SIXTEENTH ANNUAL REPORT
JOINT CENTER FOR EARTH SYSTEMS TECHNOLOGY

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

July 1, 2010 – June 30, 2011

The Joint Center for Earth Systems Technology

Sixteenth Annual Report
July 1, 2010 – June 30, 2011

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Executive Summary

This volume is the sixteenth annual report describing the scientific accomplishments and status of the Joint Center for Earth Systems Technology (JCET). This Center was established in 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 has 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's 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 BWTech Research Park 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 38 JCET faculty members (listed in Section III.10) and 17 Fellows (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 research analysts, an assistant research engineer and a research engineer (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 (listed in Section III.12). In the spirit of cooperation between UMBC and GSFC, the Associate Director for Academics is an Associate Professor of Geography and the Board Chairman is a civil servant scientist 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. These 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 July 1, 2010 to June 30, 2011. Each report includes a description of the research, accomplishments for FY 10-11, and objectives for FY 11-12. 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 41 refereed papers (and 26 others submitted for review), along with 112 conference presentations and publications and non-refereed 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 46 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 12 different courses they taught this past 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.

Late in FY11, JCET experienced significant changes. Foremost is a large growth in the cooperative institute, as 11 former faculty members of the Goddard Earth Systems and Technology (GEST) Center joined JCET's ranks in May 2011. Here we briefly introduce each of our new members. Mr. Timothy Berkoff, Assistant Research Engineer, studies optical measurements of atmospheric aerosols and clouds. Dr. Huisheng Bian, Associate Research Scientist, conducts research on atmospheric chemistry. Associate Research Scientist Dr. Allen Chu works with air quality, including satellite and field measurements of aerosols. Dr. Marcianna Delaney, an Assistant Research Scientist, focuses on NASA's education efforts in STEM. Dr. Shin-Chan Han, JCET Associate Research Scientist, works extensively with Earth's gravity field and application to earthquake monitoring and the hydrosphere. Dr. Susan Hoban, also a Senior Research Scientist, studies scientific information systems and works to advance STEM with the nation's K-12 educators. Dr. Chung-Lin Shie, Associate Research Scientist, performs advanced numerical modeling of cloud systems and their climate interactions. Dr. Christopher Shuman, Associate Research Scientist, investigates ice loss in the polar regions, and the connection to climate change, using advanced remote sensing techniques. Dr. Michael Studinger, JCET Associate Research Scientist, conducts field surveys of geophysical parameters in the Arctic and Antarctic regions. Dr. Michael Wilson, Research Associate in JCET, uses radiative transfer modeling to distinguish among snow, ice and cloud cover in remote sensing observations. And Dr. Zhibo Zhang, Assistant Research Scientist, works with the infrared properties of clouds. We congratulate Dr. Zhang as he recently accepted a tenure track position in UMBC's Department of Physics.

We welcome this talented and productive group of scientists into JCET. As you can see from the great diversity in their specializations, our new faculty members add a significant degree of breadth to JCET's mission to study the myriad facets of Earth and our environment.

Finally, after many years of leading JCET with scientific vision, keen business acumen and compassion for both the faculty and staff, Dr. Raymond Hoff has stepped down as JCET's Executive Director. Dr. Hoff will remain as a Senior Science Advisor to JCET, as he devotes himself full-time as UMBC Professor of Physics. Ms. Danita Eichenlaub, JCET's Associate Director for Administration and Finance, will serve as JCET's new Director.

July 2011

Danita Eichenlaub, Director
Jeffrey Halverson, Associate Director, Academics

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II. TECHNICAL VOLUME

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Global Modeling and Assimilation Office
(Code 610.1)

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Task 49: Carbon Cycle Data Assimilation *(Sponsor: M. Rienecker)*

Investigator: Andrew Tangborn, Research Associate Professor, Mathematics

Description of Research

Tangborn's research is carried out in the field of carbon cycle data assimilation, with an emphasis on assimilating carbon dioxide measurements from the Atmospheric Infrared Sounder (AIRS), and developing a trace gas assimilation capability in the GMAO's GEOS-5 data assimilation system.

Trace gas data assimilation has been focused on the carbon cycle species of carbon monoxide and carbon dioxide. The purpose of this work is to develop techniques to improve estimation of sources, transport and distributions of these species. A multiyear reanalysis of carbon dioxide using AIRS retrievals has been produced and validated using ground-based and aircraft data. New development of trace gas assimilation into the most current GEOS-5 assimilation system has been completed for carbon monoxide by using observations from the Measurement of Pollution in the Troposphere (MOPITT) instrument.

Accomplishments for FY 10-11

Carbon cycle data assimilation work during the past year has been focused on development work for the Gridspace Statistical Interpolation (GSI) analysis system, which is the assimilation component of the GEOS-5 system used by the Global Modeling and Assimilation Office (GMAO). Initially, Tangborn and others in the GMAO have used observations of carbon monoxide from MOPITT as a test for the system.

Assimilation of carbon dioxide has continued during the past year, using the GEOS-5 model running in "replay" mode, in which stored meteorological analysis fields are used to restart the model and transport trace gases. Carbon dioxide observations are assimilated using a univariate (meaning that CO_2 is assimilated alone) system. Retrieved carbon dioxide observations from AIRS have been assimilated into the GEOS-5 system for the years 2005 and 2006 so as to create a CO_2 reanalysis for this period. This is an optimal estimate of the distribution of carbon dioxide from the model and observations. Tangborn has used two independent retrievals in this work: the first, developed at JPL (Chahine, *et al.*), uses AIRS channels with peak sensitivity between 200-300 mb; the second, developed at UMBC (Strow, *et al.*), with peak sensitivity at around 500 mb. The former observations were found to improve comparisons with Japan Airlines CO_2 measurements, flying at around 200 mb, while the latter resulted in improved CO_2 estimates throughout the troposphere, which were compared with NOAA-ESRL aircraft data. Thus, it has been shown that assimilating AIRS carbon dioxide retrievals into a state-of-the-art chemical transport model can result in improved estimates of CO_2 at all levels of the atmosphere.

Objectives for FY 11-12

During the coming fiscal year, work will continue to be developed in GEOS-5, with more more observation types being added for carbon monoxide (AIRS, IASI, MLS, etc), and validation of the system will be carried out through comparisons with *in situ* observations. Work on carbon monoxide will also continue with the existing univariate system, with the inclusion of CO_2 data from GOSAT and simulated OCO (Orbiting Carbon Observatory) in preparation for the 2013 launch. The carbon dioxide assimilation will begin to be moved to the GSI framework in GEOS-5, and eventually radiance-based assimilation techniques will be developed.

Earth Sciences Division
(Code 610.6)

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JCET Highlight: Determination of PBL Heights from Ground-Based Vertical Profilers
Investigator: Mr. Ruben Delgado

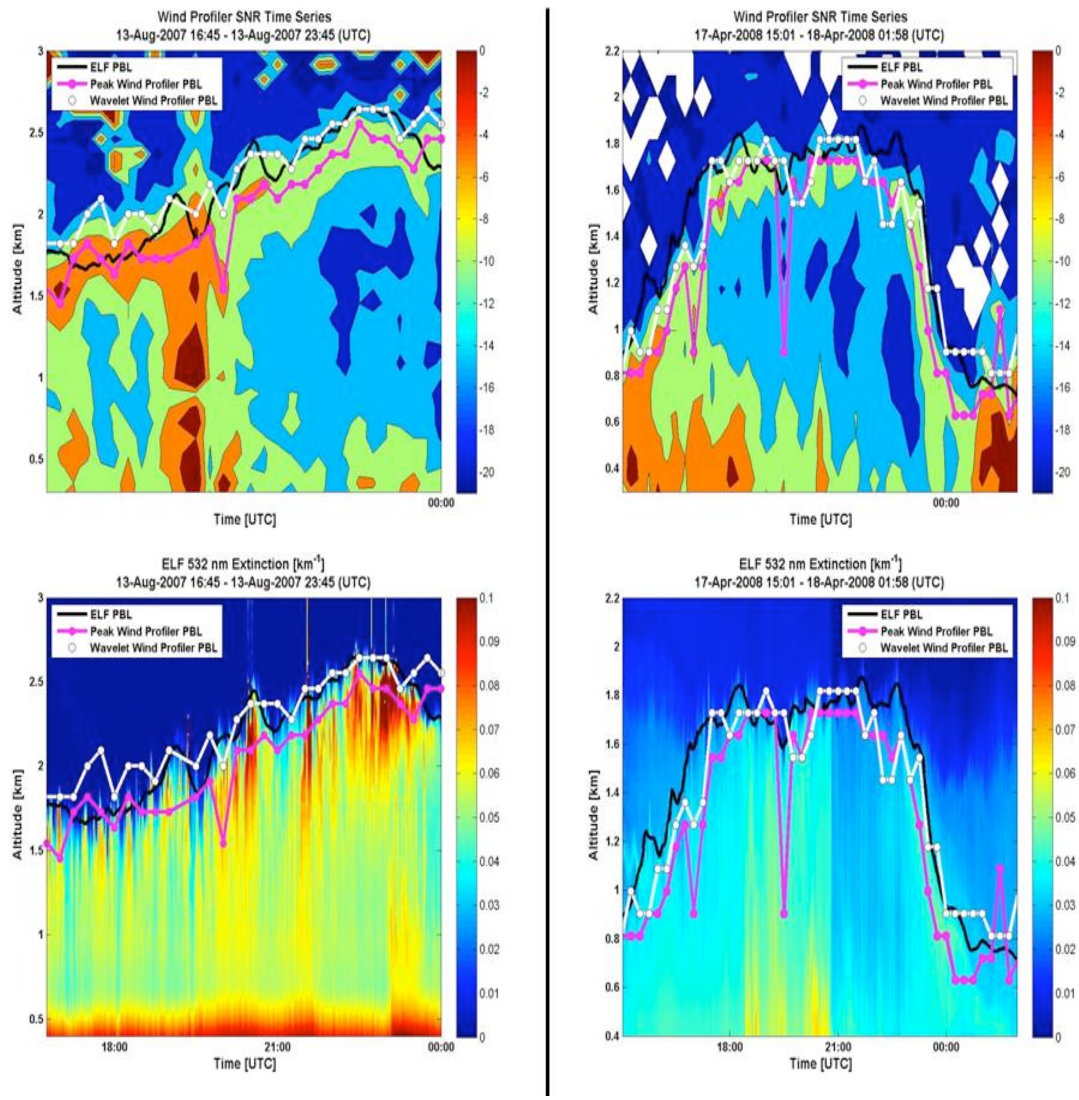

Figure 1. The National Research Council (NRC – 2009) has recommended a "network of networks" which builds new and integrates already existing radiosonde launch sites, wind profilers, and lidars into a national network to serve multiple environments' applications near the Earth's surface. One high-priority observation being addressed is the current inadequacy in determining the planetary boundary layer height (PBLH). Retrieving lidar and wind profiler PBLH with the covariance wavelet technique (CWT) is a cost-effective and accurate method in aiding in forming this large network. The country's current system of launching radiosondes at 0 and 12Z has been shown here to provide ambiguous and inaccurate PBLH, and often detect RL heights. Lidars and wind profilers can produce 1- and 5-minute temporal resolution, to continuously monitor the daily evolution of the PBL to verify and validate atmospheric transport, dispersion and air quality forecast models.

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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 (U00R6200819)**
Investigators:	Rubén Delgado, Faculty Research Assistant, JCET; Raymond Hoff, Science Advisor, JCET and Professor, Physics; Kevin McCann, Research Associate Professor, Physics; Timothy A. Berkoff, Assistant Research Engineer JCET and several co-investigators from institutions outside UMBC.
Students:	Debra Wicks Kollonige, Graduate Student; Jaime Compton, Undergraduate Student; Patricia Sawamura, Graduate Student; Daniel Orozco, Graduate Student, John Sullivan, Graduate Student; Alex St. Pé, Summer Intern; Richard Powers, Summer Intern.

