observation of Global Sulfur Dioxide Sources with Aura/OMI, COSPAR, Montreal, 14-19 July.

Krueger, A., N. Krotkov, K. Yang, G. Vicente, W. Schroeder, G. Serafino, and M. Guffanti (2008), Volcanic cloud data for NOAA, FAA, and USGS. NASA Applied Science Program Review, Boulder, CO, 18-19 November.

Krueger, A., N. Krotkov, S. Carn, G. Serafino and G. Vicente (2008), Detection and Monitoring of Sulfur Dioxide from Satellite-based UV Sensors, *Proceedings, Eumetsat Conference,* Darmstadt, Germany, 8-13 Sept.

Krueger, A., S. Carn, N. Krotkov, K. Yang, G. Serafino, G. Vicente, and C. Barnett (2008), Sulfur dioxide observations from OMI and AIRS on EOS platforms for volcanic hazard detection and climate research, IAVCEI, Reykjavik, Iceland, 18-23 August.

Krueger, A.J. (2008), Advances in Monitoring of Volcanic Eruption Hazards (keynote address), EUMETSAT Meteorological Satellite Symposium, Darmstadt, Germany, 8-12 September.

Krueger, A.J., S. Carn, K. Yang, N. Krotkov, G. Vicente, and G. Serafino (2008), Detection and Monitoring of Sulfur Dioxide from Satellite based UV Sensors, EUMETSAT Meteorological Satellite Symposium, Darmstadt, Germany, 8-12 September.

Kurtz, N. T., T. Markus, L. Sparling, D. Cavalieri, A. Gasiewski, W. Krabill, and J. Sonntag (2008b), Impact of freeboard and snow depth variabilities on ICESat sea ice thickness retrieval, ICESat science team meeting, 1 October.

Kurtz, N. T., T. Markus, L. Sparling, D. Cavalieri, A. Gasiewski, W. Krabill, and J. Sonntag (2008b), Impact of Freeboard and Snow Depth Variability on Satellite Altimetric Sea Ice Thickness Retrievals, Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract C14A-03.

Kuzmicz-Cieslak, M. and E. C. Pavlis, (2008), Implementing the new ILRS CRD data format, 16th Int. Laser Workshop, Poznan, Poland, 13-17 Oct 2008.

Lary, D. (2009), Benjamin Meaker Visiting Professorship, University of Bristol, England, Summer 2009 (invited).

Lary, D. (2009), Presentation to the NASA GSFC Earth Science Architecture Team, 3-4 February (invited talk).

Lary, D. (2009), Computation Facilitating Insight: From Autonomous Observation to Artificial Intelligence, Department of Physics, Michigan Technical University, 27 April (invited talk).

Lary, D. (2009), From Autonomous Observation to Artificial Intelligence, MIT Department of Aeronautics and Astronautics, 24 April (invited talk).

Lary, D. (2009), Using Machine Learning to Produce Seamless Records of Climate Gases from Multiple Sources, The Second International Workshop on Pacific Greenhouse Gases Measurement, Taipei, Taiwan, 25 May (invited talk).

Lary, D. (2009), Linking NASA Satellite Based Environmental Data with Health Outcomes, Ann Arbor, University of Michigan, 15 June (invited talk).

Lloyd, S., J. Acker, A. I. Prados, and G. Leptoukh (2008), Using NASA's Giovanni Web Portal to Access and Visualize Satellite-Based Earth Science Data in the Classroom, 2008 AGU Fall Meeting, San Francisco, CA, 15-19 December.

Lynnes, C., G. Leptoukh, S. Berrick, S. Shen, A. Prados, P. Fox, W. Yang, M. Min, D. Holloway, and Y. Enloe (2008), Provenance in Data Interoperability for Multi-Sensor Intercomparison, 2008 AGU Fall Meeting, San Francisco, CA, 15-19 December.

Manning, E. M., H. Aumann, R. G. Deen, Y. Jiang, L. L. Strow and S. E. Hannon (2009), Spectral calibration in hyperspectral sounders, Proc. SPIE, Vol. 7452, 74520H (2009); doi:10.1117/12.826987 (in press)

Marshak, A., R. F. Cahalan, J. A. Coakley, N. G. Loeb, L. A. Reimer, T. Várnai, and G. Wen (2008), The apparent bluing of aerosols near clouds, International Radiation Symposium 2008 (IRS2008), Foz Do Iguacu, Brazil, 3-8 August.

Martins, J. V., Y. Kaufman, L. Remer, C. A. Pires, and P. Artaxo (2008), The Spectral Critical Albedo: A new look for aerosol absorption and scattering properties, oral presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Martins, J.V., A. Correia, R. Fernandez-Borda, L. Remer, and A. Marshak (2008), Cloud Aerosol Interaction Measurements (CLAIM) via the vertical profile of cloud microphysics and thermodynamics, oral presentation at the International Radiation Symposium, Iguassu Falls, Brazil, 3-8 Aug.

Martins, J.V., S. Buczkowisky, A. Correia, D. Cieslak, R. Fernandez-Borda, W. Zhu, S. Holt, L. A. Remer, A. Marshak, and J. Simpon (2009), Cloud-CubeSat: A Pico-Satellite for the profiling of cloud microphysics and thermodynamic properties, Cubesat Developer's Workshop- CalPoly, Poster presentation, 22-25 April.

McMillan, W. W., D. Kollonige, L. Yurganov, A. Krueger, R. Hoff, C. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. P. Kurosu, G. Osterman, and O. Torres (2008), Satellite observations of megacity air pollution, biomass burning emissions, and their long- range transport, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract A21A-0107.

McMillan, W. W., D. Kollonige, L. Yurganov, A. Krueger, R. Hoff, C. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. P. Kurosu, G. Osterman, and O. Torres (2008), Satellite observations of megacity air pollution, biomass burning emissions, and their long-range transport, International Conference on Atmospheric Physics,

Kislovodsk, Russia, 23-29 September.

McMillan, W. W., L. Yurganov, A. Krueger, R. Hoff, C. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. P. Kurosu, G. Osterman, and O. Torres (2008), Satellite Observations of Megacity Air Pollution, Biomass Burning Emissions, and their Long-Range Transport, International Conference on Atmospheric Physics, Climate, and Health, p.116, Kislovodsk, Russia, 6-10 October.

McMillan, W. W., L. Yurganov, A. Krueger, R. Hoff, C. D. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. Kurosu, G. Osterman, and O. Torres (2009), Satellite observations of megacity air pollution, biomass burning emissions, and their long-range transport, 89th Annual Meeting of the American Meteorological Society, 11th Conference on Atmospheric Chemistry, Abstract 10.5, Phoenix, AZ, January.

McMillan, W., D. Kollonige, L. Yurganov, A. Krueger, R. Hoff, C. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. P. Kurosu, G. Osterman, and O. Torres (2008), Satellite observations of megacity air pollution, biomass burning emissions, and their long- range transport, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract A21A-0107, San Francisco, CA, 15-19 December.

McMillan, W., L. Yurganov, A. Krueger, R. Hoff, C. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. P. Kurosu, G. Osterman, and O. Torres (2008), Satellite observations of megacity air pollution, biomass burning emissions, and their long-range transport. International Conference on Atmospheric Physics, Kislovodsk, Russia, September 2008.

McMillan, W., L. Yurganov, A. Krueger, R. Hoff, C. Barnet, J. Gleason, E. Celarier, N. Krotkov, X. Liu, T. P. Kurosu, G. Osterman, and O. Torres (2009), Satellite observations of megacity air pollution, biomass burning emissions, and their long-range transport, Am. Met. Soc. Annual Meeting, Phoenix, AZ, January 2009.

Mertikas, S. P., Ath. Papadopoulos, and E. C. Pavlis (2008), An alternative procedure for the estimation of the altimeter bias for the Jason-1 satellite using the dedicated calibration site at Gavdos, SPIE Europe Remote Sensing 2008, University of Wales Institute, Cardiff, Wales, UK, 15 - 18 September 2008.

Middleton, E. M., Y.-B. Cheng, L. A. Corp, K. F. Huemmrich, P.K.E, Campbell, Q.-Y., Zhang, W. P Kustas, and A. L. Russ (2009), Diurnal and Seasonal Dynamics of Canopy-Level Solar Induced Chlorophyll Fluorescence and Spectral Reflectance Indices in a Corn Field, Proceedings, 6th EARSeL conference, Tel-Aviv, Israel, 16-19 March.

Olson, W. S. and M. Grecu (2009), Estimation of precipitation vertical profiles from combined radar/radiometer data using ensemble filters, presented at the 4th International Workshop on Precipitation Retrieval Algorithms Using Satellite Microwave Radiometer, Radar and IR Data, Tokyo, Japan, 16-18 February.

Olson, W., M. Grecu, C.-L. Shie, T. L'Ecuyer, G. Huffman, D. Waliser, X. Jiang, J.-L. Li, B. Tian, A. Tompkins, and W.-K. Tao (2008), Applications of remotely-sensed latent heating distributions derived from satellite microwave radiometer data, presented at the *American Geophysical Union Joint Assembly*, Fort Lauderdale, FL, 27-30 May.

Pavlis, E. C., I., Ciufolini, A. Paolozzi, G. Sindoni, and C.Vendittozzi, (2008), Error Analysis for the LARES Experiment II: Atmospheric Delay Modeling Errors in SLR and Inclination Errors, *The Nature of Gravity: Confronting Theory and Experiment in Space*, Int. Space Science Institute, Bern, Switzerland, 6–10 October, 2008.

Pavlis, E. C., I., Ciufolini, A. Paolozzi, G. Sindoni, and C.Vendittozzi, (2008), Error Analysis for the LARES Experiment III: The accuracy of GRACE-based modelsThe accuracy of GRACE-based models, *The Nature of Gravity: Confronting Theory and Experiment in Space*, Int. Space Science Institute, Bern, Switzerland, 6–10 October, 2008.

Pavlis, E. C., Magdalena Kuzmicz-Cieslak and P. M. Hinkey, (2008), Improved Modeling Approaches Towards the mm SLR, 16th Int. Laser Workshop, Poznan, Poland, Oct. 13-17, 2008.

Pavlis, E. C. and Magdalena Kuzmicz-Cieslak (2008), SLR and the Next Generation Global Geodetic Networks, 16th Int. Laser Workshop, Poznan, Poland, Oct. 13-17, 2008.

Pavlis, E. C. and Magdalena Kuzmicz-Cieslak (2008),"Geocenter Motion: Causes and Modeling Approaches, (INVITED), 16th Int. Laser Workshop, Poznan, Poland, Oct. 13-17, 2008.

Pavlis, E. C., (2008), Results from the Eastern Mediterranean Altimeter Calibration Network - *e*-MACnet, Ocean Surface Topography Mission Science Team meeting, Nice, France, Nov. 10-13, 2008.

Pavlis, E. C., (2008), Earth System Center to TRF Origin Weekly Series From SLR Analysis, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract G33B-0693.

Pavlis, E. C., Ries, J. C., MacMillan, D. S., Kuzmicz-Cieslak, M., Ma, C., Rowlands, D. D,

(2008), The Future Global Geodetic Networks to Support GGOS, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract G31C-03.

Pavlis, E. C., I. Ciufolini, G. Sindoni and P. M. Hinkey, (2008), GRACE Models in Support of SLR Analysis for LARES and the ITRF, GRACE Science Team Meeting, San Francisco, CA, Dec. 12-13, 2008.