Description of Research

Elastic lidar measurements have been conducted to measure the vertical distribution of aerosols over the Baltimore-Washington metro area to understand and aid in the assessment of whether the abundance of air pollutants and particulate matter smaller than 2.5 mm ($PM_{2.5}$) in the Baltimore-Washington metropolitan area are due to local sources or long-range transport. Active remote sensing lidar measurements support the NOAA CREST Lidar Network (CLN), 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 10-11

Lidar measurements carried out by UMBC's Atmospheric Lidar Group (ALG) provide a set of atmospheric profiles of aerosols, by which analysts can query their vertical distribution in near real time and compare to the inputs of three-dimensional forecasts models. The UMBC lidar measurements have been useful for NASA A-train (Aqua, Terra, CALIPSO, etc.) 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 aerosol variability due to 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.

The seasonal variability of the chemical speciation analysis of 24-hour $PM_{2.5}$ filters collected in the Baltimore Metro Area from 2000-2009 was evaluated to establish background concentrations and local sources of particle pollution in the Mid-Atlantic United States. Analysis indicated the presence of long-range transport pollutants impacting Baltimore's air quality (*e.g.* smoke from forest fires in Southeastern and Northwestern United States, and dust from Gobi and Taklimakan deserts in Asia). Lidar measurements confirm the presence of aloft layers of particle pollution descending into the planetary boundary layer (PBL) during non-attainment air quality days. The lidar determination of height-dependent extinction profile and aerosol optical depth (AOD) in the atmosphere allows quantification of aerosol concentrations within the PBL, presumably where it is well mixed and would be best represented by ground-based $PM_{2.5}$ measurements. Cluster analysis of column aerosol optical properties of aerosols was carried out for aerosol classification. This method provides an *a priori* method for identification of aerosols without the timely constraints of chemical sampling analysis. The absorption and extinction Angstrom exponents along with single scattering albedo were evaluated in the cluster analysis to provide physics and chemical characteristics of urban aerosols and their influences upon the air quality and solar radiation budget in Baltimore.

The National Research Council recommended a “network of networks” which builds new and integrates already existing radiosonde launch sites, wind profilers, and lidars into a national network to serve multiple environments applications near the Earth’s surface. One of the highest priority observations needed for the “network of networks” to address is the current inadequacies in determining the PBL height. UMBC has obtained hundreds of hours of elastic lidar returns from which the top of the convective mixed layer can be retrieved analytically, using aerosols as a tracer. Comparisons with radiosondes, Aircraft Communications Addressing and Reporting System (ACARS) profiles, and wind profiler measurements show that the one-minute average time resolution of the lidar data reveals convective structures, which are not resolved by current thermodynamic soundings by radiosondes and tend to be misplaced in height by aircraft profiles. Lidar and wind profiler PBL heights retrieved, with a covariance wavelet technique (*see Highlight*), are a cost-effective and accurate method for aiding in the formation of this large network. The current system in the United States of launching daily radiosondes at 0 and 12Z has been shown here to provide ambiguous and inaccurate PBL heights, often detecting residual layer heights.

The CREST Lidar Network list server was created (cln@lists.umbc.edu). This electronic mail distribution list allows for immediate communication between CREST institutions prior and during air quality events. Lidar observations within the network will aid in the determination and impact of regional and long-range transport of pollutants into the eastern US states and Caribbean. Lidar observations at UMBC are carried out within the WMO-GALION framework.

Studies of ozone, water and other trace gases near the tropopause have allowed identification of stratospheric folds and intrusions. This work involves a combination of NASA's A-Train data and aircraft missions to locate sources of ozone and trace gas enhancements measured at the surface, which result from stratosphere-troposphere exchange (STE) events over the continental and coastal United States where Environmental Protection Agency (EPA) standards were exceeded. Code yellow, orange, and red ozone air quality indices were recorded at several surface sites throughout 2006-2010, and NASA's A-Train measurements helped to determine the source of these chemical species to be STE associated with upper-level fronts and jet streaks. An integrated analysis of observations from NASA's A-Train satellites was used to determine the global frequency and spatial extent of reversible and irreversible mixing of chemical species due to STE. This work forms the core of Mrs. Kollonige's Ph.D. dissertation, expected in the Summer 2011.

UMBC/JCET faculty actively participated in NASA's Venture Class project called DISCOVR-AQ (James Crawford, PI), which was designed to examine the representativeness of column optical properties from satellites to ground-based air quality. This campaign was carried out in Baltimore during July 2011 and the UMBC team was involved in the ground-based verification of NASA aircraft over flight data.

Objectives for FY 11-12

Chemical composition data for fine and coarse particles collected at UMBC will be analyzed using a positive matrix factorization (PMF). The objective is to identify the possible aerosol sources in Baltimore and Mid-Atlantic states. PMF uses estimates of the error in the data to provide optimum data point scaling and permits a better treatment of missing and below-detection-limit values. Results will be verified with active and passive sensors to determine the impact of meteorological processes within the PBL that are critical in the transport, diffusion and chemical transformation of pollutants. Studies for comparison of platforms that yield boundary-layer parameters for studying air pollution, such as PBL heights, ventilation coefficients (product of mixing height and surface wind speed), and cloud coverage, will be evaluated and determined for air quality events and their relationship to $PM_{2.5}$, and ozone levels will be established and compared to AQ forecast/models.

NASA Grant: Particle Absorption Characterization for the Retrieval of Aerosol Optical Depth from Calipso Observations (NNX08AR46G)

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

Investigators: Sergio DeSouza-Machado, Assistant Research Professor, Physics; Adam Robinson (UMBC Undergraduate Student).

Description of Research

Dust can be transported over very large distances, affecting both the outgoing long-wave radiation as well as the reflected sunlight over vast geographical areas. Instruments on board orbiting satellites can measure different parameters of the airborne dust, such as amount, thickness and albedo. It is rare for one instrument to be able to determine all these parameters accurately; however, by using a suite of instruments, each sensitive to measurements in different portions of the electromagnetic spectrum, it is possible to determine most, if not all, these parameters. In this study, dust layer heights for various storms between 2006-2010 have been obtained using a synergetic retrieval involving AIRS thermal infrared radiances and MODIS optical depths. Unlike radiances obtained in the visible, thermal infrared radiances are sensitive to both the dust optical depth and height. The PI and his student plan to use this research to make a climatological height database for the same time period.

Accomplishments for FY 10-11

The development of a more sensitive dust detection flag for AIRS, one that can be used over ocean, was a major accomplishment. This allows for the detection of dust at lower optical depths, therefore providing greater areal coverage than the dust flag present in the AIRS L1 and L2 datasets (also developed by Dr. DeSouza-Machado). A second accomplishment was a robust comparison of dust altitudes over ocean, and a third accomplishment was studying deep convection using infrared data.

Adam Robinson, an undergraduate Physics major at UMBC, has been helping with this project from February 2010 to September 2010. Comparison of optical depths derived from AIRS data, against optical depth retrievals using MODIS visible data, indicate that there is a straight-line relationship between the MODIS- and AIRS-retrieved optical depths. This relationship varies systematically with placement of the dust layer. By finding the height at which an optimal IR:VIS optical depth ratio of 4 is obtained, they have used three years of collocated AIRS/MODIS data to provide the genesis of a climatological height database. The scheme is initialized with atmospheric state parameters from ECMWF model fields.

They have begun an intensive comparison of a number of co-located MODIS and AIRS dust contaminated FOVS. Data from June 2006 is being used, as it can be compared against heights provided by the CALIPSO lidar. The preliminary comparison work over ocean showed very promising results, and was presented at the 2010 A-Train Symposium in New Orleans last October.

They have also collaborated with Mr. Ruben Delgado and Dr. Raymond Hoff, both of JCET, to unambiguously track Asian dust as it travels from Asia to North America, using the high spectral resolution information of AIRS.

Another collaboration is the study of Deep Convective Clouds with Dr. George Aumann of Jet Propulsion Laboratory. Dr. Larrabee Strow (JCET) is partially funding this research with funds he received to develop scattering algorithms for AIRS. The results of this study are a better understanding of the changes to measured AIRS radiances under conditions of deep convection, including frequency of occurrence over ocean and land, and possible transport of moisture from the upper troposphere to lower stratosphere. Additionally, this work has resulted in a peer-reviewed publication.

Objectives for FY 11-12

Going forward, DeSouza-Machado plans to complete and evaluate the climatological database, for dust over ocean. This database will cover the main geographic regions over which dust blows, namely the Atlantic between West Africa and the Carribean, the Mediterranean, and the Red Sea/Persian Gulf area, as well as the Pacific between the Far East and the Canadian coast. Adam Robinson will extend the work over land during Summer 2011, with funding from the JCET Undergraduate Summer Interns Program.

Task 338: **Satellite analysis of fire radiative energy release, derivation of Aerosol and Carbon Monoxide (CO) emission rates, and air-quality applications** ***(Sponsor: Charles Ichoku)***

NOAA Grants: **GOES-R Air Quality Proving Ground (NA09NES4400022 and NA10NES4280016)**

NASA Cooperative Agreement: **DISCOVER-AQ Mission**

DOD Award: **Lower Atmospheric Research Using Lidar Remote Sensing**

Investigators: Raymond Hoff, Science Advisor, JCET and Professor, Physics; Rubén Delgado, Faculty Research Assistant, JCET, Timothy A. Berkoff, Assistant Research Engineer JCET, Kevin McCann, Associate Professor, Physics; Amy Huff, Battelle Memorial Institute, Shobha Kondragunta, NOAA NESDIS.

Students: Patricia Sawamura, Daniel Orozco, Thishan Dharshana Karandana-Gamalathge, Jaime Compton, John Sullivan, Graduate Students; Alex St. Pé, Chris Lo, Summer Interns.

Description of Research

This diverse set of projects covers extramural funded and internal graduate research for the Atmospheric Lidar Group (ALG) not covered by work of Hai Zhang or Ruben Delgado (see other reports). Research is designed to relate air quality as measured by satellites with emission fields and ground exposure measurements. All use lidar and satellite measurements to estimate profiles of aerosols in the atmosphere.

Accomplishments for FY 10-11

The first project above is a new one in JCET designed to couple the measurements of fire radiative power from MODIS measurements with carbon monoxide emissions as measured by MOPITT, AIRS and IASI. Thishan Dharshana Karandana-Gamalathge will propose a Ph.D. research project to combine these measurements to better assess mass emission rates of carbonaceous species from biomass combustion.

The second project comprises a long-term planning and training exercise to get the US air quality forecast community prepared for the launch of the new GOES-R mission in 2015. GOES-R will have the Advanced Baseline Imager aboard and will provide data of MODIS quality every five minutes from a starting geostationary orbit. The views from this mission will revolutionize researchers' ability to forecast aerosol air quality but the forecasting community needs to be trained on how to use these new projects. The Air Quality Proving Ground does this through workshops and training sessions.

UMBC participated in NASA's Venture Class project called DISCOVER-AQ (James Crawford, Langley Research Center, PI) that seeks to relate column measurements of air quality with profiles from lidar and measurements at the ground. The question being asked is "How can we best relate column measurements to surface observations?" The first deployment of DISCOVER-AQ will occur in July 2011 and take place in the Baltimore-Washington Urban area. Hoff is a Co-Investigator on this Venture Class Mission.

Hoff's team was recently awarded a component of a DOE PIRT award to better characterize aerosols over urban areas with lidar. Dr. Kevin McCann and Daniel Orozco will lead this effort, working with the PI, Dr. Patrick McCormick of Hampton University.

Objectives for FY 11-12

In FY11-12, three of the students covered on these projects are expected to advance to candidacy (Karandana-Gamalathge, Sawamura and Orozco). Sawamura will use the ALEX lidar system to develop a microphysical retrieval algorithm for aerosol properties based on the $3\beta+2\alpha$ technique used in Europe and Asia. Karandana-Gamalathge is expected to have results that should lead to a journal article from research conducted over the summer of 2011.