Pavlis, E. C., K. Evans, B. Beckley, X. Frantzis, S. P. Mertikas, P. Milas, and D. Paradissis, (2009), OSTM/JASON-2 Cal/Val Results From The Eastern Mediterranean Altimeter Calibration Network – *e*MACnet, EGU2009-6608, Vienna, Austria, 19 – 24 April, 2009

Pavlis, E. C., M. Kuzmicz-Cieslak, J.-P. Boy, and P. M. Hinkey, (2009), Improved modeling approaches towards the mm SLR, EGU2009-6584, Vienna, Austria, 19 – 24 April, 2009.

Pavlis, E. C., V. Luceri, C. Sciarretta, and R. Kelm, (2009), The ILRS contribution to ITRF2008, EGU2009-6564, Vienna, Austria, 19 – 24 April, 2009.

Pavlis, E. C., (2009), SLRF2008: The ILRS Reference Frame for SLR POD Contributed to ITRF2008, OST Mission Science Team meeting, Seattle, WA, June 22-24, 2009.

Pavlis, E. C., K. Evans, et al., (2009), OSTM/JASON-2 Cal/Val Results From The Eastern Mediterranean Altimeter Calibration Network – *e*MAC*net,* OST Mission Science Team, Seattle, WA, June 22-24, 2009.

Pearlman, M., G. Kirchner, W. Gurtner, E. C. Pavlis, and Carey Noll, (2008), Satellite Laser Ranging and Its Impact on WEGENER, 2008 Assembly of WEGENER, Darmstadt, Germany, Sept. 15-18, 2008.

Pickering, K., R. Pinder, A. Prados, E. Celarier, and J. Gleason (2009), Use of OMI in Monitoring Air Quality Changes Resulting from NOx Emission Regulations over the United States, Atmospheric Composition Workshop, European Space Agency, Frascati, Italy, 15-17 June.

Prados, A. I., G. Leptoukh, and A. Gopalan (2008), Visualization, Exploration, and model comparison of NASA Air Quality Remote Sensing data via Giovanni, 7th Annual CMAS Conference, Chapel Hill, NC, 6-8 October.

Prados, A. I., G. Leptoukh, J. Johnson, and H. Rui (2009), Access And Analysis of

NASA Remote Sensing Data Via Giovanni, Air and Waste Management Association Annual Conference and Exhibition, Detroit, MI, 16-19 June.

Prados, A. I., G. Leptoukh, R. Kleidman, and D. Giles (2009), Tools for Access and Visualization of NASA Satellite Data Products for Air Quality Event Analysis, EPA 2009 National Air Quality Conference, Dallas, TX, 2-5 March.

Prados, A.I., G. Leptoukh, and J. Johnson (2008), Visualization and Exploration of NASA Air Quality Remote Sensing Data via Giovanni, AWMA Symposium on Air Quality Measurement Methods and Technology, Chapel Hill, NC, 3-6 November.

Spinei, E. C., S. Carn, N. Krotkov, K. Yang, A. Krueger, P.K. Bhartia, and G. H. Mount (2008), Validation of OMI satellite measurements of SO_2 by ground-based MFDOAS spectroscopy during the Okmok volcanic eruption in July 2008, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract A53B-0270.

Strow, L. and S. Hannon (2008), Inter-Calibration of the AIRS and IASI Operational Infrared Sensors, 2008 CALCON Technical Conference, Logan, UT, 25-28 August.

Strow, L., H. Motteler, and S. Hannon (2008), Pre-Launch Spectral Calibration of the CrIS Sensor on NPOESS/NPP, 2008 CALCON Technical Conference, Logan, UT, 25-28 August.

Strow, L., S. De Souza-Machado, S. Hannon, and B. Imbiriba (2008), Hyperspectral Radiance Time-Series from AIRS for Climate Observations, AGU, San Francisco, CA, 15-19 December.

Trahan, S. G., L. C. Sparling, J. Halverson and J. Bacmeister (2008), Scale Analysis of Spatial Variability in Observations of Tropical Cyclones, AMS 28TH Conference on Hurricanes and Tropical Meteorology, P2E.6, Orlando, FL, 28 Apr – 2 May.

Várnai, T., A. Marshak, and P. Chambon (2008), 3D radiative effects in MODIS observations, International Radiation Symposium 2008 (IRS2008), Foz Do Iguacu, Brazil, 3-8 August.

Várnai, T., A. Marshak, and R. F. Cahalan (2008), Overview of the 3D radiative codes (I3RC) project, International Radiation Symposium 2008 (IRS2008), Foz Do Iguacu, Brazil, 3-8 August.

Várnai, T., and A. Marshak (2009), Statistics of simulated 3-D solar radiative effects over three ARM sites, 2009 DOE ARM Science Team Meeting, Louisville, KY, 30

March -3 April.

Várnai, T., and J. Y. Harrington (2008), Developing a parameterization of 3-D radiative effects for CRMs, DOE ARM Radiative Processes Cloud Modeling Joint Working Group Meeting, Princeton, NJ, 17-19 November.

Várnai, T., and R. F. Cahalan (2009), Modeling and analysis of offbeam lidar returns from thick clouds, snow, and sea ice, paper #201770 at 2009 International Conference on Advances in Mathematics, Computational Methods, and Reactor Physics, American Nuclear Society, Inc., ISBN: 978-0-89448-069-0, Saratoga Springs, NY.

Venema, V. K. C., R. Lindau, T. Várnai, and C. Simmer (2009), A new algorithm combining geostatistics with the surrogate data approach to increase the accuracy of comparisons of point radiation measurements with cloud measurements, EGU General Assembly, Vienna, Austria, 19-24 April.

Vicente, G., et al. (2008), Near Real-time Satellite Detection of SO_2 and Volcanic Ash Cloud, SPIE Europe - Remote Sensing - Remote Sensing for Environmental Monitoring, GIS Applications, and Geology VII, Cardiff, United Kingdom, 15-18 September.

Vicente, G., G. Serafino, A. J. Krueger, S. A. Carn, K. Yang, N. A. Krotkov, W. Schroeder, J. Guo, M. Guffanti, and P. Levelt (2008), Volcanic ash, aerosol and SO_2 cloud monitoring via satellite (poster), EUMETSAT Meteorological Satellite Symposium, Darmstadt, Germany, 8-12 September.

Vicente, G., G. Serafino, A. J. Krueger, S. A. Carn, K. Yang, N. A. Krotkov, W. Schroeder, J. Guo, M. Guffanti, and P. Levelt (2009), The NOAA-NASA volcanic SO_2 cloud and aerosol index online, near-real-time distribution system (poster), 16SATMET/GOESRNPOESS – Natural Hazards session, 89th American Meteorological Society Annual Meeting, Phoenix, AZ, 11-15 January.

Vicente, G., G. Serafino, A. Krueger, W. Schroeder, S. Carn, K. Yang, N. Krotkov, M. Guffanti, and P. Levett (2009), The NOAA-NASA Operational System for Near-Real-Time Volcanic Eruption Detection via Satellite Observations. Volcanic Threats - Hazard Identification, Assessment and Risk Mitigation session, European Geosciences Union (EGU) General Assembly 2009, Vienna, Austria, 19-24 April.

Warner, J. (2009), Update of TES Validation using AIRS, TES science team meeting, Boulder, CO, 22-25 February.

Warner, J., (2009), Combining AIRS and TES CO Measurements, ARCTAS 2009 Data Workshop, Virginia Beach, VA, January 2009.

Warner, J., and G. Sachse (2008), Validation of AIRS CO operational products using the latest NASA Airborne Measurements, AIRS science team fall meeting, Greenbelt, MD, September.

Warner, J., Z. Wei, L. Sparling, G. Diskin, G. Sachse, M. Luo, S. Kondragunta, and J.-L. Attie (2008), CO Profile Comparisons for TES and AIRS Measurements in 2006, poster presentation, Aura Science Team Meeting, Columbia, MD, 27-30 October.

Weber, S. A., J. Engel-Cox, R. Hoff, A. I. Prados, H. Zhang and C. Kittaka (2008), Evaluation of 3-D Air Quality System Remotely-Sensed Aerosol Optical Depth for the Baltimore/Washington Metropolitan Air Shed, 2008 AGU Fall Meeting, San Francisco, CA, 15-19 December.

Weldegaber, M., B. B. Demoz, L. C. Sparling, R. Delgado, R. M. Hoff, K. McCann, and M. Woodman (2009), A Modeling Study of Low-Level Jets over the Mid-Atlantic Region, 4th Symposium on Lidar Applications, 89th American Meteorological Society Meeting, Phoenix, AZ, January 2009.

Weldegaber, M. H. (2009), Investigation of stable and unstable boundary layer phenomena using observations and a numerical weather prediction model, PhD Thesis, University of Maryland Baltimore County, Baltimore, MD.

Wilson, R. C., W. McMillan, and L. Yurganov (2009), Remote Sensing of Trace Gases during Boundary Layer Turbulence, International Symposium Of Former USSR Countries On Atmospheric Radiation And Dynamics (ISARD-2009), "Current Problems in Atmospheric Radiation", Saint Petersburg, Russia, 22–27 June.

Wilson, R.C., M. Weldegaber, R. Delgado, R. M. Hoff, and W. W. McMillan (2008), Remote Sensing of Boundary layer Trace Gases in the Presence of Dynamic Boundary Layer Events, American Geophysical Union 2008 Fall Meeting, San Francisco, CA, 15-19 December.

Yang, K., N. A. Krotkov, A. J. Krueger, S. A. Carn, and P. K. Bhartia (2008), OMI measurements of sulfur dioxide abundances and altitudes of the volcanic plumes from eruptions of Okmok and Kasatochi in 2008, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract A53B-0269.

Yang, K., N. Krotkov, S. Carn, P. K. Bhartia, and A. Krueger (2008), OMI O3 and SO2 Combo Algorithm, Aura Science Team meeting, Columbia, MD, 27-30 October.

Yang, Y., A. Marshak, T. Várnai, and W. J. Wiscombe (2009), Properties of thin clouds observed by ICESat and CALIPSO over ice sheets and their impact on ice altimetry measurements, Fourth Symposium on Lidar Atmospheric Applications, American Meteorological Society, Phoenix, AZ, 11-15 January.

Yuan, T. and Z. Li (2009), Aerosols changing micro- and macro- physical properties of deep convective clouds, poster presented at the ARM annual science meeting, Norfolk, VA, 10-14 March.

Yuan, T., L. Remer, Z. Li, and J. V. Martins (2008), Aerosol affect deep convective cloud properties as observed by A-Train, poster presented at the AGU Fall meeting, San Francisco, CA, 15-19 December.

Yurganov, L., W. McMillan, E. Grechko, and A. Dzhola (2009), Anomalies of CO Global and Regional Burdens Measured by Satellites: Update to Present Time, *Eos Trans. AGU, 90*(22), Joint Assembly Suppl., Abstract B73B-09, Toronto, Canada, 24-27 May.

Yurganov, L., C. Wilson, and W. McMillan (2008), Monitoring Global Biomass Burning CO emissions: MOPITT, AIRS, and Ground-based Spectrometers, *Eos Trans. AGU, 89*(53), Fall Meet. Suppl., Abstract B31C-0301, San Francisco, CA, 15-19 December.