The DISCOVER-AQ mission and the Air Quality Proving Ground activities will dominate the research effort, and the analysis of the July 2011 data will be expected to take most of the year. The Air Quality Proving Ground is running a testbed during the DISCOVER-AQ deployment to provide near-real time ABI imagery to the forecasters in the eastern region. These results will be assessed and presented in a workshop at UMBC in October 2011.

NASA Grant: **The Science of Terra and Aqua, New Global Measurements of Tropospheric NH3 and HDO from AIRS**

NASA Grant: **Atmospheric Composition, Intercomparison of EOS CO Sensors Using a Uniform Algorithm**

NASA Grant: **Tropospheric Chemistry, ARCTAS Support and Analyses**

NASA JPL: **Optimization and Validation for Version 6 of AIRS Trace Gas Products (Subcontract to AIRS Team)**

Investigators: Juying Warner, Research Associate Professor, Physics Department; Zigang Wei, Assistant Research Scientist, JCET; Larrabee Strow, Professor, UMBC Physics Department; Scott Hannon, UMBC Physics Department; Allen Chu, Associate Research Scientist, JCET

Description of Research

Warner's projects involved the evaluations of the current NASA tropospheric trace gas measurements and the developments of new and more accurate methods to retrieve atmospheric composition that are important to air quality and climate change studies. The detailed aspect of her team's work can be summarized in the following areas: (a) the inter-comparison of AIRS/TES/MOPITT/MLS CO against current AIRS operational products; (b) the development of refined AIRS CO retrievals using the Optimal Estimation (OE) method to generate not only the trace gas quantities but also other sensitivity-related retrieval variables, such as the Averaging Kernels (AKs), error covariance matrices, and degrees of freedom, similarly defined as "other sensors"; (c) the development of new products that do not yet exist using AIRS measurements, specifically ammonia (NH_3) and heavy water (HDO) (d) the science analyses for the global emission and transport of pollutions especially for the Arctic regions; (e) the collaborations and support to the greater science community.

Accomplishments for FY 10-11

Warner's team conducted tests and validations for AIRS operational V6 CO outlined by their JPL subcontract. Tropospheric CO comparisons between AIRS and MOPITT were featured in manuscripts published by Warner *et al.* [2007] for AIRS V4 and Warner *et al.* [2010] for AIRS V5. This year's efforts were focused on comparing all the collocated CO profiles between AIRS and TES operational products for AIRS new V6 CO. The main improvement for AIRS V6 CO is to use a separate uniform first-guess for the Northern Hemisphere (NH) and SH. They have also provided feedback to the AIRS science team on how the changes by other AIRS properties in the new operation codes affect CO, and they helped to correct one large potential error. They used data from multiple days for testing and 90 *in situ* profiles to validate AIRS V6 CO. The new codes were delivered to the NOAA, GSFC, and JPL teams for final testing to prepare for data release, planned for the end of August 2011.

They have developed and published an alternative method for AIRS CO retrievals using the OE method (Rodgers, 2000), which provides a better way to compare not only the CO accuracy but also the information contents of AIRS against MOPITT, TES, and MLS using quantities with the same definitions. Warner and her team have compared the AIRS operational algorithm with the algorithm using OE formulations. They studied 10 years of

AIRS data recorded in the previous year and demonstrated that AIRS OE CO results are more realistic than AIRS V5 operational CO, especially in the lower troposphere and in the SH (Warner *et al.*, 2010). The remaining task is to analyze the sources of this product's uncertainties and produce several datasets for distribution through the UMBC ftp site.

In terms of the NASA TCP ARCTAS campaign effort, Warner has switched her focus this year to the data analysis using their newly refined products. She and her team concluded that AIRS CO retrievals at high latitudes perform very well in the summer campaign, which achieved similar accuracies as those at mid- to low-latitudes. However, the operational CO products under-estimate significantly compared with the *in situ* data in the Spring portion of the campaign. They developed an algorithm suitable to handle the unique difficulties in the retrieval from the extreme conditions over the Arctic. Warner has studied the pollution transport patterns into the Arctic Circle and co-authored a paper by Fisher *et al.* (2010).

AIRS Level 2 (L2) retrieval algorithm utilizing cloud clearing to handle cloud contaminations in the measurements helps to increase the L2 data coverage significantly. AIRS cloud clearing uses 9 neighboring pixels with different cloud fractions to solve for clear radiances. For the AIRS footprints sized at approximately 15km^2, the number of clear pixels is only 5-10%; with cloud clearing, AIRS L2 data coverage exceeds 50%. It is desirable, however, to understand if and how the cloud clearing affects the overall quality of the retrievals. To select AIRS clear pixels, they used collocated MODIS cloud mask with the ratio of MODIS clear pixels in each AIRS pixel to be greater than 99%. They then analyzed the CO distribution parallel between clear pixels and cloud-cleared pixels to draw conclusions on the statistical property of the two samples. A manuscript titled "Tropospheric Carbon Monoxide Variability Measured by AIRS Under Cloudy Verses Clear Conditions" that summarizes this work is in preparation.

The funding cycle for the development of AIRS new products NH3 and HDO began in early March 2011. Warner's initial efforts are to develop the forward model and to prepare the retrieval codes to adapt the added products. Scott Hannon, under Dr. Strow's direction, has developed the forward model with the NH3 and HDO lines added and delivered to Warner's team for testing. Zigang Wei is working on the retrieval portion of the project by implementing the forward model into their retrieval systems.

Objectives for FY 11-12

The PI and her team will continue to refine the AIRS OE CO algorithm, taking step-by-step approaches to compare the outputs with the new AIRS operational products. They will continue to produce and distribute large amounts of AIRS OE CO data research to the collaborators and via the web. Efforts will continue with regard to testing and validating the trace gas products for AIRS team algorithm products and to make recommendations for AIRS version 6 through funding by a JPL sub-contract. Two new NASA grants have begun, and Warner will focus on these efforts in the coming year. She and her team will coordinate with Co-I Strow to update and implement the new RTA and develop the retrieval algorithm for the HDO and NH3 products as funded by the NASA program "The Science of Terra and Aqua". Also, the project regarding the study of the uncertainty in the AIRS CO measurements will begin and the new IASI CO retrievals will be developed as funded by the NASA program "The Error Analyses in Climate Records".

JPL Subcontract: Optimization, Validation, and Integrated EOS Analysis of AIRS Trace Gas Products

Investigator: Dr. Leonid Yurganov, Senior Research Scientist (JCET)

NASA Grant: Cross Validation of TES with AIRS (NNX07AG73G)

Investigators: Dr. Leonid Yurganov (Co-I), Senior Research Scientist (JCET); Dr. L. Larrabee Strow (PI), Research Professor (JCET)

Description of Research

Yurganov's research is two-fold: his research with NASA/JPL includes several specific topics connected with carbon monoxide measurements and retrievals, particularly conducting the development and validation of CO retrieval technique for a ground-based IR emission spectrometer. CO retrievals for the spectra measured by IASI/Metop-A sounder and an analysis of measurements was underway, and the validation of satellite data during wildfires using ground-based sun-tracking spectrometers and measurements were conducted, and resulted in a publication. His research with Cross Validation involved the development of an algorithm for retrieval methane concentrations from satellite data.

Accomplishments in FY 10-11

A paper published in 2010 [Yurganov *et al.*, 2010b] presented a new algorithm for CO retrieval from the Atmospheric Emission Radiance Interferometer (AERI) spectra deployed at the ARM/SGP site in Oklahoma. The results of this can be easily applied to other instruments of this type, deployed at the ARM network worldwide. CO (and potentially CH_4 and CO_2) measurements complement satellite data and can be used for validation. The old algorithm was subjected to a significant influence of erroneous water vapor profiles in humid conditions. Also, the retrieved CO mixing ratios are affected by parasite solar radiation scattered by aerosol and thin clouds. Both effects have been taken in account and a long set of results between 2000 and 2009 have been presented. This data set in particular confirmed a diminution of CO mixing ratio in late 2008 – early 2009. As it is well known, during this time the maximum decline in anthropogenic emissions due to the world economy recession took place; these results were in good agreement with satellite data published earlier (Yurganov *et al.*, 2010a). For two years (2008 and 2009), tower measurements of CO concentration conducted by Lawrence Berkeley National Laboratory were available for comparison, and spectrometric data supplied information about pollution in the bottom 2-km thick layer of the atmosphere. The comparison with surface CO concentrations revealed seasonal changes in the vertical stratification: in summertime, CO was mixed along the altitude significantly better than during wintertime.

Catastrophic forest and peat fires in Russia in July-August 2010 demonstrated a topicality of the satellite-based CO measurements. These fires were induced by a drought caused by an extremely strong and stable high-pressure system that blocked zonal circulation. Several temperature records were broken in July-August in Moscow. During the wildfires, the AIRS CO data were posted on the *JPL* official page, highlighting an unusual location and severity of the fires for Russia. This *JPL* post received good press coverage, which helped support the importance of AIRS products. Yurganov followed up with three meeting presentations and a paper submitted to the *ACP,* in which analytical results of this event were discussed.

Of special importance regarding this event is the availability of vast amounts of ground-truth information for the area under the plume of polluted air dispersing from the fire. Normally, Northern Hemisphere wildfires occur in non-populated forests, and no surface data are available. Satellite data are quite helpful, but the accuracy of the satellite measurements is questionable; validation data are lacking for such severe conditions. For the first time, an opportunity to verify CO satellite data for a strong wildfire appeared. Thermal IR sounders supplied the effective CO total column amount (TC) that is a result of convolution between the true profile, *a priori* profile, and sensitivity function. The sensitivity function ("averaging kernel") diminishes from the mid-troposphere to the surface, and the effective TC is expected to be less than true one. This is the first time the magnitude of this error was investigated experimentally: the underestimation may be as high as 100-200%. The total emitted CO during this event was estimated as 40 Tg being twice as large compared to a similar calculation based on the uncorrected data.

In Yurganov's Cross Validation research, a new CH_4 retrieval code for IASI/MetOp-1 was developed and investigated. The main idea is to use CH_4 lines near 3.6 μm where solar radiation reflected from the ground is equally important compared to the thermal Earth radiation. In principle, this opens a door for sounding lower parts of the troposphere; the thermal Earth's radiation spectra alone only allows for measurements above 6 km of altitude. It was discovered that the vertical sensitivity function depends on the ratio between solar and thermal radiances; in turn, this ratio depends on the seasonally changing geometry of solar radiation. Over ocean, these effects may be taken into account; conversely, over the land surface, a significant influence of aerosol takes place. These two effects mask these small CH_4 variations, and 3.6 μm spectral region is difficult to use quantitatively, especially over continents, where the main CH_4 emissions are located.

Objectives for FY 11-12

At present, Yurganov is preparing a proposal for ROSES-2011. An algorithm of express validation for NRT calculations of CO emitted by wildfires and dispersed over the Globe will be proposed. The latter project of on-line forecasting is now under development in GMAO.

Yurganov's next Cross Validation project is at a border between aerosols and informatics. He and his team will be trying to characterize and systematize various aspects of data quality using semantic web and ontology approach. The goal is to develop a computer expert system that can provide a user with a comparative table of quality aspects of aerosol data from MODIS and MISR over the user's selected area and time period.

NOAA Grant: Alternate Algorithm Development of GOES AOD Retrievals (NA10NES4280014)

Investigators: Hai Zhang, Assistant Research Scientist, Research Faculty; Raymond M. Hoff, Professor, Physics (JCET).

Description of Research

GASP (GOES Aerosol/Smoke Product) is an aerosol optical depth (AOD) retrieval algorithm from GOES imagery data. The product provides AOD monitoring at high temporal resolution during daylight so that it can be used to track the motion of aerosols from smoke, pollution and dust, and quantitatively be related to the mass of aerosols. This product is important for public health and valuable for air quality forecast meteorologists. To further improve the GOES AOD retrieval accuracy, Zhang and Hoff developed new algorithms. Since surface BRDF (bidirectional reflectance distribution function) retrieval has a large influence on the accuracy of AOD retrieval, the new algorithms focus on improving the retrieval accuracy of surface BRDF. One method derives surface BRDF and AOD with the aid of seasonally averaged MODIS 2.1 μm BRDF through MAIAC (Multi-Angle Implementation of Atmospheric Correction) algorithm. A second, alternate approach uses daily average AOD and GOES visible channel signals to derive surface BRDF. They then validate the retrieval results at different AERONET sites and compare them against original GASP retrievals. They have found that the new algorithms demonstrate better accuracy than the GASP algorithm.

Accomplishments in FY 10-11

In their previous research, they developed a MAIAC algorithm for GOES data, which uses seasonally averaged BRDF from MODIS 2.1 μm as a reference for GOES BRDF retrieval. The algorithm assumes the BRDF shape is the same between that in the MODIS 2.1 μm channel and that in the GOES visible channel. The ratio between them is retrieved through a time-series analysis. The results for GOES-EAST imager data show good accuracy over the western US; however, large errors are observed close to the backscattering geometry over the eastern US. These errors are caused by the error that originated from MODIS BRDF retrievals, since MODIS usually does not sample the backscattering geometry. In the backscattering geometry, the surface reflectance is much larger than those in the other geometries. Therefore, failing to sample backscattering geometry can introduce large errors in BRDF retrievals. To solve this problem, they developed a second algorithm to improve BRDF retrieval from GOES; this new algorithm uses daily average AOD each day and GOES channel 1 data to retrieve surface reflectance at each observation time. Three days of time sequence of the surface reflectance is employed for the retrieval of Ross-Li coefficients in BRDF model. To reduce BRDF retrieval error, they only used observation days with low average AOD (<0.3). A temporal filter was also applied to remove observations with large variations due to cloud contamination or large AOD variations.

Over the eastern US, where the surfaces are mostly dark and the operational MODIS AOD retrieval has good accuracy, Zhang and Hoff use spatial and temporal average AOD from MODIS Terra and Aqua as input for daily average AOD. Over the western US, where surface reflectance is mostly high and the MODIS operational algorithm performs poorly, they use average AOD from MAIAC for GOES in the time period with good accuracy. By estimating the average area to be around 200x200 km^2, the average AOD from MODIS Terra and Aqua is found to be in good agreement with daily average AOD from AERONET. In the western US, if the average AOD is taken from MAIAC in the afternoon (*i.e.* after 2100 UTC when the TOA reflectance is more sensitive to the aerosol variations), they can find good agreement between average MAIAC AOD and average AERONET AOD. Using the new algorithm, the problem of large errors close to backscattering position in MAIAC is solved and is validated at several AERONET sites.

The improvement of the new AOD retrieval algorithm is due to its shortened time period for BRDF retrieval. To demonstrate this, they analyzed the origin of the systematic error in GASP retrieval algorithm. In the operational code of GASP algorithm, the surface reflectance is retrieved by looking for the second lowest channel 1 TOA radiances or photon counts in 28 days at each observation time; this assumes the surface-reflected radiances do not change much during the 28-day period. However, this assumption is not always true since channel 1 surface-reflected radiances depend on both the Sun-satellite geometry and seasonal color variation of vegetation. At GSFC, they observed that surface reflected radiances increase from winter to spring and from summer to fall, and decrease from spring to summer and from fall to winter. The retrieval error is large when the surface reflected radiance is in uptrend, since the algorithm tends to pick the earliest value in the 28-day sequence for surface reflectance retrieval. Zhang and Hoff did observe such seasonal variation in errors in GASP AOD retrieval: errors are large in spring and fall but small in summer. Their new algorithm successfully solved this problem: since it uses only three days of data for surface reflectance retrieval, the effect of surface reflectance change due to Sun-satellite geometry and vegetation color is greatly reduced.

The calibration difference between GOES-11 (GOES-WEST) and GOES-12 (GOES-EAST) is compared at the Boulder AERONET site since it is located close to the middle of the two satellites. They retrieved BRDF using the average daily AOD method as described above. Since the site is between the two satellites, surface reflectance from the two satellites should be symmetrical around noon. They found that reflectance measured from GOES-11 is about 8% than that from GOES-12. Such results will be used to develop a combined AOD retrieval algorithm for further improvements of the retrieval over the western US.

Objectives for FY 11-12

In the coming year, Zhang and Hoff will work to develop an AOD retrieval algorithm combining data from GOES-WEST and GOES-EAST. They also plan to apply the MAIAC algorithm to SEVIRI data. They will use SEVIRI 1.6 μm channel to substitute 2.1 μm for surface BRDF shape retrieval, in order to test the MAIAC algorithm in geostationary satellite geometry and prepare it for GOES-R data. Additional plans involve collaborating with the GOES-R air quality proving ground group, in which they plan to develop an air quality data distribution system for GOES-R similar to the current IDEA (Infusing satellite Data into Environmental Applications) system.

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Mesoscale Atmospheric Processes (Code 613.1)

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NASA Grant:	**Differences and Similarities of Tropical Cyclone Rainfall Over Land and Sea Using Multisatellite Analyses: Implications for Inland Flooding Prediction (NNX07AL41G)**
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 (NNX09AG03G)**
Investigators:	Jeffrey B. Halverson, JCET Associate Director-Academics, Associate Professor of Geography; Gerald Heymsfield, (GSFC); Lin Tian (UMBC/GEST)
NASA Grant:	**In Situ Measurement of Meteorological State Variables Using Dropsondes On the NASA DC-8 and Global Hawk During NASA GRIP, and Composite Analysis of a Large Dropsonde Database (NNX09AV79G)**
Investigator:	Jeffrey B. Halverson, JCET Associate Director-Academics and Associate Professor of Geography

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 10-11

Halverson continued his research as a member of NASA's Hurricane Science Team. He participated as a mission scientist and DC-8 platform scientist in the GRIP (Genesis and Rapid Intensification Processes) experiment, during Fall 2010, to investigate hurricane structure and evolution in the Atlantic Basin. During this campaign, Halverson also served as the dropsonde P.I. on the NASA DC-8. His role was to develop aircraft flight strategies, supervise a team of weather forecasters during the experiment, and assure the quality of the dropsonde data. Halverson's graduate student Ms. Janel Thomas (St. Louis University) and colleague Professor Robert Pasken (SLU) participated in GRIP as dropsonde scientists on the DC-8. Ms. Thomas is developing her M.S. Thesis using NASA field campaign data to study hurricane intensity change. Halverson also collaborated with scientists at NASA Goddard and other institutes and received a 5-year Venture Class grant, titled Hurricane and Severe Storm Sentinel (HS3). The mission will fly two instrumented Global Hawks into the Atlantic from the NASA Wallops Flight Facility to study hurricane structure and dynamics. Halverson prepared a manuscript reviewing NASA's 25-year involvement in hurricane research for a special upcoming journal issue, to be submitted during Summer 2011. Halverson and UMBC Geography colleague Professor Tom Rabenhorst signed a contract with Oxford University Press to write an introductory, undergraduate textbook called *Severe Storms and Their Environmental Impacts*. Halverson will serve as lead author on this four-year project.

Objectives for FY 11-12

Halverson's 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 along 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. Many new analyses of both large- and small-scale storms and their impacts in the Mid Atlantic will be developed for *Severe Storms and Their Environmental Impacts*. A new PhD student, Mr. Aaron Poyer, will work with Halverson starting in Fall 2011 to examine the relationship between thunderstorm formation, precipitation and electrification along the Washington-Baltimore urban corridor using a high-resolution, regional lightning detection array.

Halverson will also continue his investigations of hurricane intensity change. He will contribute to a manuscript providing an overview the NASA GRIP campaign, analyzing the warm core of Hurricane Earl and its response to rapid intensification. Additionally, he will participate as a mission scientist during a four-week "dry run" or mock mission planning exercise for HS3, during Fall 2011. Halverson also hopes to hire an additional graduate student for Fall 2011 to do forecasting work on the HS3 campaign and additional analysis of the NASA GRIP datasets. Halverson and Dr. Owen Kelley (NASA GSFC) are shepherding a manuscript through the review process, titled, "How much tropical cyclone intensification can result from the energy released inside of a convective burst", submitted to the *Journal of Geophysical Research*. Steady work will continue with Rabenhorst on chapter writing for the textbook *Severe Storms and Their Environmental Impacts*.

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 (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); Gail Skofronick-Jackson (PI), NASA GSFC; James W. Wang, NASA GSFC, William Olson, NASA GSFC/JCET; Mircea Grecu (GEST).

Description of Research

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 10-11

The primary accomplishments during this reporting period are focused toward precipitation retrieval algorithm development for the upcoming Global Precipitation Measurement Mission. The primary focus has been on modifying an existing Bayesian retrieval algorithm to improve snowfall retrieval accuracy. In support of the development of the retrieval algorithm, Johnson has focused on computing the microwave properties of realistically shaped aggregates of hydrometeors and incorporating this into a database for use in the retrieval algorithm.

Johnson is currently a co-investigator with Dr. William Olson (JCET) on creating a melting-layer model for use in the official combined radar/radiometer retrieval algorithm for GPM. This involves developing a 3-D precipitation particle melting model, which is designed to realistically simulate the melting of complex ice-particle shapes and aggregates of these shapes.

During this year, Johnson has served on the Ph.D. committee of Lijun Diao (UMBC, Physics), who is working with Dr. Olson on developing a melting model for radar observations. Lijun is now completing her M.S. degree.

In addition to his research, he is also a member of the Global Precipitation Mission (GPM) combined radar/radiometer precipitation algorithm development team, and radiometer-only algorithm team. As a member of these teams, 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 GPM/PMM.

Johnson also participated in the 2010 International Workshop on Space-based Snowfall Measurement (3rd IWSSM), and the 2011 MC3E field experiment located near the DOE-ARM Central Facility. Johnson's role in MC3E was as instrument scientist for the University of North Dakota Citation research aircraft. Their primary tasks were to sample aerosol, liquid water, and ice particles in anvil and stratiform precipitation in coordination with the NASA ER-2 research aircraft and ground-based radar instrumentation.

As for his professional obligations, Johnson has been an active reviewer for the *Journal of Applied Meteorology and Climatology (JAMC)*, and *Journal of Geophysical Research Atmospheres (JGR-A).* He is also corresponding with high school students at a school in France (their teacher is Mrs. Meunier, a GIFT participant), and he answers their questions about science research and college options for studying science/meteorology.

Objectives for FY 11-12

Johnson's primary objective is to develop, test, and validate GPM-era combined passive microwave/radar (GMI/DPR) retrieval algorithm(s) for light rain and snow over both land and ocean using a variety of existing satellite and ground based observations, new retrieval methods, and field experiment results.

The research direction is toward developing a working "real-time" 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, with validation and an estimation of the uncertainties in the retrieved quantities.

Additionally, he and his team are investigating the relationship between the complex physical properties of ice-phase precipitation particles (including melting particles) and their interaction with active and passive microwave radiation at wavelengths typically employed by remote sensing platforms.

Similar to the objectives above, they are developing a radar algorithm for over-land retrievals of snowfall using CloudSat radar observations, as part of an ongoing study to better utilize CloudSat data in conjunction with passive microwave observations.

These research topics are expected to continue to generate material suitable for publication and presentation at conferences and seminars.

Task 913-18-130: Modeling of Rainfall Statistics from Satellite and Ground Based Radar and Rain Gauge Measurements (NNG05GQ79A)
(Sponsor: T. Bell)

NASA Grant: Error Estimates for TRMM and GPM Average Rain-rate Maps

Investigators: Prasun K. Kundu, Research Associate Professor, Physics; Thomas L. Bell (GSFC 613.2, Emeritus); Matthew R. Schwaller (GSFC 422).