Yurganov, L., W. McMillan, C. Wilson, M. Fischer, S. Biraud, and P. C. Novelli (2009), Retrieval of CO Mixing Ratios From the Atmospheric Emission Spectra of Down-Welling Middle IR Radiance in Oklahoma, *Eos Trans. AGU, 90*(22), Joint Assembly Suppl., Abstract A11C-06, Toronto, Canada, 24-27 May.

Yurganov, L., W. McMillan, E. Grechko, and A. Dzhola (2008), CO Pollution Measured from Satellites and from the Ground: Focus on Beijing and Tai Shan, International Conference on Atmospheric Physics, Climate, and Health, p. 115, Kislovodsk, Russia, 6-10 October.

Yurganov, L., W. McMillan, E. Grechko, and A. Dzhola (2008), CO pollution measured from satellites and from the ground: focus on Beijing and Tai Shan, International Conference on Atmospheric Physics, Kislovodsk, Russia, 23-29 September.

Yurganov, L., W. McMillan, E. Grechko, and A. Dzhola (2009), Anomalies of CO Global and Regional Burdens Measured by Satellites: Update to Present Time, *Eos Trans. AGU, 90*(22), Jt. Assem. Suppl., Abstract B73B-09.

Yurganov, L., W. McMillan, E. Grechko, and A. Dzhola (2009), Carbon monoxide and

methane in the troposphere: satellite data and validation, International Symposium Of Former USSR Countries On Atmospheric Radiation And Dynamics (ISARD-2009), "Current Problems in Atmospheric Radiation", Saint Petersburg, Russia, 22–27 June.

Zell, E. R., E. Cherrington, V. Duke, L. A. Friedl, O. Gonzales, R. Hoff, and D. E. Irwin (2008), An Integrated Approach to Measuring Air Quality in Central America, AWMA Symposium on Air Quality Measurement Methods and Technology, Raleigh-Durham, NC. DATES?

Zhang, H., R. Hoff, K. McCann, P. Ciren, S. Kondragunta, and A. Prados (2008), Influence of the ozone and water vapor on the GOES Aerosol and Smoke Product (GASP) retrieval, NOAA Technical Report NESDIS 128, July 2008.

III.5 Courses Taught

FYS 103D: *First Year Seminar on "Global Warming"* — The science of global warming involves a broad understanding of several scientific disciplines (physics, chemistry, math/statistics, biology). The general public has a very poor conception of how scientific consensus is developed on complicated socially linked issues. In this course, students reviewed the scientific literature behind this important issue and examined the processes by which scientists try to reach consensus on difficult issues. Students in this course were challenged to represent and refute the scientific arguments leading to our current understanding of the state-of-the-science and, subsequently, examined the process by which such scientific information can be used to affect the making of public policy. This includes the development of our current climate over eons (paleoclimate), the variability in modern climate (the last 1000 years), the concept of climate versus weather (the last 100 years), the evolution of our current atmospheric state due to emission of greenhouse gases and aerosols (last 50 years) and the predictions for the next 10, 50 and 100 years. (Taught by Raymond Hoff, Spring 2009)

GES 110: *Physical Geography* — This course presented a study of the principles and processes of climate, earth materials, landforms, soils and vegetation that give logic to their integrated patterns of world distribution. (Taught by Jeffrey Halverson, Spring 2009)

GES 311: *Weather and Climate* — This course offered an introduction to the physical processes that control weather and climate. Topics covered included the mechanics of atmospheric behavior, weather systems, the global distribution of climates and their causes, as well as various topics related to climatology. (Taught by Amita Mehta, Fall 2008)

GES 400A: *Arctic Geography* — This course was designed to acquaint students with the physical, biological, and cultural characteristics of high latitude regions. The class examined past, present and potential future climate conditions; climate interactions with the physical environment such as snow cover, permafrost, and sea ice; effects of climate on terrestrial and marine ecosystems; and how humans interact with this environment. (Taught by K. F. Huemmrich, Spring 2009)

GES 415: *Climate Change* — This course dealt with the question of climate change and variability. Topics covered included changes in climate in different time scales (geologic, historic and the present), environmental evidence of climate change, factors controlling climate variations, and the use of computer models in

reconstructing past climates and predicting climate changes. (Taught by Jeffrey Halverson, Spring 2009)

GES 601: *Introduction to Geography and Environmental Systems* — This course is a graduate-level introduction to the principles underlying geographic and environmental systems. Guiding theories of human geography, physical geography and environmental science were introduced through detailed examination of cross-cutting multidisciplinary issues including natural hazards and human vulnerability, the management of water resources and fossil fuels, and global environmental changes such as the recent atmospheric-oceanic warming trend and land-use/land-cover change. Within these topics, specific theories guiding geographic and environmental research were covered in depth, including spatial analysis, critical geographic theory, postmodern social theories and political ecology. Important theories governing the functioning of environmental systems were presented, including the cycling of mass and energy between Earth's various spheres and the theory of Earth as a dynamic system seeking equilibrium in the face of multiple perturbations both natural and anthropogenic. (Taught by Jeffrey Halverson, Fall 2008)

HCST 100: *Human context of Science and Technology* — The Science and Politics behind Global Warming (2 lectures). This team-taught course focuses on various aspects of the interface between science and culture. (Taught by Lynn Sparling, Spring 2008, Fall 2008)

MEES 899: *Ph.D. Research* — Doctoral dissertation research under the direction of a UMBC MEES faculty member. (Taught by Raymond Hoff, Spring 2009)

PHYS 224: *Introductory Physics III* — Oscillations and waves: This course emphasizes vibrations, wave motion and optics. Topics included mathematical characterization of vibrations and waves, sound, superposition of standing waves, geometrical and physical optics, diffraction, interference and polarization of light. (Taught by J. V. Martins, Fall 2008 and Spring 2009)

PHYS 340L: *Electronics for Scientists* — This is a basic lecture and laboratory course in electronics: properties of semiconductor devices and their combinations in amplifiers, oscillators, timers, switching circuits, digital circuits, and electronic instruments in common use in the scientific laboratory. (Taught by W. W. McMillan, Spring 2009)

PHYS 425: *Relativistic Physics* — This course covered the following topics: general relativity from a modern viewpoint, the Schwarzschild solution, other solutions of the Einstein field equation, the role of general relativity in astrophysics and an introduction to the unified field theories. (Taught by Prasun Kundu, Spring

2009)

PHYS 450: *Special topics in physics* — Undergraduate research in wind energy. (Taught by Lynn Sparling, Spring 2008)

PHYS 440/660: *Computational Physics* — This course gives an introduction to a wide variety of computational methods outlining both the theory and practice. More modern methods were also included such as machine learning and artificial intelligence. (Taught by David Lary, Spring 2009)

PHYS 602: *Atmospheric Physics II* — The following topics were covered: Fundamentals of drop size distribution and measurement techniques of individual raindrops and snowflakes, and bulk rainfall at the ground. (Guest Lecturer Ali Tokay, Spring 2009)

PHYS 621: *Atmospheric Physics I* — Composition and structure of the Earth's atmosphere, atmospheric thermodynamics, development of the fundamental equations of motion for a rotating, stratified fluid, balanced flow, waves, vorticity, overview of planetary boundary layer, the global circulation, and other selected topics. Dr. Johnson's portion covered thermodynamics of the atmosphere and had 3 objectives: (a) Identify the basic driving factors influencing both atmospheric thermodynamics and dynamics (e.g., seasons, insolation, etc.); (b) Convey the relevant thermodynamic concepts (pressure, temperature, humidity, buoyancy, stability, etc.); (c) Show how these concepts are interrelated and influence the atmosphere at both large and small scales. (Co-Taught by Ben Johnson with Lynn Sparling, Fall 2008/Spring 2009)

PHYS 622: *Atmospheric Physics II* — This course on physical meteorology covers the basics of atmospheric aerosols and clouds, and an introduction to atmospheric radiative transfer. The course discussed the typical properties of aerosols and clouds, as well as some of the most important physical processes associated with them, for example precipitation formation. The lectures also covered the impact of aerosols, clouds, and radiation on climate and weather. (Co-Taught by W. W. McMillan and T. Varnai, Spring 2009)

PHYS 650: *Experimental Atmospheric Physics* — This course covers the design, simulation, and execution of experiments in atmospheric physics and earth sciences using teaching and research instrumentation. The students were exposed to the processes of development, construction, calibration, and application of instrumentation for the measurement of relevant parameters of the atmosphere. Students also used state of the art instrumentation from the atmospheric research laboratories connected to the department. (Taught by J. V. Martins, Spring 2009)

PHYS 698: *Physics Seminar* — Graduate student attends and discusses a weekly research seminar. (Taught by Lynn Sparling, Spring 2009)

III.6 Colloquia and Seminars

Bulmer, M.H., A tour of the Solar System, Moor Park School, 14 May (invited talk).

Bulmer, M., Special Interest News and Seminars, UMBC College of Engineering and Information Technology, http://www.umbc.edu/engineering/newsletter/May09newsletter.htm

Campbell, P., Organizer of CEOS 29th Plenary Meeting, Avignon, France, August 2008.

Campbell, P., Hyperspectral Infrared Imager (HyspIRI) Science Workshop, Monrovia, CA, 21-23 October.

Campbell, P., The Joint Workshop on NASA Terrestrial Ecology, Biodiversity and Related Applied Sciences, College Park, MD, May 2009.

Campbell, P., 4th Global Vegetation Workshop, Missoula, MT, 15-19 June.

Chiu, J. C., Cloud and Aerosol Properties Inferred from Zenith Radiance Measurements, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, 15 January.

Chiu, J. C., Learning about cloud optical properties from ground-based zenith radiance measurements, seminar given at the Atmospheric Sciences Division, Brookhaven National Laboratory, Upton NY, 28 May.

Dolgos, G., Lives and Discoveries of Lord Rayleigh and Gustav Mie, Light Scattering by Small Particles, Mulligan lecture, Department of Physics, UMBC, Baltimore, MD, 6 May.

Hall, F., Howard County Legacy Leadership Institute: The Global Carbon Cycle, GSFC Visitor Center, Greenbelt, MD, 3 February.

Hall, F., Science and Religion: A Post-Modern View, Montgomery Scholars, Montgomery College Colloquia, 5 March.

Hall, F., Science and Religion: A Post-Modern View, Rotary Club, Columbia, MD, 11 March.

Hall, F., Humans and Climate: Is Our Climate Changing? What is the Cause?, Johns Hopkins MLA program, Baltimore, MD, 9 April (invited talk).

Hall, F., Humans and Climate: Is Our Climate Changing? What is the Cause?, Howard County Legacy Leadership Institute, 17 June (invited talk).

Hall, F., The Carbon Cycle and Remote Sensing, JCET Summer Fellows Colloquia, 2 July.

Hall, F., Panel speaker on Government, University and Industry cooperation in the Earth Sciences, Canadian Remote Sensing Society, 22-26 June (invited).

Hall, F., NASA Field Campaigns, A Review, Terrestrial Ecosystems Scoping Study, Fairbanks, Alaska, 10-14 August.

Johnson, B.T., Life of a Snowflake -- Measuring Snowfall from Space, University of Maryland Baltimore County, Department of Physics, Baltimore, MD, 11 March (invited).

Johnson, B.T., and G. Skofronick-Jackson, Recent research on developing a snowfall retrieval framework using WRF simulations, NASA Goddard Space Flight Center, Code 613 Branch Meeting, Greenbelt, MD, 5 March.

Martins, J.V., The UMBC-NASA Cloud-CubeSat Satellite proposal, CubeSat Workshop, UMBC Physics Department, Baltimore, MD, 26 March.

Martins, J.V., Aerosol Absorption from In situ and remote sensing measurements, IDS workshop, UMBC Physics Department, Baltimore, MD, 19 March.

Martins, J.V., Development of Wide FOV Imaging Polarimeters for Earth Sciences Applications, Polarization Technology and Resources for Earth Science Mission, NASA GSFC, Greenbelt, MD, 15 September.

McMillan, W. W., AIRS CO, CH4 Update: v5, v6, Global Trends, AIRS v IASI, NASA Sounder Science Team Meeting, Pasadena, CA, 5 May (invited).

McMillan, W. W., Tropospheric Carbon Monoxide Retrievals from the Atmospheric Infrared Sounder and Correlations with Other Trace Gases: What are people doing?, Department of Earth and Planetary Sciences Atmospheric Chemistry Group, Harvard University, Cambridge, MA, 7 November (invited).

McMillan, W. W., A-Train Trace Gas Correlations: What are people doing?, Aura Science Team Meeting, Columbia, MD, October 2008 (contributed talk).

McMillan, W. W., v5.0.14.0 CO Validation Update, NASA AIRS Science Team Meeting, Greenbelt, MD, 14 October (invited talk).

McMillan, W. W., A-Train Trace Gas Correlations: What are people doing?, NASA AIRS Science Team Meeting, Greenbelt, MD, 14 October (invited talk).

Sedlak, J., and J. V. Martins, How to Plan a Spacecraft-Based Science Experiment: Cloud CubeSat, UMBC Physics Department, Baltimore, MD, 1 April.

Tangborn, A., Wavelets in timeseries analysis, Lectures in METEO 630 class, Department of Meteorology, University of Maryland, College Park, 7 May.

III.7 Proposals Submitted by JCET Members

(primary sort alphabetical by funding agency, then proposal title)

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
20% Wind by 2030: Overcoming the Challenges	DOE		Sparling	Awarded
Aerosol processing by deep convection and the radiative effect of its anvil cirrus and outflow	DOE		Koren, Várnai	Not Awarded
Airborne Open Polar/Imaging Nephelometer for Ice Particles in Cirrus Clouds and Aerosols	DOE	Martins		Pending
Integration and Analysis of Global Diabatic Heating Products Derived from Satellite Observations	DOE	Olson	Grecu	Pending
Vilcanota Valley Slope Monitoring of Flash Floods and Other Natural Hazards	ESA Earth Observation Missions Program	Bulmer		Awarded
AIRS Climate and Calibration Algorithms	JPL	Strow		Awarded
Optimization, Validation, and Integrated EOS Analysis of AIRS Trace Gas Products	JPL – AIRS	McMillan		Awarded
Mesoscale model analysis of windpower intermittency for a geographically distributed wind facility	Maryland DNR	Sparling		Awarded
Statistical Analysis of Low Level Winds in Western Maryland from a Numerical Weather Prediction Model	Maryland DNR	Sparling		Awarded
A Multi-Resolution Study of High-Latitude Ecosystem Changes	NASA		Huemmrich	Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Aerosol Optical-Physical-Chemical Models from Remote Sensing and Spectral Absorption In Situ Measurements	NASA		Martins	Pending
Carbon monoxide and methane measurements from satellites: validation, comparisons, and recent trends	NASA	Yurganov	McMillan	Pending
Combining field observations, satellite data, and model predictions to predict distributions of keystone species and related organisms from local to continental scales	NASA		Huemmrich	Not Awarded
Constraining long range transport of CO by assimilating AIRS and IASI CO observations	NASA	Tangborn	McMillan	Not Awarded
Detailed aerosol characterization and estimates of direct forcing from combination of Glory-APS, MODIS, CALIPSO and ground-based observations	NASA		Martins	Pending
Estimating uncertainties in tropospheric composition and transport from assimilation Carbon monoxide data	NASA	Tangborn	L. Ott, W. McMillan, I. Stajner	Pending
Historical Rendition of Mediterranean Water Cycle based on Earth Satellite Measurements	NASA		Mehta	Awarded
In situ Measurement of Meteorological State Variables using Dropsonde on the NASA DC-8 and Global Hawk During NASA-GRIP	NASA	Halverson		Awarded
Interactions between tropical biomass burning, clouds, precipitation and land use changes	NASA		Martins	Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
on a regional scale				
Investigation of aerosol effects on clouds using CALIOP-MODIS joint retrieval over ocean	NASA		Martins	Pending
Investigation of global biomass burning emissions using CO as a proxy; validation and reconciliation of MOPITT AIRS, TES, and IASI CO data using remote sensing spectrometers	NASA	Yurganov	McMillan	Not Awarded
Laboratory/In situ measurements of phase function and hygroscopic properties of aerosol particles	NASA	Martins		Not Awarded
Microphysical and Radiative Properties of Midlatitude Cirrus: Modeling and Observation	NASA		Varnai	Pending
NASA Satellite Training Activities	NASA		Prados	Awarded
Optimizing Major Sources and Sinks of Tropospheric Anthropogenic Aerosols in an Aerosol-Climate Model	NASA		Martins	Pending
Pilot Spectral Library	NASA		Huemmrich	Not Awarded
The Baltimore-Washington AERI Experiment (B-WAX): Ground-based measurements of ozone and carbon monoxide tropospheric columns in the Baltimore-Washington corridor for satellite validation and air quality studies	NASA	McMillan	Yurganov	Not Awarded
Validation of satellite based tropospheric T, Q, O3 and CO measurements using AERI, ozonesonde, airborne measurements and chemical/meteorological analyses	NASA	Knuteson, McMillan	Yurganov	Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Optimization of NASA's Next Generation Global Geodetic Networks	NASA-HEC	Pavlis		Awarded
Investigating Relationships Between Eyewall Replacement, Intensification, and Precipitation Production in Atlantic Hurricanes Using Satellite/Aircraft Observations and GFS Model Analyses	NASA – Hurricane Research Program		Mehta	Awarded
Solar Excited Chlorophyll Fluorescence System for the Assessment of Vegetation Photosynthetic Function	NASA GSFC IRAD 2009	Middleton	Campbell	Pending
Assessing ecosystem sustainability and urban boundaries using surface reflectance and emissivity at varying spectral and spatial scales	NASA ROSES	Campbell		Awarded
Assessment/Cross-comparison of Global Land Cover Products, Generated by Multiple Satellite Sensors	NASA ROSES	Campbell		Pending
Combining MODIS and OMI Observations to improve the Analysis of Surface Particulate Air Quality	NASA ROSES	Prados		Not Awarded
Data Synergy	NASA ROSES		Prados	Awarded
Improved ground validation rain estimates at Kwajalein, RMI and Melbourne, Florida for comparison and validation to TRMM and Other Satellite Estimates	NASA ROSES		Tokay	Awarded
Interferometric Sensor for Plant Fluorescence	NASA ROSES	Georgieva	Campbell	Not Awarded
LARES: LAser Relativity and Earth	NASA ROSES	Pavlis		Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Science Satellite Mission				
Measurements of the hydrometeors size distribution through surface based instruments.	NASA ROSES	Tokay		Awarded
MIDAS: Middleware based Distributed Assimilation of Science data	NASA ROSES		Prados	Not Awarded
Millimeter Laser Ranging to the Moon	NASA ROSES		Pavlis	Pending
NASA Earth Science Research Results for Improved Hypoxia Modeling to Support Nutrient Control Decisions in the Gulf of Mexico	NASA ROSES		Prados	Not Awarded
Quantitative Error Characterizations of TRMM and GPM Rainfall Products for Climate Studies and Validation	NASA ROSES	T. L. Bell	Kundu	Awarded
Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency II: Synthesis and Integration	NASA ROSES	Middleton	Campbell, Huemmrich	Pending
Use of NASA Earth Science Products to Aid in Air Quality Management and Planning Analyses – Natural Events Rule, PM10 NAAQS Attainment, and Regional Haze Rule Periodic Assessments	NASA ROSES		Prados	Not Awarded
Mid-Atlantic Tall Tower Wind Resource Data Collection Coalition	Natl Renewable Energy Laboratory NREL/DOE		Sparling	Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
An Air Quality Proving Ground	NOAA	Hoff		Awarded
Climate and Satellite Research and Applications	NOAA		Huemmrich	Not Awarded
Fast Radiative Transfer Modules for IASI and CrIS	NOAA	Strow		Awarded
IDEA product improvements	NOAA	Zhang		Awarded
Collaborative Research: Attacking the roots of ill posedness in the estimation of surface fluxes of carbon and moisture	NSF	Tangborn		Pending
CSEDI Collaborative Research: Variational Approaches to Geomagnetic Data Assimilation	NSF	Tangborn	Kuang	Awarded
CubeSat-Cloud: A Pico Satellite for the profiling of cloud microphysics and thermodynamic properties	NSF	Martins		Pending
Investigation of free tropospheric pollutants entering US from Asia using a ground-based spectrometer at the Mt. Bachelor Observatory, satellite data, and model calculations	NSF	Yurganov	McMillan	Not Awarded
MRI: Acquisition of an Interdisciplinary Facility for High-Performance Computing	NSF		Sparling	Awarded
MRI-R^2: Acquisition of Atmospheric Profiling Instrumentation for Studies of the Mid-Atlantic Boundary Layer	NSF	McMillan	Sparling	Pending
The Northern Specnet Tundra Array (NorthSTAR): Automated Stations for Measuring Vegetation Biophysical Characteristics and Dynamics	NSF	Huemmrich		Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Investigations of Tropical Cyclone inner core dynamics and its impact on storm intensity	UMBC-SFF (Summer Faculty Fellowship)	Sparling		Awarded
Vilcanota Valley Slope Monitoring for Flash Flood Prevention	World Bank	Bulmer		Awarded

III.8 Biographies

Dr. William Barnes is a senior research scientist with the Joint Center for Earth Systems Technology, University of Maryland, Baltimore County and an emeritus research scientist with the Sciences Exploration Directorate of NASA's Goddard Space Flight Center. He served as the MODIS Sensor Scientist and as a member of the MODIS Science Team for more than 12 years. He led the MODIS Characterization Support Team (MCST) for more than two years and was NASA's representative on the National Polar Orbiting Environmental Satellite System's Joint Agency Requirements Group (NPOESS/JARG) for more than five years. He has over thirty years experience in the development and radiometric calibration of Earth-observing imaging radiometers including TIROS/AVHRR, AEM-1/HCMR, NOSS/CZCS-2, OrbView-1/SeaWiFS, TRMM/VIRS, EOS/MODIS and NPP/VIIRS.