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 datasets from a variety of sources, including satellite and ground-based radar and 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, which takes into account the natural variability of rain and the spatio-temporal mismatches for near-collocated observations.

Accomplishments for FY 10-11

In collaboration with Dr. Ravi Siddani, a former graduate student at JCET, Kundu and his team investigated the temporal scale dependence of rainfall intermittence using the time-averaged precipitation data (TRMM standard product 2A56) from a large network of tipping bucket gauges located in Central and South Florida as part of the TRMM ground validation (GV) program. The 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 similar empirical relationship was found to hold for the spatial scale dependence of the zeroes of rain in the multi-year gridded radar rainfall data (TRMM standard product 2A53) collected at the TRMM GV site near Melbourne, FL. 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, which is based on the premise that rainfall process has an intrinsic memory. The researchers found that the observed behavior reveals an interesting aspect of the rainfall process that can be interpreted as a phenomenon of “persistence of drought”: the longer a zero rain period, the less likely it is for it to end. A paper based on these results will appear in *Water Resources Research*.

With the help of Mr. James Travis, a graduate student at UMBC’s Department of

Mathematics and Statistics, Kundu has initiated a new project of obtaining a comprehensive statistical model of area- and time-averaged precipitation from co-located radar and rain gauge measurements at a GV site. A new statistical model based on a linear stochastic differential equation of fractional order is introduced to describe the second moment statistics of radar rainfall data. It generalizes a previous model of Bell and Kundu [1996] and Kundu and Bell [2003] that was originally devised to primarily describe the statistics of radar rainfall data. The new model is found to successfully fit the second moment statistics of precipitation data over a much larger range of length and time scales that encompass both radar and gauge measurements. Once the parameters of the model are tuned to the space-time covariance statistics of a radar data set, such as the Melbourne radar data (TRMM standard product 2A-53), the model automatically fits the space-time covariance statistics of a network of rain gauges located within the radar field of view (TRMM standard product 2A-56) fairly well without any further adjustment. A preliminary account of the work was presented at the 2010 AGU Fall Meeting and a full-length paper on the subject is being prepared. A unified description of the statistical properties of both near-instantaneous spatially averaged rain rate from a radar and time-averaged rain rate from a rain gauge network located within the radar's field of view will be extremely useful for the purpose of quantifying the inevitable statistical sampling error in rain rate estimation [Bell and Kundu 2003]. An unambiguous separation of this sampling error from the various retrieval errors is essential for a successful rainfall validation program.

Objectives for FY 11-12

In the coming year, the immediate goals are: to apply the new fractional stochastic dynamics model to various radar-gauge inter-comparison scenarios relevant for GPM validation; to examine spatial statistics of TRMM PR (Precipitation Radar) derived rain data and test the model predictions with regard to the multi-scaling behavior; to use the second moment statistics to formulate an error model for improving a regression analysis of pairs of nearly space-time collocated satellite observations of rain over an area [in collaboration with T.L. Bell (GSFC, retired) and X. Lin (GEST)]; 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 co-located satellite data sets.

Task 301: Research Support for NASA Energy and Water Cycle Studies (NEWS) ***(Sponsor: E. Smith)***

Task 330: Development of Training Module for Water Resources ***(Sponsor: David Starr)***

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

Description of Research

The main objective of this research for the past year has been to analyze the atmospheric water cycle over the Mediterranean basin (Med) under NASA Energy and Water Cycle Studies (NEWS) Program. Additional research projects involved observational analysis and model simulations of heavy precipitation events over the central United States Great Plains (USGP) and Gulf of Mexico - Caribbean Sea (GM-CS) basin. Moreover, two new projects were initiated during the past year: 1) a National Institute for Food and Agriculture (NIFA), US Department of Agriculture (USDA) project to downscale rainfall from satellite measurements and from climate prediction model simulations over the USGP region. This information will be used to study decadal scale variability of rainfall and its impact on agricultural production over the USGP. This project will be conducted with collaborators with the Center for Research on the Changing Earth System, National Drought-Mitigation Center, and Texas A&M University. Additionally, Mehta is involved with a NASA Applications Program-supported project to develop information modules to demonstrate usefulness, access, and analysis of NASA satellite products (rain, snow, ground water) for water resource managers and other users in the southwestern US. This project will be carried out in collaboration with Dr. Ana Prados (JCET).

Accomplishments in FY 10-11

An ongoing project of Cloud Dynamics and Radiation database (CDRD) for improved rain retrievals from future microwave radiometers, particularly for extreme rain cases, is close to its conclusion. A database of hydrometeorological profiles associated with storms over GM-CS, based on the University Wisconsin Non-hydrostatic Modeling System (UWNMS) simulations [Tripoli, 1992], has been archived for further research.

Under NASA's Energy and Water Cycle Project, quantitative examination of atmospheric water cycle over the Mediterranean Basin (Med) was continued, extending an earlier study of Mehta and Song [2008]. Based on the extension of the data sets used by Mehta *et al.* [2005], atmospheric moisture source term "EmP" (evaporation E minus precipitation P) was analyzed over Med. Preliminary results showed that average EmP during the last two decades was positive over the entire Mediterranean basin, with maximum magnitude found over the eastern Mediterranean Sea, indicating that the Med acts as a moisture source for the atmosphere. However, E, P, and EmP over both eastern and western Mediterranean domains showed substantial interannual variability. It was noted that the P and EmP behaviors were qualitatively different over the western Mediterranean domain compared to the eastern Mediterranean domain. Over the Eastern Mediterranean, the seasonal cycles of the E, P, and EmP were found to have clear annual cycles with autumn-winter maxima and summer minima. Conversely, over the western Mediterranean domain, the P showed substantial seasonal variability with intermittent bimodal pattern, which was reflected in the irregular seasonal behavior of EmP during the analysis period. The study clearly demonstrated spatial and temporal complexity of Mediterranean moisture source behavior.

A detailed analysis of the Tropical Rainfall Measurement Mission (TRMM)-merged precipitation product was conducted to identify extreme rainfall events over the USGP. This study focused on warm season (April-September) rain events over the region between (100°-95°W and 35°-45° N). The extreme rain events were identified as events when daily rain amount exceeded the 95-percentile value from 2000-2009 daily rain measurements at spatial resolution of 0.25°x0.25° latitude-longitude grids. The 95-percentile rainfall exceeded 35 mm/day in the eastern part of the GP. Seasonal extreme rain frequency was defined as the number of days when rainfall exceeded the 95-percentile value. Extreme warm season rain frequency over the last decade (2000-2009) ranged from 2-10 days and exhibited spatial coherence over the USGP region. Substantial inter-annual variability of rain frequency was noted with minimum extreme events during 2006 and maximum during 2008. An analysis of the North American Regional Reanalysis (NARR) showed that there was an eastward shift in low-level meridional jet (at 925 hPa) while upper-level zonal wind (at 200 hPa) showed a southward shift in 2008 compared to 2006, indicating large-scale dynamical controls on the extreme rain frequency over the USGP.

Objectives for FY 11-12

One of the objectives for the next year is to continue in-depth and quantitative analysis of the water cycle over the Med region under the NEWS program. Also under NEWS, selected extreme precipitation events over the USGP will be simulated by using UWNMS to understand how synoptic processes may influence development of localized extreme rain.

There are two additional objectives related to the two new projects recently initiated. First, under the NIFA-USDA project, the objective will be to develop a data downscaling technique. The task will include gathering high-resolution surface and satellite pixel-level data of rainfall, temperature, and humidity, which will be used to develop statistical relationships between these surface data sets and relatively low-resolution climate model outputs. Second, under the NASA Applications project, water resource training modules will be developed focusing on the western US. These modules will describe NASA satellite products and web-based tools, which can be used by water resource managers in the western US.

NASA Grant:	Improved Ice and Mixed-Phase Precipitation Models for Combined Radar-Radiometer Retrieval Algorithm Applications (NNX10AI49G)
NASA Grant:	A Combined Satellite Radar-Radiometer Precipitation Algorithm for TRMM and GPM, Based upon Ensemble Filtering (NNX10AJ28G)
Task 104:	Global Retrieval of Precipitation and Latent Heating Distributions from Spaceborne Radiometer/Radar Observations *(Sponsor: A. Hou)*
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 MSU/GESTAR; Lin Tian, MSU/GESTAR; Benjamin Johnson, UMBC/JCET; Kwo-Sen Kuo, Caelum Research Corporation; Arthur Hou, GSFC, Code 610.1; Christian D. Kummerow, Colorado State University

Description of Research

The main emphasis of Olson'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 + 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, Olson's team's 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 10-11

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 the researchers' "best" estimates of precipitation and latent heating vertical profiles, and the estimates, 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. This past year, Dr. Mircea Grecu and Olson have applied their efforts to develop a combined radar-radiometer algorithm for satellite applications. Over time, the algorithm has evolved, as weaknesses in the original optimal estimation framework (occasional instability of the dual-wavelength radar inversion method) and the advantages of an alternative ensemble filtering approach were examined. The difference in spatial resolution of the radar and passive microwave observations has been accommodated using a Gibbs sampling approach that selects, from an ensemble of radar-derived precipitation profile solutions, those profiles that lead to simulated upwelling microwave radiances consistent with observed radiances. Their recent focus has been to refine the estimation of environmental parameters, such as atmospheric humidity, cloudiness, and surface microwave emissivity, in non-raining regions. These environmental parameters are spatially interpolated into the precipitation regions, and therefore they can have a significant impact on precipitation estimates.

Also under GPM, Olson leads a small team of investigators who endeavor to improve the representation of ice and mixed-phase precipitation physics in combined algorithms. The combined radar-radiometer algorithm framework previously described will be tested against airborne radar-radiometer data using different vertical precipitation profile parameterizations, which can be modified by inserted alternative precipitation particle single-scattering tables. Specifically, the researchers have computed the single-scattering properties of aggregate ice particles using a numerical simulation to create the aggregates and a discrete dipole analysis method to compute the particle scattering properties (led by Dr. Kwo-Sen Kuo). Ms. Lijun Diao, a UMBC graduate student, received her MS for her work supporting this project. Also, team members Drs. Lin Tian and Benjamin Johnson recently participated in the Midlatitude Continental Convective Cloud Experiment (MC3E) to help collect airborne dual-wavelength radar and radiometer data from sensors aboard the high-altitude ER-2 aircraft. In conjunction with simultaneous *in situ* observations of precipitation size distributions from probes on the underflying Citation aircraft, these data will be utilized to better define the choice of scattering models representing ice and mixed-phase precipitation in satellite algorithms.

Under NASA’s Energy and Water cycle Study (NEWS), Olson continues to participate in the NEWS Climatology working group to improve the current description of the earth's annual and seasonal budgets of water and energy, using a combination of satellite and earth-based data from roughly the last ten years of observations. Using these data, Dr. Tristan L'Ecuyer (Colorado State University) and the PI are exploring different ways of "closing" the water and energy budgets in the atmosphere and at the earth's surface, using both optimal estimation and Lagrange multiplier techniques.

Supported by the NASA MEaSUREs program, Olson is testing long-term, global precipitation products for their sensitivity to input microwave brightness temperature calibration and precipitation algorithm parameterizations. During the past year, production software was developed to calibrate geostationary infrared observations using revised Special Sensor Microwave/Imager (SSM/I) algorithm estimates of precipitation to update the current Global Precipitation Climatology Project (GPCP) multisensor precipitation algorithm.

Objectives for FY 11-12

The combined radar-radiometer precipitation algorithm developed by Dr. Grecu and Olson will undergo testing, using both existing TRMM observations and synthesized GPM observations. The ice/mixed-phase precipitation team will evaluate different physical parameterizations of precipitation, including the ice aggregate models described above, using field observations from the Wakasa Bay and MC3E field campaigns. Dr. L'Ecuyer and Olson will contribute to a NEWS working group publication on the current best description of the earth's water and energy budgets. The long-term record of consistently calibrated rainfall estimates from SSM/I will be used to adjust GPCP infrared rain estimates.