Dr. Mark Bulmer is a Research Associate Professor in the Joint Center for Earth Systems Technology affiliated with the UMBC Department of Geography and Environmental Sciences. He is an Adjunct Associate Professor of Geology at University of Buffalo, SUNY, a Visiting Scientist at the Smithsonian Institute, and an Associate Fellow at the Royal United Services Institute. He has 14 years of experience in earth and planetary research. His research interests are in the area of mass movement dynamics, both on Earth and the terrestrial planets, combining field measurements with remotely sensed data. He has led or participated in over 22 major field tests and campaigns. He is the author of journal articles, technical reports, conference proceedings papers, and educational videos for middle-school students, and has given numerous public presentations of his work. Dr. Bulmer obtained a Bachelor of Science degree in Geography at University of London, King's College in 1990 and a Ph.D. in Astronomy & Physics (Planetary Volcanology) at University College London in 1994. He has conducted research at the NASA Jet Propulsion Laboratory and Goddard Space Flight Center, and the Smithsonian National Air and Space Museum. He serves on the American Geophysical Union Tellers Committee and the Landslide Working Group of the Committee for Earth Observing Satellites. He has received grants from NASA, ESA, CSA, ISA, NSF, National Geographic, Royal Geographical Society, Smithsonian Institution and Radarsat International. He has peer review roles at NASA and NSF and has held memberships in four scientific societies.

Dr. Petya K. Entcheva Campbell received a BS in Forestry from the Academy of Forest Engineering, Sofia, Bulgaria in 1988, MS in Forest Sylviculture and Ecology from the University of Massachusetts at Amherst, MA and a Ph.D. in Forest Analysis/Remote Sensing in 2000 from the University of New Hampshire, Durham, NH, where her research focus was on the development of remote sensing techniques for forest health assessment. In 2000, Dr. Campbell joined NASA as NRC Associate and worked at Goddard Space Research Center for two years before joining JCET/UMBC where she is currently employed. Her experience and expertise are in remote sensing for natural resources (PhD), with a specific interest in remote sensing, especially spectral analyses and assessments for the development of methods (algorithms, measurement techniques) for vegetation stress assessments and land cover change

detection. She started work in this direction as a post-doctoral research associate of Dr. Middleton at NASA/GSFC, and later continued as a Prime Investigator on a small grant for Exploratory Research (funded by the National Science Foundation). At GSFC she participates in NASA's "Light Use Efficiency and Carbon Science" research led by Dr. Middleton and has participated in the development of the satellite hyperspectral mission's Flora/SpectraSat for vegetation assessment led by Drs. Ungar and Asner. Currently, she is part of a research effort to develop spectral bio-indicators of vegetation stress, to facilitate the remote-sensing assessment of vegetation photosynthesis and carbon sequestration. She is also participating in an EO-1 Hyperion data intercalibration and analysis effort, with the goal to compare existing and suggest new land cover products, addressing vegetation type and function. At the University of Maryland, Baltimore County (UMBC), Dr. Campbell has taught the Remote Sensing of Environment undergraduate/graduate classes within the Department of Geography. As the current Technical Secretariat of the Working Group on Calibration and Validation of the Committee on Earth Observation Satellites (CEOS/WGCV), under the chairmanship of Dr. C. Cao (NOAA), she follows with interest the plans for new satellite capabilities of various agencies and would like to contribute to the efforts on data calibration, product development, validation and inter-comparison.

Dr. J.-Y. Christine Chiu received her Bachelor of Science in Atmospheric Science from National Central University of Taiwan in 1992. Following the acquisition of a Master of Science degree in Atmospheric Physics from National Central University in 1994, she worked at the Environmental Protection Agency of Taiwan for three years. In 1998, she commenced her doctorate at Purdue University, and received her Ph.D. in Earth and Atmospheric Sciences in 2003. She has worked in the area of microphysics schemes in both mesoscale and microwave radiative transfer modeling, and microwave retrieval algorithm development, validation, and applications, with an emphasis on the retrieval of instantaneous rain intensity, water vapor, and surface wind speed over the ocean. In 2003, she joined JCET as a Research Associate. Her research currently focuses on the spatial correlation of cloud droplets, the shortwave radiative interactions between the surface and clouds, and their impact on climate modeling and remote sensing applications.

Mr. Ruben Delgado received a B.S. and M.S. in Chemistry from the University of Puerto Rico in 1995 and 2004, respectively. He expects to receive his Ph.D. in 2008, also from the University of Puerto Rico, for his dissertation work entitled "Observations and Modeling of Sporadic Metal Layers over the Arecibo Observatory". Since November 2006, he has been a Research Associate at JCET. Currently, he is working with the Atmospheric Physics Group at UMBC, under the supervision of Dr. Raymond M. Hoff, in research involving active atmospheric measurements of atmospheric aerosols and gases with LIDAR. He has published four refereed journal articles about LIDAR measurements and chemical models of the mesospheric potassium layer. During his career, he has also carried out computational and experimental research involving laser photolysis of gas phase polyatomic species followed by probing of the nascent radicals and ions with Laser Induced Fluorescence and Time-of Flight Mass Spectroscopy.

Dr. Sergio DeSouza-Machado obtained a B.A. in Math/Physics from the College of Wooster, OH in 1988. He then attended graduate school at the University of Maryland at College Park, where he obtained his M.S. in 1990 and Ph.D. in Plasma Physics in 1996. After this, he joined the Atmospheric Spectroscopy Laboratory at the University of Maryland, Baltimore County in September 1996. He has developed kCARTA, a package that rapidly computes monochromatic absorption spectra, radiances and jacobians, and does scattering and NonLTE computations. In addition, he has developed a line-by-line code that includes CO_2 P/R linemixing and water continuum corrections. His current research work is on retrievals of dust heights and optical depths, and trace gas retrievals.

Dr. Forrest Hall has been active in the field of remote sensing since 1972 and has been at NASA's GSFC since 1985. He is Senior Research Scientist at JCET UMBC. Dr. Hall has an undergraduate degree in Mechanical Engineering from the University of Texas, and M.S. and Ph.D. degrees in Physics from the University of Houston.

Dr. Jeffrey B. Halverson has traveled the world's tropical latitudes to better understand how intense storms of rain and wind develop and intensify. He has conducted research in Brazil, Australia, the South China Sea, Costa Rica, the Marshall Islands, West Africa and various locations in the Caribbean studying tropical weather systems. Dr. Halverson's research examines the atmospheric factors that cause hurricanes to rapidly change intensity. In 2001, he helped pioneer a new aircraft-based, upper atmospheric measuring system to take direct measurements in the eye of a mature hurricane from an altitude of 70,000 feet. Dr. Jeffrey Halverson is currently an Associate Professor of Geography at the University of Maryland Baltimore County (UMBC). He also serves as Associate Director-Academics at the Joint Center for Earth Systems Technology (JCET), a cooperative institute between NASA and UMBC. He also served as Deputy Project Manager at NASA Headquarters, where he managed NASA field programs to investigate hurricanes in 2005 and 2006. Dr. Halverson has authored more than 28 professional papers and writes a monthly column on severe and unusual weather for *Weatherwise Magazine*. He is currently examining the extratropical transition of hurricanes making landfall over the Mid Atlantic.

Dr. Richard Hartle received a B.S. from the University of Michigan in 1959, and a Ph.D. in Physics in 1964 from Pennsylvania State University, where his major research interest was theoretical plasma physics. In 1964, he joined NASA, and worked at the Ames Research Center for three years before transferring to GSFC, where he is still employed. During his career, he has carried out theoretical and experimental research on the solar wind, planetary atmospheres and ionospheres, plasma physics, and gas dynamics using measurements made from the instruments on satellites such as the Atmosphere Explorers, Dynamics Explorer, Mariner 10, Voyager, Pioneer Venus, Galileo and Cassini. He has published over 100 refereed papers; the most recent concentrate on various gas escape mechanisms and how they affect the evolution of planetary atmospheres, and especially the evolution of water (oceans) on Venus and Mars. He is also active in plasma studies of Saturn's moons, especially Titan, using measurements made from the Cassini orbiter. At GSFC, he has been the head of the

Planetary Atmospheres Branch (1975 – 1985, 1991 – 1995), project scientist for the Earth Observing System (1983 – 1987), and assistant chief of the Laboratory for Atmospheres (1985 – 1991).

Mr. Ernest Hilsenrath received his BS in Physics at the George Washington University in 1961 and did graduate work at the American University until 1963. He began his career at the National Bureau of Standards (now the National Institutes of Standards and Technology) in 1958 and joined NASA in 1962 at the Goddard Space Flight Center. After retiring from NASA in August 2005, he was appointed to UMBC JCET (also in August 2005). During his career at NASA, he developed and conducted several instruments to measure ozone on aircraft, balloons and sounding rockets. He developed and managed a calibration facility at GSFC which was used as a reference standard for calibrating US and international BUV type instruments, including TOMS, SBUV/2, SCIAMACHY, OMI, and GOME-2. He was the Principal Investigator for the Shuttle-borne SBUV (SSBUV), which flew eight times to provide in-orbit calibration for the NOAA SBUV/2 instruments, and he was Principal Investigator for several analysis tasks for validation ozone data from TOMS, POESS and Envisat. He was also the Co-Principal Investigator for the first instrument to measure stratospheric limb scattering from the Shuttle using a CCD detector, which imaged the Earth's limb on the detector. This technique was selected for the NPOESS ozone profile monitoring instrument. He has published over 50 papers in refereed literature dealing with instrument calibration and performance and ozone climatology. He has chaired and served on several US and international panels for establishing ozone monitoring requirements and establishing CAL/VAL requirements for future stratospheric monitoring instruments. NASA has awarded Mr. Hilsenrath six Group Achievement Awards and seven individual awards, including the NASA Exceptional Medal.

Dr. R. M. Hoff is a Professor of Physics at the University of Maryland, Baltimore County. He is also Director of the Joint Center for Earth Systems Technology. Dr. Hoff has 33 years of experience in atmospheric research. His research interests are in the optical properties of aerosols and gases in the atmosphere. Dr. Hoff has been central in formulating major research programs on Differential Absorption, airborne and spaceborne lidar, volcanic emissions, atmospheric transport of toxic chemicals to the Great Lakes, atmospheric visibility, Arctic Haze, and dispersion of pollutants. He has led or participated in over 20 major field experiments. He is the author of 83 journal articles and book chapters, 94 other refereed works and numerous public presentations of his work. Dr. Hoff obtained a Bachelor of Arts degree in Physics at the University of California Berkeley in 1970 and a Ph.D. in Physics from Simon Fraser University in 1975. He has conducted research at UMBC, Environment Canada, NASA Langley Research Center, the Jet Propulsion Laboratory, and the National Oceanographic and Atmospheric Administration's Environmental Research Laboratories. Dr. Hoff was a member of the Science Advisory Group for the NASA Laser In-Space Technology Experiment (LITE), a space shuttle experiment. He was a member of a proponent team for a spaceborne Differential Absorption Lidar (DIAL) involving NASA, the Canadian Space Agency and the Meteorological Service of Canada. He is also a science team member on the ESSP-2 spaceborne lidar, named CALIPSO. He was a member of the International Radiation Commission International

Coordination Group on Laser Atmospheric Studies (ICLAS), the American Meteorological Society Committee for Laser Atmospheric Studies (CLAS) and the Stratospheric and Upper Tropospheric Aerosol focus of the International Global Aerosol Program (SUTA/IGAP/IGAC). He was Rapporteur for Long Range Transport on the WMO Executive Committee Panel of Experts/Commission of the Atmospheric Science Working Group on Environmental Pollution and Atmospheric Chemistry. Dr. Hoff is a member of the Science Advisory Group on Aerosols to the Commission of the Atmospheric Sciences of the World Meteorological Organization, and he is Chair of the NASA Applied Sciences Advisory Panel. He has had committee and peer review roles at NASA, EPA, Environment Canada, and the European Economic Community. He has held memberships in six scientific societies and served as Chairman of committees for those societies.

Dr. Karl Fred Huemmrich received a B.S. in Physics from Carnegie-Mellon University in 1977 and a Ph.D. in Geography from the University of Maryland, College Park in 1995. In 1978, he began working as a NASA contractor at Goddard Space Flight Center, initially as operations analyst on the satellite attitude determination and control. Later, he provided programming and analysis support of passive microwave remote sensing data of sea ice, where he was task leader. In 1987, he joined the team for the First International Satellite Land Surface Climatology Project Field Experiment (FIFE), a multidisciplinary field experiment on the Kansas prairies. Following the completion of FIFE, he worked on the Boreal Ecosystem and Atmosphere Study (BOREAS), a field experiment in the Canadian boreal forests. Dr. Huemmrich was the Assistant Information Scientist on these experiments and has experience in the development and operation of interdisciplinary information systems in support of large field experiments. He has developed and used models of light interactions with vegetation, and has studied the use of remotely sensed data to collect information on biophysical variables using both computer models and field measurements concentrating on uses of bidirectional and hyperspectral reflectance data. He has performed fieldwork in a variety of habitats including arctic and sub-arctic tundra, boreal and temperate forests, croplands, prairies, and deserts.

Dr. Breno Imbiriba received his B.Sc. degree in 1997 from the Universidade Federal do Par´a (UFPA) -Bel´em, Brazil. In 1999, he received his M.Sc. degree in Theoretical Physics from the Instituto de Fisica Te´orica (IFT) -S˜ao Paulo, Brazil. In 2007, he received his Ph.D. in Physics from the University of Maryland at College Park (UMCP). His research was on numerical simulation of binary black hole collision and gravitational wave extraction. Since Fall 2006, he has been a Research Associate at the Joint Center for Earth Systems Technology (JCET) at the University of Maryland Baltimore County (UMBC), in Baltimore, MD. His research interests are on remote sensing studies of atmospheric trace gases retrieval, trace gases climate record, climate change and numerical modeling.

Dr. Weiyuan Jiang received a B.S. degree in Applied Mechanics and a M.S. degree in Fluid Mechanics from Fudan University, Shanghai in 1993 and 1996, respectively. He worked at the Shanghai Institute of Applied Mathematics and Mechanics, Shanghai University for two years. He received his Ph.D in 2004 from Clarkson University,

where he worked on the instability of multi-layer fluid motion at the Department of Mechanical and Aeronautical Engineering. He subsequently joined JCET at UMBC as a Research Associate. His research interests range from instabilities of fluid motion, film coating, computational fluid dynamics, parallel computation and geodynamo. His research is currently focused on the time-variable gravity caused by large-scale mass redistribution of the mantle and the parallel computation on the MoSST (Modular, Scalable, Self-consistent, Three-dimensional) core dynamics model and the Martian historical dynamo. He is currently a Research Assistant Professor affiliated with UMBC's Department of Mechanical Engineering.

Dr. Benjamin Johnson received his Bachelor of Science degree in Physics from Oklahoma State University in 1998, a Master of Science degree in Atmospheric Sciences from Purdue University in December 2001, and completed his Ph.D. degree in December 2007 from the University of Wisconsin-Madison. He is currently a Research Associate in JCET. His research interests cover a broad spectrum of precipitation cloud modeling, radiative transfer, cloud microphysics, and radar/radiometer remote sensing from air, space, and ground. Dr. Johnson is focusing on combined dual-frequency radar and multi-channel radiometer retrievals of frozen and mixed-phase precipitation at microwave frequencies in the 10 to 340 GHz range, with a focus on the upcoming Global Precipitation Mission (GPM) science objectives. He is also a member of the GPM combined radar/radiometer algorithm development team, and is actively involved in developing improved retrieval algorithms for snowfall using passive microwave and radar remote sensing methods.

Dr. Arlin J. Krueger received his undergraduate degree in Physics from the University of Minnesota in 1955 and his Ph.D. degree in Atmospheric Sciences from Colorado State University in 1984. He began his career in 1959 at the Naval Weapons Center, China Lake, California, where he developed balloon and rocket instruments and techniques for ozone measurements. He joined GSFC in 1969, initially serving as technical officer on the Nimbus-4 backscatter UV experiment, where a new method for remote sensing of total ozone from satellites was tested. Based on this experience he proposed an instrument for mapping of total ozone, the Total Ozone Mapping Spectrometer (TOMS) instrument, for flight on the Nimbus-7 satellite. Following its launch in 1978, he investigated many applications of the TOMS total ozone data and developed a new technique for mapping volcanic sulfur dioxide clouds. He was awarded the NASA Exceptional Scientific Achievement Medal in 1991, the University of Maryland Elkins Professorship of Physics in 2000, and the NASA Exceptional Service Medal in 2001. Dr Krueger served as sensor scientist for the Nimbus-7 TOMS, instrument scientist on the Meteor 3/TOMS (launched on August 15, 1991), and the Earth Probe TOMS (launched in July 1996), and as principal investigator on the ADEOS/TOMS (launched in August 1996). He was the principal investigator of the VOLCAM Mission, which was selected as an Alternate ESSP mission. Dr Krueger is a member of the William T. Pecora Award-winning NASA TOMS science team and the EOS Aura OMI science team.

Dr. Ilan Koren received his degrees from the department of Geophysics and Planetary Sciences in Tel Aviv University, Israel. He received his Ph.D with distinction in 2002

where his major research interest was on spatial and temporal patterns in clouds and aerosols. He joined NASA's MODIS aerosol team as a National Research Council (NRC) fellow and received two awards for Best Senior Author Publication for his work on cloud-aerosol interaction. In Summer 2004, he joined JCET as an Assistant Research Scientist. His research interests include remote sensing and modeling of clouds and aerosols, the role of aerosols on climate, and the impact of aerosols on the lifecycle and optical properties of clouds.

Dr. Weijia Kuang received his B.Sc. degree in Space Engineering Sciences from Changsha Institute of Technology, Peoples Republic of China (PRC) in 1982, his M.Sc. degree in Theoretical Physics from Wuhan University, PRC in 1985, and his Ph.D. degree in Applied Mathematics from the University of California, Los Angeles in 1992. He subsequently joined Harvard University as a postdoctoral fellow, and later as a research associate. He joined JCET as a Research Associate Professor in June 1998. His research interests range from nonlinear wave-wave interactions and pattern formations, instabilities in magnetohydrodynamic systems, to general computational geophysical fluid dynamics. His main research activities are focused on studying dynamic processes in the deep interior of the Earth, in particular the nonlinear convective flow in the Earth's outer core and generation of the geomagnetic field. He has developed one of the first two working dynamo models (Kuang-Bloxham model) to simulate three-dimensional, fully nonlinear core flow. He has had more than 20 peer-reviewed papers published, most recently a paper on the application of geodynamo modeling to geopotential studies.

Dr. Prasun K. Kundu received a B.Sc. (with honors) in Physics from Calcutta University, India in 1974 and a M.Sc. in Physics from the Indian Institute of Technology, Kharagpur, India in 1976. He then joined the High Energy Physics Group at the University of Rochester in New York, where he earned his Ph.D. degree in 1981 in Theoretical Physics for his work on a new class of exact and asymptotic solution the Einstein field equations of general relativity. During 1980-82 he was a postdoctoral research associate at the Enrico Fermi Institute, University of Chicago; during 1982-85 he was an instructor at the University of Utah, Salt Lake City. In 1985 he joined the Department of Physics and Astronomy at Ohio University, Athens as an assistant professor, where he taught a variety of graduate and undergraduate courses in Physics and continued research in relativistic gravitation theory. Since 1992 he has worked at the Climate and Radiation Branch, GSFC on various aspects of rainfall statistics related to Tropical Rainfall Measuring Mission (TRMM) and other satellite- and ground-based remote sensing measurements of precipitation. For his work he received an exceptional scientific support award in 2000. Dr. Kundu is currently a Research Associate Professor at JCET, UMBC. He has taught graduate level physics courses in thermodynamics and statistical mechanics at UMBC and Johns Hopkins Applied Physics Laboratory. His past work in collaboration with Dr. T. L. Bell at GSFC involves theoretical development of stochastic dynamical models of precipitation and their application to rainfall sampling problems. He has recently co-supervised the Ph.D. dissertation of Mr. R.K. Siddani, a graduate student at the Mathematics and Statistics Department, UMBC, leading to the discovery of a novel type of probability distribution governing the statistics of rainfall.

Dr. David J. Lary received a First Class Double Honors B.Sc. in Physics and Chemistry from King's College London (1987) with the Sambrooke Exhibition Prize in Natural Science, and a Ph.D. in Atmospheric Chemistry from the University of Cambridge, Churchill College (1991). His thesis described the first chemical scheme for the ECMWF numerical weather prediction model. He was awarded a Royal Society University Research Fellowship in 1996 at Cambridge University. From 1998 to 2000 Dr. Lary held a joint position at Cambridge and the University of Tel-Aviv as a senior lecturer and Alon fellow. In 2000 the chief scientific adviser to the British Prime Minister and Head of the British Office of Science and Technology, Professor Sir David King, recommended Dr. Lary to be appointed as a Cambridge University lecturer in Chemical Informatics. In 2001, he joined UMBC/GEST as the first distinguished Goddard fellow in earth science at the invitation of Richard Rood. Dr. Lary's automatic code generation software, AutoChem, has received five NASA awards. He is currently involved with NASA Aura validation using probability distribution functions and chemical data assimilation, neural networks for accelerating atmospheric models, the use of Earth Observing data for health and policy applications, and the optimal design of Earth Observing Systems. The thread running through all the research is atmospheric chemistry, and the use of observation and automation to facilitate scientific discovery.

Dr. J. Vanderlei Martins has received a Bachelor's degree in Physics in 1991, a Master's degree in Physics/Nuclear Applied Physics in 1994, and a Ph.D. in Physics/Applied Physics in 1999 from the University of Sao Paulo (USP), Brazil. He joined the Group of Air Pollution Studies at the Institute of Physics (USP) in 1990, and conducted research in environmental and atmospheric applied physics. In particular, he developed analytical nuclear techniques using particle accelerators for material analysis, including aerosols and tree-rings, and participated in several ground-based and aircraft field experiments studying properties of aerosols from biomass burning and biogenic emissions. He was a member of the University of Washington, Department of Atmospheric Sciences' Cloud and Aerosols Research Group, from November 1995 to August 1996, and of the NASA GSFC Climate and Radiation Branch from August to December 1996, both as a Visiting Scientist. He taught at the University Sao Judas Tadeu between 1998 and 1999 while conducting research at the University of Sao Paulo. After starting his postdoctoral work at the University of Sao Paulo, he joined JCET in December 1999 as a Visiting Assistant Research Scientist. He has authored and co-authored over 25 refereed papers and has given over 60 presentations at international conferences, the most recent being on the spectral absorption properties of aerosol particles, and on the measurement of the vertical profile of cloud microphysical and thermodynamic properties. He served as elected member of the International Radiation Commission from 2001-2008. In 2006 he assumed an Associate Professor position in the Department of Physics of the University of Maryland Baltimore County, while keeping his affiliation with the Joint Center for Earth Systems Technology.