NASA Grant: Measurements of the Hydrometeor Size Distribution through Surface-based Instruments (NNX07AF45G)

NASA Grant: Quantifying Particle Size Distributions in Support of GPM Combined Precipitation Retrieval Algorithms (NNH09ZDA001N-PRECIP)

Task 122: Measurements of Hydrometeor Size Distributions during Global Precipitation Measurement (GPM) Field Campaigns ***(Sponsor: M. Schwaller)***

Investigator: Ali Tokay, Research Associate Professor, Affiliated Associate Professor

Description of Research

The theme of Tokay's study is to improve the precipitation measurements under the umbrella of the 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 measurement 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 field of view. Third, efforts have been made to determine precipitation microphysics in rain, mixed precipitation, and snow. Four, steps have been taken to evaluate the existing operational rainfall products that can be used to validate the satellite precipitation products.

Accomplishments for FY 10-11

A manuscript has appeared in a peer-reviewed journal on the variability of raindrop size distribution and rain parameters in radar pixel. The study was conducted employing three disdrometers at NASA Wallops Flight Facility (WFF). The statistics (correlation coefficent and standard deviation) of four-month long observations showed noticeable differences in size distribution and rainfall parameters [Tokay *et al.,* 2010].

A field campaign was conducted in Helsinki, Finland where the focus was the light rain under the validation of NASA's Cloudsat and upcoming Global Precipitation Measurement (GPM) missions. The experiment involved laser-optical disdrometer (Parsivel), 2D video disdrometer (2dvd), impact type Joss-Waldvogel disdrometer (JW), and weighing bucket gauges, as well as other ground and airborne instruments. Tokay processed all the disdrometer and gauge data, which was uploaded to the NASA Data Active Archive Center (DAAC).

A manuscript is in review on the variability of rainfall within a satellite footprint. This study was conducted through six dual rain gauge sites at WFF and focuses on the rainfall decoration distance and its dependency on the time integration and rainfall types. Noticeable variations were observed in rainfall variability between the seasons, 6-month periods, and years [Tokay and Ozturk, 2011]

A comprehensive study on the accuracy of collocated Parsivel, JW, and 2dvd was conducted by employing six-month-long database from Northern Alabama. The impact-type disdrometer measured small drops more accurately while 2dvd was able to capture large drops. The collocated gauge was considered a reference for event rainfall. A manuscript will be submitted on this research during the second half of 2011.

An investigation on the variability of raindrop size distribution within a satellite footprint is underway using the disdrometer data sets from WFF and Spain. Two graduate students, Jan-Bernd Schroer of University of Bonn, Germany and Ramiro Checa of University of Llada, Spain, are leading these efforts. The correlation distances at WFF ranged from 45 km in stratiform rain to 2 km in convective rain.

A field campaign conducted in Northeast Brazil showed that Parsivel overestimates the size of large drops. As a result, the rain accumulation in Parsivel was quite high when compared to the collocated gauges and JW. Additionally, a new version of Parsivel became available for testing purposes and the comparisons with impact-type disdrometer, old version of Parsivel, and rain gauges are underway at the roof of Building 33 at the NASA Goddard Space Flight Center. The new version measures the small raindrops more accurately than the old version.

A field campaign was conducted in Northern Central Oklahoma where the deep convective events were sampled as part of the GPM validation efforts. A network of autonomous Parsivel and video disdrometers as well as rain gauges was deployed with a satellite footprint. At the central facility, vertically pointed radars and disdrometers were collocated for the measurement accuracy. Very large drops were observed during the field campaign and Tokay processed the disdrometer and gauge data, which was uploaded to the DAAC.

Objectives for FY 11-12

Tokay expects to complete these ongoing studies and submit three manuscripts to peer-reviewed journals. The recently completed field campaign datasets brought new opportunities to study the instrument accuracy, and the variability of rainfall within a satellite footprint. The small-scale variability of rainfall will be further evaluated through a specialized rain gauge network in the mid-Atlantic region. The new network will include dual 25 gauge sites, which will cover a 5 x 5 km area. The available disdrometers and NASA's S-band polarimetric radar will be utilized in the experiment. Measurements of raindrop size distribution have been continuously collected on the roof of NASA GSFC Building 33. This site is expected to serve multi-purpose science objectives among GSFC colleagues. Also, Tokay will participate in a cold climate field campaign during early 2012 in Ontario, Canada. It is expected that a field campaign in mountainous North Carolina will be conducted where the focus will be the hydrological validation.

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Climate and Radiation
(Code 613.2)

JCET Highlight: **Aerosols enhance Convective Vigor and Lightning for Maritime Clouds**

Investigators: **Tianle Yuan (JCET); L.A. Remer, K.E. Pickering, H. Yu**

Volcanoes can emit sulphur dioxide gases. These gases can be oxidized in the atmosphere and turn into tiny particles called aerosols. NASA satellites are capable of observing this process: the map in Figure A shows sulphur dioxide gas concentration measured by NASA's OMI on June 14, 2005 and the map in Figure B shows the corresponding aerosol concentration meausured by MODIS.

Anatahan is an active volcano on the northern Mariana Islands (red dots in Figures A and B). It was active in summer 2005 and increased aerosol concentrations downwind (west of it) by 60% (the bump in Figure C). We show that as a result the number of lightning flashes increased dramatically (by 150%) above its usual value over the same area downward of the volcano, the bump in Figure D. This solves a long-standing mystery surrounding tall towers of cumulonimbus over tropical warm waters: unlike their continental counterparts, these clouds are very quiet and lightning is seldom observed inside them. Our study indicates that the lack of lightning over ocean is at least partially due to the lack of aerosols. The theory behind the lightning increase by aerosols is detailed in Yuan *et al.* (2011) and can be summarized by the following chain reaction: aerosols slow down the rain process, enhance the vigor inside the clouds, create more charges, and produce more lightning.

JCET Highlight: Aerosols enhance convective vigor and lightning for maritime clouds
Investigator: Dr. Tianle Yuan

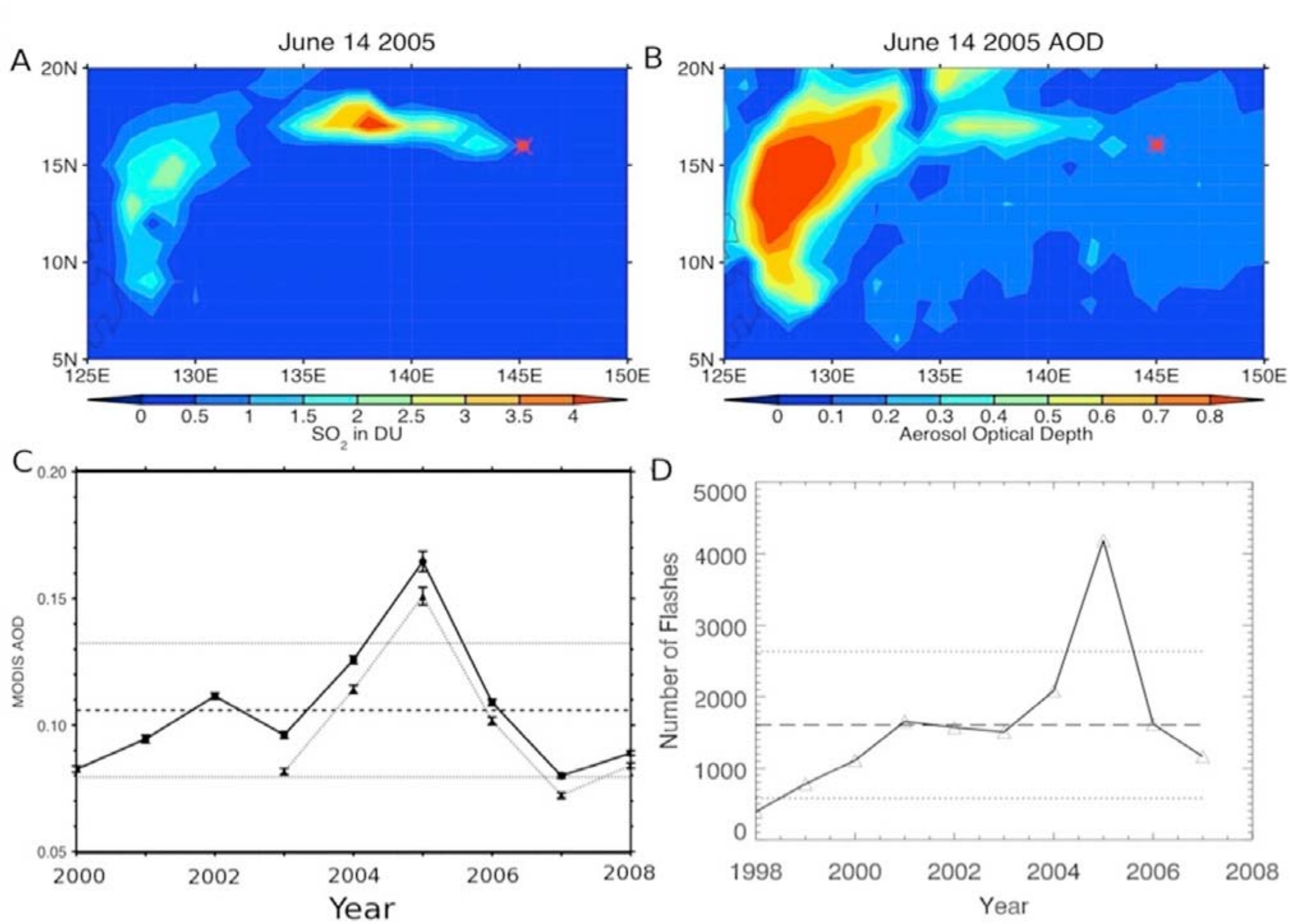

Fig. A: Sulphur dioxide concentration map measured by Ozone Monitoring Instrument (OMI) on June 14, 2005. The volcano is noted as the red dot in the map. *Fig. B*: On the same day, aerosol concentration map measured by MODIS. *Fig. C*: Time series of aerosol concentration year by year from both Terra and Aqua MODIS (dotted thin line). *Fig. D*: Time series of number and lightning flashes measured by TRMM Lightning Imaging Sensor. Note, there is a big bump in both the aerosol concentration and number of lightning flashes in 2005.

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Task 321: **Satellite measurements of aerosol properties near clouds** *(Sponsor: R. Cahalan)*

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

Investigators: Tamás Várnai, Research Associate 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 understanding of 3D radiative processes that occur in and around clouds. Várnai's work focuses on four particular areas. First, it examines the influence of 3D radiative interactions on solar heating and cloud development. Second, it investigates the uncertainties 3D radiative processes cause in satellite retrievals of cloud optical thickness and aerosol properties near clouds, and uses the results to examine the changes in aerosol properties that occur near clouds. Third, it explores 3D radiative processes in lidar measurements of thick clouds, snow, and sea ice. Fourth, it brings improvements to the 3D radiative transfer tools available to the research community by coordinating model intercomparisons and providing on-line resources.

Accomplishments for FY 10-11

This year Várnai's team continued their research on the impact of 3D radiative processes on solar radiative heating and cloud development. In order to enable dynamical atmospheric simulations to consider the 3D nature of radiative processes, they kept developing a new radiation parameterization. This parameterization provides a correction factor to the 1D radiation modules used in current dynamical simulations by using a neural net. Early testing indicates that the parameterization can significantly improve upon the accuracy of 1D radiation calculations. They also completed the analysis of 3D radiative processes in the dataset used for training the new parameterization. This dataset includes observed cloud structures and simulated radiation fields for clouds observed over three years at three sites of the Department of Energy Atmospheric Radiation Measurement program. The results [Várnai, 2010] indicate that 3D effects increase large-scale long-term average solar heating and satellite radiances, especially for high sun and for cumuliform clouds. The findings also indicate locally strong 3D effects in a large portion of cloudy regions.

Várnai and his collaborators also continued to research 3D radiative processes that affect satellite retrievals of aerosol properties in the vicinity of clouds. They began by analyzing a dataset of 1 km-resolution aerosol products obtained by the experimental MAIAC algorithm. Initial results revealed that, as expected from theoretical studies, 3D effects often increase the retrieved abundance of small particles near clouds. To help understand changes in particle properties without interference from 3D radiative processes, they completed the analysis of a CALIOP lidar dataset that is not influenced by 3D processes [Várnai and Marshak, 2011]. In order to characterize the influence of cloud and aerosol properties on near-cloud changes both in particle characteristics and in satellite-measured radiances, they built a yearlong dataset of co-located CALIOP and MODIS data. An initial analysis of this dataset revealed distinct geographical patterns and seasonal cycles in both particle and radiance changes near clouds. They also found that complications, such as clouds developing or drifting in the roughly one minute between CALIOP and MODIS observations, had only minor effects, and that when the analysis was limited to aerosols detected with the highest confidence possible, particle changes were limited to a narrower zone around clouds.

Finally, as part of the Intercomparison of 3D Radiation Codes project, Várnai's team completed and released to a select group of researchers the initial version of the first online 3D radiative transfer calculator.

Objectives for FY 11-12

Next year Várnai plans to complete the development of a parameterization that is fast enough to allow 3D radiative calculations in dynamical models of cloudy atmospheres, and to examine the impacts of considering 1D, 2D, or 3D radiative processes.

In addition, Várnai plans to continue exploring the 3D radiative effects through which clouds influence aerosol measurements near them, and to continue developing a technique that will adjust aerosol measurements for the influence of 3D effects. This will include both radiative simulations and further analysis of high-resolution retrievals of aerosol optical thickness and particle size distribution.

He and his team will also further analyze their new dataset of co-located MODIS and CALIOP data with the goal of understanding spatial and seasonal patterns in particle changes near clouds, and to understand the impact of aerosol and cloud properties on these changes.

They intend to use their datasets of simulated clouds and cloud structures observed at DOE sites for examining the implications of 3D radiative effects in 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.

Finally, Várnai plans to further improve the I3RC website so that it provides additional resources for the 3D community, including the new online 3D radiative transfer calculator.

Atmospheric Chemistry and Dynamics (Code 613.3)

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Task 302: **Development of Active and Passive Sensors for Remote Sensing Applications** ***(Sponsor: William Heaps)***

Investigator: Elena Georgieva

Collaborators: William Heaps (GSFC, Code613.3), Elizabeth M. Middleton (Code 614.4), Petya K. E. Campbell (JCET/UMBC), Emily Wilson Steel (GSFC, Code 694), Wen Huang (SSAI, Code 613.3), Huguens Jean (Code 554)

Description of Research

This research is focused on developing passive and active sensors for remote sensing determination of various atmospheric trace gases. The objective for the active sensor work is to build up a unique airborne laser system for measuring carbon dioxide changes in the lower atmosphere, using as its detector a section of the Fabry-Perot (FP) Interferometer constructed as a passive sensor during previous years. The advantages of this new approach are that it reduces the number of lasers required for the measurement; by reducing the risk for a space borne system, it places much of the responsibility for wavelength control on the detector rather than the laser, eliminating one of the difficulties facing presently proposed laser systems. It also provides a straightforward path to space since the majority of components involved in construction of the system have already flown on satellites. The work in the laboratory includes building and testing the new laser transmitter for CO_2 measurements using a Nd:YAG (neodymium-doped yttrium aluminium garnet) laser and an Optical Parametric Amplifier (OPA); using a Nd:YAG laser and an Optical Parametric Amplifier (OPA) for the 1.57 micron lidar receiver and conducting tests; building and testing a lidar receiver for 2 microns; and, developing a miniaturized gas correlation radiometer (GCR) for column trace gas measurements in the Martian atmosphere. This work is focused on reduced size gas correlation radiometer that will simultaneously measure and localize the sources of four trace species important for identifying active regions on the Mars surface to identify landing sites.

Accomplishments for FY 10-11:

Georgieva completed the development of a lab prototype of a new lidar for CO_2 measurements. The broadband lidar uses an optical parametric amplifier pumped by a Nd:YAG laser. This offers the highest power at the lowest cost for the purposes of Georgieva's demonstration.

Georgieva actively participated in two flight campaigns on a NASA DC-8 research airplane. For over five weeks, she worked to install and test the broadband lidar instrument in the belly of the DC-8 at the NASA Dryden Aircraft Operations Facility in Palmdale, CA. The broadband lidar has succeeded in making an airborne measurement of CO_2 in its first ever field trial. During the May flight, the system exhibited about a 4% change in the t=0 absorption ratio down and back up while the laser power was falling. During most of the flight, it was stable to better than 1%; in the last hour of the flight, it drifted down and back about 4%. The cargo bay where the laser is mounted is subject to large changes in temperature and the lidar system has no protection from these swings. The gain of the researchers' APD detectors is known to change with temperature. Georgieva believes they can correct for these changes to some extent, but they cannot determine with certainty if changes in laser wavelength are responsible for a slight change in the ratio.

Throughout the year, Georgieva presented the results of her work at national and international conferences, including the IGARSS, SPIE and AGU 2009 fall meetings.

Also, in addition to the experimental optical engineering work in the lab, Georgieva continued to work on data analysis and modeling using IDL routines. She is also a co-investigator on several proposals submitted to NASA ROSES Research opportunities, which are detailed in the Appendices (Proposals Submitted).

Objectives for FY 11-12

Georgieva's principal goal is to demonstrate the ability of the Fabry-Perot Interferometer technique to be used to make ultra precise determinations of the total column abundance for CO_2 and O_2. She and her team are planning for new airborne tests with the lidar system for CO_2 measurements. They will also study the calibration of both ground and flight versions. The development of the miniaturized gas correlation radiometer (GCR) for column trace gas measurements in the Martian atmosphere will continue, and they will also continue to refine the precision of the CO_2 system as a ground-based and airborne system, particularly for use in the validation of GOSAT.

NASA Grant:	**Improving an Air Quality Decision Support System through the integration of Satellite Data with Ground-Based, Modeled, and Emissions Data (NNH07ZDA001N)**
NASA Grant:	**Multi-Sensor Data Synergy Advisor (NNX09AH65G)**
Task 309:	**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** *(Sponsor: K. Pickering)*
Task 310:	**Utilization of NASA Atmospheric Products for Improved Nutrient control decisions in the Gulf of Mexico** *(Sponsor: K. Pickering)*
Task 323:	**Coordination of NASA Air Quality and Water Resource Management** *(Sponsor: G. Leptoukh)*
Investigators:	Ana I. Prados; Uma Shankar, University of North Carolina, Shawn McClure (co-I), CIRA; Greg Leptoukh (PI), NASA/GSFC; Ken Pickering (PI), NASA/GSFC; Dale Allen (co-I), University of Maryland College Park; Shahid Habib (PI), NASA/GSFC; Jeff Stehr (co-I), University of Maryland College Park; Amita Mehta (JCET).

Description of Research

Prados led a capacity building project for the NASA Applied Sciences program on the utilization of NASA remote sensing data for air quality management applications internationally and across the U.S. In April 2011, Prados began the development of trainings and other capacity building activities for water resources management and climate applications, to include the identification of end-users and application areas that could benefit from NASA remote sensing and model data products. Applications research focused on analyzing Ozone Monitoring Instrument (OMI) NO_2 observations to examine the region of influence from clusters of electrical generating units on air quality in the eastern U.S. This work also supported the development of the Visibility Information Exchange Web System (VIEWS), which makes available a variety of NASA Earth science data sets, modeling, and surface *in situ* observations.

Accomplishments for FY 10-11:

During this reporting period, Prados coordinated NASA Applied Sciences Program air quality and water resources management remote sensing trainings. A total of six air quality remote sensing workshops were developed during the past year. The main purpose of the training workshops is to enable scientists, managers and other technical staff who support decision-making activities to utilize NASA observations and decision-support tools for environmental management applications. Workshops include hands-on activities and examples of applications via Case Studies. Prados and her collaborators conducted the first training at a state regulatory agency, the California Air Resources

Board, which was preceded by a lecture for air quality managers in California provided by the PI. The result was increased interest and understanding of NASA products capabilities for air quality applications. The project increased the number of applied end-users reached through the program via trainings in EPA Region 9 (California), Region 4 (North Carolina), and internationally via training workshops in Vietnam and Australia. Prados also provided information about the project at several conferences (*Prados, et al.*, 2010c, 2011a, 2011b, 2011c, 2011d, see Appendices) and via many seminars at universities and U.S government agencies (*Prados, et al.*, 2010d, 2010e, 2010f, 2010g, 2011e, 2011f, see Appendices). The purpose of these public presentations was to gather interest from the scientific communities in contributing their research results to the program, and to increase awareness among potential end-users regarding NASA capacity building activities. A book chapter was published in <u>The Handbook of Satellite Remote Sensing Image Interpretation: Applications for Marine Living Resources Conservation and Management</u> [*Prados, et al.,* 2010a]. This details how atmospheric trace gas data from the NAA OMI NO_2 instrument can be accessed and analyzed using the Giovanni online tool at NASA GSFC for assessing impacts on water quality.

Prados also provided guidance and remote sensing expertise to the VIEWS project, to include information on OMI NO_2, MODIS AOD, and OMI AOD. She provided expertise on access to Level 2 and Level 3 datasets from various NASA data archiving centers, how to read the data files, dataset formats, metadata, and spatial and temporal characteristics of the datasets. She also continued 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. to help inform air quality management activates at the Environmental Protection Agency (EPA). Modeled NO_2 concentrations from the EPA Community Multiscale Air Quality (CMAQ) Model were used to identify areas of influence from coal burning electrical generating units, and the information was used to better refine both the satellite OMI NO_2 and GOME NO_2 trend analysis. For the NASA project entitled "Utilization of NASA Atmospheric Products for improved Nutrient control decisions in the Gulf of Mexico", OMI NO_2 data were regridded to the CMAQ model grid to help facilitate the utilization of NASA satellite data by the air quality modeling community.

The Multi-Sensor Data Synergy Advisor (MDSA) is a service that provides end-users with better interpretation and utilization of parameter difference and correlation visualizations within the Giovanni online webtool at NASA GSFC. An initial Sensitivity Study was performed comparing Polar Orbiting and Geostationary Aerosol Optical Depth. Instrumentation on Polar Orbiting satellites is available once daily, whereas Geostationary AOD instruments provide observations at higher temporal resolution. Because aerosols can exhibit high temporal variability, a user comparing observations between these two instruments needs to be informed of potential biases that could be due to the differences in their temporal resolution. The results of this sensitivity study are currently not easily accessible to end-users but will become available through the

Giovanni MDSA advisory service to help advance aerosol research and inform future NASA missions such as GEO-CAPE.

Objectives for FY 11-12

In FY11-12 research activities related to OMI NO_2 trends over the eastern U.S will provide a final package to be delivered to the U.S EPA to enable incorporation of NASA OMI NO_2 trend analysis into their routine air quality assessment activities. Prados will also continue to coordinate NASA satellite training activities for air quality and water resources management applications. The main goals will be to identify additional end-user communities that could benefit from NASA data for air quality applications and to develop initial capacity building opportunities to help support managers' risk management activities as it relates to the impact of climate change on water resources, floods, and droughts.