Dr. Kevin J. McCann is a Research Associate Professor in JCET and is affiliated with the Physics Department at UMBC. Dr. McCann is engaged in research to use LIDAR to measure atmospheric aerosols to help estimate pollution levels. Dr. McCann has

worked for over 20 years in the field of theoretical and experimental underwater acoustics at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). Prior to APL, he had been working on theoretical atomic and molecular collisions and atom/molecule surface interactions at Georgia Tech and the University of Virginia. This work was directed at an understanding of the collision cross sections that are relevant in the interstellar medium and, to some extent, planetary atmospheres. Dr. McCann received all three of his college degrees from Georgia Tech and did his Ph.D. dissertation work (1974) with Dr. Ray Flannery there on atomic collision processes. Dr. McCann has published over 50 refereed journal articles in the areas of atomic and molecular collisions and acoustic propagation.

Dr. W. Wallace McMillan is an Associate Professor of Physics at UMBC, Director of UMBC's Atmospheric Physics Graduate Program, and a JCET Fellow. His research activities focus on tropospheric chemistry and dynamics of carbon monoxide (CO); observations of upper tropospheric water vapor; and the validation of satellite remote sensed atmospheric parameters. Dr. McMillan has developed an extensive familiarity with air- and ground-based FTIR spectra, including the BBAERI and BNAERI instruments in his Atmospheric Remote-sensing Facility (ARF), and has participated in several NASA field experiments. Prior to coming to UMBC, Dr. McMillan spent two years in the Laboratory for Extraterrestrial Physics at NASA Goddard Space Flight Center as a National Research Council Postdoctoral Fellow with the Mars Observer thermal emission spectrometer team. He is an active member of the American Geophysical Union (AGU) and the Optical Society of America (OSA). Dr. McMillan received his Ph.D. in Earth and Planetary Sciences from The Johns Hopkins University in 1992 for studies of the chemistry and dynamics of the stratosphere of Uranus. He earned a Masters degree from JHU in 1990, and graduated cum laude, Phi Beta Kappa with a B.S. in Physics from Rhodes College in 1985.

Dr. Amita Mehta joined JCET as a Research Scientist in May 2000. Dr. Mehta obtained her M.Sc. in Physics from Gujarat University, India in 1982, and obtained her Ph.D. in Meteorology from Florida State University in 1991. After completion of her Ph. D, Dr. Mehta worked as a research scientist in the Sounder Research Team (SRT) at Goddard Space Flight Center until August 2001. Since then Dr. Mehta has been working in the Mesoscale Atmospheric Processes Branch as a research scientist, and is an Affiliated Assistant Professor in the Department of Geography and Environmental Sciences, UMBC. Dr. Mehta's interests and expertise are in satellite remote sensing of geophysical parameters and their analysis to understand climate and its variability.

Dr. William Olson received an AB in Physics from Cornell University in 1978 and a Ph.D. in Meteorology from the University of Wisconsin-Madison in 1987. The primary focus of his research activities has been in the field of satellite microwave radiometry, with particular emphasis on the remote sensing of precipitation and latent heating distributions. In 1987 he developed the first minimum variance approach for the physical retrieval of rain distributions from satellite microwave data. He later designed, with Dr. William Raymond, a method for assimilating latent heating estimates from SSM/I into numerical weather prediction model forecasts, and more recently collaborated with scientists at NCEP and NASA to assimilate precipitation and

latent heating distributions into global models. His current work involves the adaptation of cloud microphysics/radiative models for simulating spaceborne passive microwave, radar, and infrared observations in support of TRMM and GPM mission research.

Dr. Lazaros Oreopoulos (a.k.a Lazaros Oraiopoulos) received his B. Sc. in Physics with honors from Aristotle's University of Thessaloniki, Greece in 1989. He received M. Sc. (1992) and Ph. D. (1996) degrees from McGill University, Montreal. After working for a year as a Research Scientist for the Cloud Physics Research Division of the Meteorological Service of Canada, he was offered a postdoctoral fellowship from the National Science and Engineering and Research Council of Canada, but chose instead to join JCET in October 1997. Soon thereafter he established an affiliation with the UMBC Department of Physics, where he regularly teaches a graduate course on atmospheric radiation. Dr. Oreopoulos served as the leader of the JCET Radiation Focus Group for three years. He currently holds the rank of Research Associate Professor and leads research on the modeling and remote sensing of clouds, cloud-aerosol interactions, and three-dimensional radiative transfer. He is a member of the Landsat and ARM Science Teams.

Dr. Erricos C. Pavlis received his Dipl. Ing. from the Nat. Tech. Univ. of Athens, Greece in 1975, and his PhD in Geodetic Science from The Ohio State Univ., Columbus, Ohio. Dr. Pavlis is currently a Research Associate Professor, Physics, at the Univ. of Maryland, Baltimore County, doing research for NASA. He participated in the LAGEOS, LAGEOS 2, the Crustal Dynamics and WEGENER Projects, the TOPEX/POSEIDON and JASON Missions, and the development of EGM96. Currently science team member of GRACE and OST missions, and a co-PI of the LARES mission, Science Coordinator for the GGOS Bureau for Networks and Communications, member of the GGOS Steering Committee, the IERS Directing Board, the ILRS's Governing Board, the Central Bureau and ILRS Coordinator for Analysis and Modeling, chairman of the ILRS Refraction Study group, member of IAG's Subcommission 3.3, and associate editor for the journal of Celestial Mechanics and Dynamical Astronomy.

Dr. Ana I. Prados received her B.A in Physics and Chemistry from the University of Florida in 1992, and her Ph.D in Chemistry from the University of Maryland, College Park in 2000 where her major research was in-situ measurements and modeling of U.S air pollutants. She joined JCET in October 2005 and her primary research focus is in the area of remote sensing of aerosols and air quality applications. She currently works on the integration of in-situ and remote sensing data for air quality applications at the Goddard Earth Sciences Data and Information Services Center (GES DISC) via the Giovanni online tool for remote sensing data exploration and visualization.

Dr. Lynn C. Sparling is an Associate Professor of Physics at UMBC and is a UMBC affiliate member of JCET. She received a B.S. in Chemistry from the University of New Mexico in 1976, a M.S. in Physics from the University of Wisconsin-Madison in 1980 and a Ph.D. in Physics from the University of Texas at Austin in 1987. She held postdoctoral research positions in chemical engineering and pharmacology, and conducted research in biophysics at the National Institutes of Health until 1992. She

joined STX Corp. in 1993, working under contract to NASA at Goddard Space Flight Center, became a member of JCET in 1998 and joined the faculty at UMBC in 2001. During her career, Dr. Sparling has done theoretical work in a variety of different areas in statistical mechanics, biophysics and hydrodynamics, and is currently working in the areas of atmospheric dynamics and tracer transport and mixing.

Dr. L. Larrabee Strow received his B.S. degree in Physics from the University of Maryland Baltimore County in 1974 and his M.S. and Ph.D. degrees in Physics from the University of Maryland, College Park in 1977 and 1981, respectively. He is currently a Research Professor in the Department of Physics at the University of Maryland Baltimore County. His research interests include molecular spectroscopy, especially spectral line shapes, and radiative transfer, and atmospheric remote sensing. He is a Member of the NASA AIRS and NPP (CrIS Sensor) science teams, and a Co-Investigator on EUMETSAT's IASI sounder on the new METOP platform.

Dr. Andrew Tangborn received undergraduate degrees from the University of Washington in Mathematics and Mechanical Engineering and M.S. and Ph.D. degrees from the Massachusetts Institute of Technology in Mechanical Engineering. Since coming to JCET, he has been involved in research projects in the field of data assimilation, with a variety of geophysical applications. These include atmospheric constituent data assimilation for the carbon cycle (SCIAMACHY and MOPITT), assimilation of polar wind observations using data from the VORCORE balloon experiments and solid earth data assimilation in which geomagnetic field observations are assimilated into a geodynamo model. He is currently a Research Associate Professor and is affiliated with the Department of Mathematics at UMBC, where he teaches graduate courses in data assimilation, computational fluid dynamics and wavelet transform methods.

Dr. Ali Tokay received his B.S. from Istanbul Technical University in 1984, his M.S. from Saint Louis University in 1988, and his Ph.D. from the University of Illinois at Urbana-Champaign in 1993. Dr. Tokay was a research associate through the National Research Council Fellowship between 1993 and 1995. He then joined Saint Louis University as an assistant professor in 1995 and the University of Maryland Baltimore County (UMBC) as a research assistant scientist in 1997. He later was promoted to research assistant professor and became a research associate professor in 2007. Dr. Tokay was a principal investigator during a series of field campaigns under the NASA Tropical Rainfall Measuring Mission. He has taught a number of undergraduate and graduate courses at both Saint Louis University and UMBC. Dr. Tokay mentored 12 undergraduate and five graduate students, and was an advisor of a M.S. student who graduated in 1998. Dr. Tokay is an Affiliated Associate Professor of the Department of Geography and Environmental Sciences and a Research Assistant Professor of the Joint Center for Earth Systems Technology at UMBC. Dr. Tokay is also a member of NASA's precipitation science team.

Dr. Tamas Várnai received his M.Sc. equivalent degree in Meteorology from the Eötvös Loránd University, Budapest, Hungary in 1989. He then joined the Hungarian Meteorological Service for two years, after which he enrolled in McGill University in

Montreal, Canada. His research focused on how cloud heterogeneities influence the way clouds reflect solar radiation. After receiving his Ph.D. in Atmospheric and Oceanic Sciences in 1996, he continued his research as a post-doctoral fellow, first at McGill University, then at the University of Arizona. In addition to examining the theory of three-dimensional radiative effects, his work also included the development of operational algorithms for the MISR (Multi-angle Imaging SpectroRadiometer) instrument on board the Terra satellite, calculating the amount of solar radiation clouds reflect. Dr. Várnai joined JCET in 1999, where he works on estimating the influence of cloud heterogeneities on operational MODIS (Moderate Resolution Imaging Spectroradiometer) cloud property retrievals and develops cloud property retrieval algorithms for the THOR (THickness from Offbeam Returns) lidar system.

Dr. Juying X. Warner received a B.S. from Nanjing University in Atmospheric Physics in 1983 and a Ph.D. in Meteorology in 1997 from the University of Maryland College Park where her major research interest was radiative transfer modeling. In 1997, she joined the National Center for Atmospheric Research and worked at the Atmospheric Chemistry Division until she joined the Joint Center for Earth Systems Technology at the University of Maryland Baltimore County in 2004. Since her doctorate degree, she has focused on the remote sensing of atmospheric chemistry and other properties using satellite and airborne technologies. She has published over 20 refereed papers on the analyses of atmospheric chemistry and remote sensing algorithms and techniques, and has received awards from NASA and NCAR for her contributions to the science and technology advancements.

Dr. Zigang Wei received his Bachelor degree from the department of Application Physics of Beijing Institute of Technology, Peoples Republic of China in 1996, and his Ph.D. degree in Geomagnetism from Institute of Geology and Geophysics, Chinese Academy of Science in 2001. He subsequently joined the Institute of Geology and Geophysics as a research associate. His research experiences ranged from the geomagnetic observation, modeling geomagnetic survey data and compiling charts, studying main geomagnetic field and its secular variations. He joined JCET in August 2005. Since 2007 he has been involved in the retrieval of atmospheric satellite data.

Dr. Leonid Yurganov is a Senior Research Scientist at UMBC, Physics Dept. and JCET. His current research expertise is connected with remote sensing of tropospheric composition, mostly CO and other members of carbon family, as well as ozone. He graduated from Leningrad State University in 1969 (MS) and Institute of Atmospheric Physics in 1979 (Ph.D.) (both in Russia). For many years he has been using grating spectrometers for atmospheric research in Moscow and St. Petersburg (Russia). He studied total column and surface CO abundances in 1995-1996 at the Geophysical Institute, UAF, Fairbanks, Alaska. Validation of MOPITT Terra instrument was his duty during 1997-2001 at the University of Toronto. Between 2001 and 2006 he studied variations of CO burden in the Northern Hemisphere at the Japan Marine and Earth Science and Technology Center (JAMSTEC) in Yokohama. He is a co-author of 41 refereed publications.

Dr. Hai Zhang received his B.S. in Physics in 1992 from Nankai University and M.S. in Optics in 1995 from Xi'an Institute of Optics and Precision Mechanism in China. He received his M.S. in Computer Science in 2002 from Towson University, and his Ph.D. in Atmospheric Physics from the University of Maryland Baltimore County in 2006. He has been working in JCET as a Research Associate since 2006, where he conducts research on atmospheric circulation modeling using quasi-uniform grids. His recent research interest is in atmospheric aerosol remote sensing, and the applications in the air quality monitoring and forecasting.

III.9 Table 1: JCET Faculty (as of September 30, 2008)

NAME	TITLE	AFFILIATION
Dr. William Barnes	Senior Research Scientist	Research Faculty
Dr. Roberto Borda	Assistant Research Scientist	Research Faculty
Dr. Mark Bulmer	Research Associate Professor	Geography and Environmental Systems
Dr. Petya Entcheva-Campbell	Research Assistant Professor	Geography and Environmental Systems
Dr. Christine Chiu	Research Assistant Professor	Physics
Mr. Ruben Delgado	Research Associate	Research Faculty
Dr. Sergio deSouza-Machado	Research Assistant Professor	Physics
Dr. Forrest Hall	Senior Research Scientist	Research Faculty
Dr. Jeffrey Halverson	Associate Professor	Geography and Environmental Systems
Mr. Scott Hannon	Research Assistant	Research Faculty
Mr. Ernest Hilsenrath	Professor of Practice	Research Faculty
Dr. Raymond Hoff	Professor	Physics
Dr. K. Fred Huemmrich	Research Assistant Professor	Geography and Environmental Systems
Dr. Breno Imbiriba	Research Associate	Research Faculty
Dr. Weiyuan Jiang	Research Assistant Professor	Mechanical Engineering
Dr. Ben Johnson	Research Associate	Research Faculty
Dr. Meloe Kacenelenbogen	Research Associate	Research Faculty
Dr. Ilan Koren	Assistant Research Scientist	Research Faculty
Dr. Arlin Krueger	Research Professor	Physics
Dr. Prasun Kundu	Research Associate Professor	Physics
Dr. Magdalena Kuzmicz-Cieslak	Research Associate	Research Faculty

NAME	TITLE	AFFILIATION
Dr. David Lary	Research Professor	Physics
Dr. Kevin McCann	Research Associate Professor	Physics
Dr. Amita Mehta	Research Assistant Professor	Geography and Environmental Systems
Dr. William Olson	Research Associate Professor	Physics
Dr. Lazaros Oraiopoulos	Research Associate Professor	Physics
Dr. Erricos Pavlis	Research Associate Professor	Physics
Dr. Ana Prados	Research Assistant Professor	Chemistry
Dr. Andrew Tangborn	Research Associate Professor	Mathematics and Statistics
Dr. Ali Tokay	Research Associate Professor	Geography and Environmental Systems
Dr. Tamás Várnai	Research Assistant Professor	Physics
Dr. Juying Warner	Research Assistant Professor	Geography and Environmental Systems
Dr. Zigang Wei	Assistant Research Scientist	Research Faculty
Dr. Leonid Yurganov	Senior Research Scientist	Research Faculty
Dr. Hai Zhang	Research Associate	Research Faculty

III.10 Table 2: JCET Fellows (as of September 30, 2008)

NAME	AFFILIATION
Dr. Robert Cahalan	NASA GSFC
Dr. Belay Demoz	Hampton
Dr. Jill Engel-Cox	Battelle Memorial Institute
Dr. Richard Hartle	NASA GSFC
Dr. Weijia Kuang	NASA GSFC
Dr. Thorsten Markus	NASA GSFC
Dr. Alexander Marshak	NASA GSFC
Dr. Vanderlei Martins	UMBC Physics
Dr. W. Wallace McMillan	UMBC Physics
Dr. Harvey Melfi	Emeritus
Dr. Lazaros Oraiopoulos	NASA GSFC
Dr. Chintan Patel	UMBC CSEE
Dr. Steven Platnick	NASA GSFC
Dr. James Plusqellic	UMBC CSEE
Dr. Marcos Sirota	Sigma Space Corporation
Dr. Lynn Sparling	UMBC Physics
Dr. David Starr	NASA GSFC
Dr. Larrabee Strow	UMBC Physics
Dr. Marco Tedesco	NASA GSFC
Dr. Omar Torres	UMBC Physics
Dr. David Whiteman	NASA GSFC

III.11 Table 3: JCET Associate Staff (as of September 30, 2008)

NAME	TITLE
Mr. Dominic Cieslak	Engineer
Mr. Keith Evans	Research Analyst

III.12 Table 4: JCET Administrative Staff (as of September 30, 2008)

NAME	TITLE
Ms. Valerie Casasanto	Program Coordinator
Ms. Mary Dawson	Business Specialist
Ms. Danita Eichenlaub	Acting Director
Dr. Franco Einaudi	Chair, Executive Board
Dr. Jeffrey Halverson	Associate Director
Dr. Richard Hartle	Associate Director
Dr. Raymond Hoff	Executive Director
Ms. Amy Houghton	Communications Specialist
Ms. Camilla Hyman	Accountant I
Dr. Tom Low	Associate Director
Ms. Cathy Manalansan	Administrative Assistant II
Ms. Grace Roscoe	Executive Administrative Assistant
Mr. Derek Stivers	Business Specialist
Ms. Nina von Gunten	Administrative Assistant I
Ms. Margo Young	Business Specialist

Acronyms and Abbreviations

ABOVE	AIRS BBAERI Ocean Validation Experiment
ACCA	Landsat-7's Automated Cloud Cover Assessment
ADRO	Application Development and Research Opportunity
AERI	Atmospheric Emitted Radiance Interferometer
AERONET	Aerosol Robotic Network
AFL	Atmospheric Fourier Transform Infrared (FTIR) Laboratory
AGU	American Geophysical Union
AIRS	Advanced Infrared Sounder
ALEX	Atmospheric Lidar Experiment
AMSR-E	Advanced Microwave Scanning Radiometer – EOS
AMSU	Advanced Microwave Sounding Unit
AOD	Aerosol Optical Depth
ARM	Atmospheric Radiation Measurement
BBAERI	Baltimore Bomem Atmospheric Emitted Radiance Interferometer
BOREAS	Boreal Ecosystem Atmosphere Study
C3VP	Canadian Cloudsat/CALIPSO Validation Project
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CHAMP	Challenging Minisatellite Payload
CLAMS	Chesapeake Lighthouse and Aircraft Measurements for Satellites
CMAQ	Community Multiscale Air Quality
CNR	Italian National Research Council
CREST	Cooperative Center for Remote Sensing Science and Technology
CrIS	Cross-Track Infrared Sounder
CRM	Cloud Resolving Model
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment

DOE	U.S. Department of Energy
DRU	Data for Research Use
ELF	Elastic Lidar Facility
EOS	Earth Observation System
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
EUMETSAT	European Organization for the Exploration of Metrological Satellite
GALION	Global Atmosphere Watch Atmospheric Lidar Observation Network
GASP	GOES Aerosol and Smoke Product
GCM	General Circulation Model or Global Climate Model
GEST	Goddard Earth Sciences and Technology Center
GOCE	Gravity Field and Steady-State Ocean Circulation Mission
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
GPM	Global Precipitation Measurement Mission
GPS	Global Positioning System
GRACE	Gravity and Climate Recovery Experiment
GRSP	Geologically Rough Surfaces Project
GSFC	Goddard Space Flight Center
GV	Ground Validation
HSB	Humidity Sounder Brazil
I3RC	Intercomparison of 3-D Radiation Codes
IAG	International Association of Geodesy
IASI	Infrared Atmospheric Sounding Interferometer
IDEA	Infusing satellite Data into Environmental Applications
IEEE	Institute of Electrical and Electronics Engineers
IERS	International Earth Rotation Service
IGAC	International Global Atmospheric Chemistry Project
IGARSS	IEEE International Geoscience and Remote Sensing Symposium
IHOP	International H_2O Project

ILRS	International Laser Ranging Service
ISCCP	International Satellite Cloud Climatology Program
ISLSCP	International Satellite Land Surface Climatology Project
LAGEOS	Laser Geodynamics Satellites
LANDMOD	Landslide Modeling and Forecasting Utilizing Remotely Sensed Data
LaRC	Langley Research Center
LBA	Large Scale Biosphere Atmosphere Experiment
LIDAR	Light Detection and Ranging
LITE	Lidar In-Space Technology Experiment
MASSMOVE	Mass Movement (model)
MGS	Mars Global Surveyor
MISR	Multiangle Imaging SpectroRadiometer
ML	Maximum Likelihood
MODIS	Moderate Resolution Imaging Spectroradiometer
MOSST	Modular, Scalable, Self-consistent, Three-dimensional
MPLNET	Micropulse Lidar Network
NACP	North American Carbon Program
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NESDIS	National Environmental Satellite, Data, and Information Service
NGS	National Geodetic Survey
NIMA	National Imagery Mapping Agency
NLLJ	Nocturnal Low Level Jet studies
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRA	NASA Research Announcement
NSF	National Science Foundation
NWP	Numerical Weather Prediction

OMI	Ozone Monitoring Instrument
OSTM	Ocean Surface Topography Mission
PDF	Probability Distribution Function
PI	Precipitation Index or Principal Investigator
PR	Precipitation Radar
R	Rain Rate
RAMMMP	Regional Air Monitoring, Measurement, and Modeling Program
REALM	Regional East Atmospheric Lidar Mesonet
SCS	South China Sea
SCHIMACHY	Scanning Imaging Absorption SpectroMeter for Atmospheric Cartography
SLR	Satellite Laser Ranging
SSM/I	Special Sensor Microwave/Imager
SWCRF	Shortwave cloud radiative forcing
SWS	Shortwave spectrometer
THOR	Thickness from Offbeam Returns
TMI	TRMM Microwave Imager
TOGA	Tropical Ocean Global Atmospheres Experiment
TOMS	Total Ozone Mapping Spectrometer
TRF	Terrestrial Reference Frame
TIROS	Television Infrared Observation Satellite
TRMM	Tropical Rainfall Measuring Mission
UMBC	University of Maryland, Baltimore County
USDA	U.S. Department of Agriculture
USNO	U.S. Naval Observatory
UV	Ultraviolet
VIEWS	Visibility Exchange Web System
WAVES	Water Vapor Validation Experiments
WMO	World Meteorological Organization
WVIOP	Water Vapor Intensive Operations Period
Z	Radar Reflectivity Factor