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Hydrospheric and Biospheric Sciences (Code 614)

JCET Highlight: **Photosynthesis from Space**

Investigators: **Dr. Forrest Hall (JCET), Dr. Thomas Hilker**

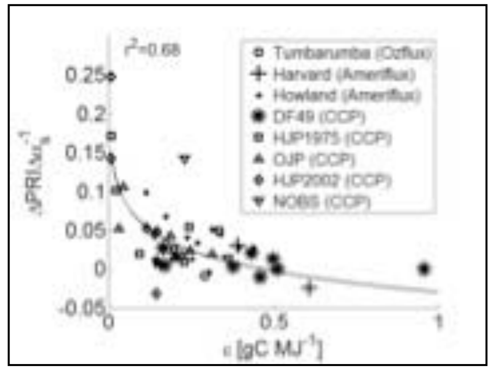
One of the largest factors contributing to the uncertainty in the atmospheric exchange of terrestrial carbon and moisture is the inability to measure the regional-scale photosynthetic uptake of carbon uptake and evapotranspiration from terrestrial vegetation. Currently, photosynthesis, or gross ecosystem productivity (GEP), can only be estimated using surface-vegetation-atmosphere (SVAT) models that rely on approximate methods to calculate light-use efficiency (LUE), a highly variable fraction expressing the ratio of carbon fixation to absorbed light. Soil fertility, soil moisture and atmospheric humidity are key controlling variables. Soil moisture cannot be measured remotely with sufficient accuracy and soil fertility cannot be measured remotely at all. In two recent publications, Hall and Hilker have used the European satellite CHRIS/Proba, a MISR-like instrument capable of making instantaneous multi-angle measurements of PRI, a narrow waveband spectral index that is directly related to the biochemical control of photosynthesis, and shadow fraction simultaneously. In this work, they showed theoretically that the change in PRI with shadow fraction (α) is a robust measure of LUE. They validated the theory over a range of global forested ecosystems (Fig. A). Their satellite inference of LUE using the derivative ΔPRI $\Delta\alpha^{-1}$ to infer LUE compared well with theory and tower data (Fig. B). Their new approach mitigates most of the problems inherent when using single-angle observations of PRI to estimate LUE: variation in the PRI-LUE relationship caused by variations in the PRI of non-photosynthetic canopy elements; variation in unstressed PRI with biome type; variation in α with view angle. With such an imager, periodic observations of LUE from space could be used in a data assimilation scheme with SVAT models to greatly improve estimates of carbon uptake and evapotranspiration.

Hall, F.G., T. Hilker and N.C. Coops (2011), PHOTOSYNSAT, Photosynthesis from space: Theoretical foundations of a satellite concept and validation from tower and spaceborne data (2011), *Rem. Sens. Env.*, doi:10.1016/j.rse.2011.03.014.

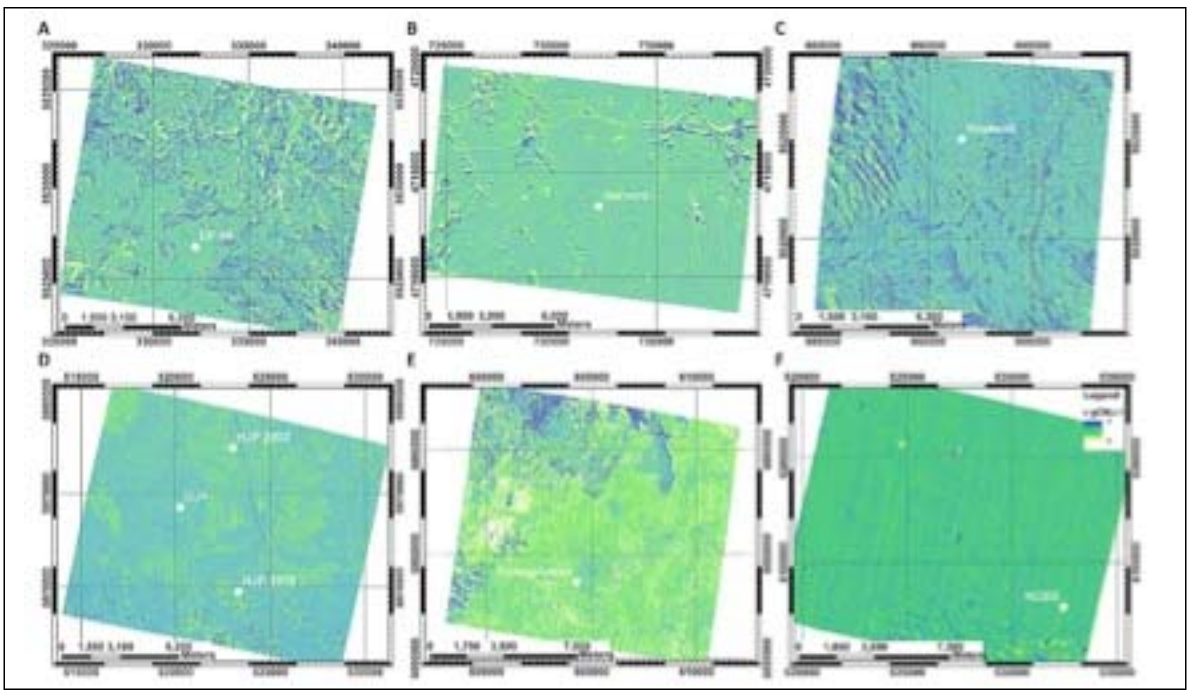
Hilker, T., N.C. Coops, F.G. Hall, C. J. Nichol, A. Lyapustin, T. A. Black, M. A. Wulder, R. Leuning, A. Barr, D. Y. Hollinger, B. Munger, and C. J. Tucker (2011), Global Terrestrial Photosynthetic Light-Use Efficiency Can Be Inferred from Space, *JGR- Biogeosciences*, (in press).

JCET Highlight: Photosynthesis from Space
Investigators: Dr. Forrest Hall (JCET) and Dr. Thomas Hilker

(A)

(B)



(C)

Fig. A: Location of research sites from which both CHRIS/Proba and eddy-flux data were available (2001-2009); *Fig. B*: Relationship between ΔPRI $\Delta\alpha^{-1}$ (PRI') as predicted theoretically (black line) and observed (symbols) from CHRIS/Proba (y-axis) and eddy correlation towers (x-axis); *Fig. C:* LUE images from CHRIS/Proba for eight different research sites.

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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/GSFC.

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

Investigators: P. Campbell; E. Middleton, Biospheric Sciences Branch, Laboratory for Terrestrial Physics, NASA/GSFC.

Description of Research

With the changing climate, it has become critical to understand the dynamics of ecosystem carbon uptake through seasonal changes and in response to environmental conditions such as water, temperature, and light and nutrient availability (Sarmiento and Wofsy 1999; Walther et al. 2002). Remote sensing offers a unique opportunity to monitor ecosystems at synoptic time and space scales through observation and understanding of ecosystem carbon-related spectral responses. A measure of ecosystem carbon uptake is the photosynthetic light use efficiency (LUE), a ratio of the Gross Ecosystem Production (GEP) to the Absorbed Photosynthetically Active Radiation (APAR), or LUE = GEP/APAR.

The distributions and compositions of ecosystems are largely regulated by environmental factors, such as temperature, water availability, nutrient accessibility, atmospheric CO_2, and sufficient sunlight. All of these factors have been studied in the context of particular questions, but the role of sunlight on the LUE of vegetation at all scales (leaf, plant, canopy, ecosystem) needs more study. Campbell's previous study at multiple sites found that the sunlit foliage fraction under relatively high solar irradiance levels typically displays short-term and reversible physiological stress that causes reduced LUE. In contrast, the shaded fraction, which is correlated to the total leaf area, maintains its LUE unless the high irradiance intensities are associated with unfavorably high temperatures or water deficits, although a large leaf volume in a canopy buffers these negative influences. In this successor project to the previous study, she and her team will develop and test models of leaf and canopy level radiative transfer, photosynthesis, and spectral reflectance, utilizing their existing body of accumulated measurements to simulate ecosystem-level carbon and water dynamics in our experimental systems (cornfield, deciduous forest). Existing datasets will be supplemented with their focused field measurements for model parameters and with EO-1 Hyperion satellite imagery. From combined *in-situ* information and remote sensing data, they will determine how the carbon uptake/efficiency is affected by the partitioning of the canopy into functionally different sunlit and shaded foliage fractions, as expressed with the PRI and other stress indices including solar-induced chlorophyll fluorescence (SIF), as well as chlorophyll-related spectral indices. They will verify that the daily and seasonal changes in the sunlit and shaded canopy fractions constitute an important ecological factor in carbon balance that affect the GEP as determined for the whole ecosystem by eddy covariance methods. Their investigation of carbon uptake/efficiency will extend through models for selected ecosystems, utilizing several IPCC future climate scenarios that affect PAR environments, such as increased cloudiness or increased diffuse/direct PAR ratios due to atmospheric aerosols. This research will support future missions (*e.g.*, HyspIRI) by providing optimal remote sensing strategies and a critical modeling tool for monitoring ecosystem stress (*i.e.*, down-regulation of GEP) and a better understanding of the role of canopy structure in defining ecosystem carbon uptake.

Campbell (Co-I) leads the EO-1 Hyperion satellite and other associated data processing, assisting with project coordination, participating in data collections, image processing, data analysis, spectral algorithm development, data base coordination, and publications. The goal is to detect early vegetation stress based on bio-physiological, fluorescence and spectral optical reflectance remote sensing, using field, airborne and spaceborne (EO-1 Hyperion) spectral radiometers. The research will result in developing and validating algorithms and cost-effective remote sensing techniques for assessing vegetation stress and physiological condition. Also, the abilities of passive and active spectral measurement approaches for assessing vegetation photosynthetic rate and physiological conditions will be compared. Her team will conduct evaluations of change in vegetation spectral reflectance as affected by CO_2 and N variability, and by diurnal and seasonal dynamics.

Accomplishments for FY 10-11

EO1 Hyperion

The goal is to compare existing and suggest new land cover products, addressing vegetation type and function. Initiated in Spring 2007, this effort uses the only available spaceborne spectrometer (EO-1 Hyperion) to contribute to comparing current data products, generated by multiple and frequently disparate systems. Datasets and comparisons were 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 contributes toward the development of recommendations in the NRC Decadal Survey: HyspIRI (Hyperspectral/IR Imagery) and GEO-CAPE (Geostationary Coastal and Air Pollution Events) missions.

Spectral Bio-Indicators of Ecosystem Stress

Recent studies demonstrated that superior results are attainable with narrow band visible/near-infrared spectral reflectance analyses, 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. High spectral resolution reflectance data obtained for vegetation over a range of functional types, species, phenology, and stress conditions were evaluated to establish which spectral algorithms perform rigorously with respect to correlation to photosynthetic function and efficiency. Reflectance data having contemporaneous photosynthetic data were assembled from various field measurement projects by Campbell's team and other investigators; this data set was supplemented by additional focused data collections. The impact of chlorophyll fluorescence contributing to the apparent red edge reflectance was also considered. 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. The high performance of candidate spectral bio-indices, ascertained from an *a priori* list compiled from previous research, is being evaluated for remote sensing application at ecosystem scales at the AmeriFlux and at 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 a NASA program 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).

Fluorescence for carbon science research (at 10 %)

Improving the current state of knowledge of the links between the global C and N cycles is essential to the successful interpretation of current and future feedbacks between the atmosphere and the terrestrial biome. More research is required to study photosynthetic dysfunction 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. Fluorescence from vegetation can relate inversely to photosynthetic efficiency and directly to chlorophyll concentration, and offers a non-destructive, fast alternative with diagnostic potential for early detection of changes in photosynthetic capacity, efficiency, rate, and the detection of disturbances in the photosynthetic system. As result from this effort, they expect to 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.

Support for NOAA's GOES-R calibration and validation in specific technical areas

Along with Drs. Ungar and Middleton, Campbell is working on NOAA/NASA MOU to support NOAA's GOES-R calibration and validation in specific technical areas, using EO-1 Hyperion data. NOAA's GOES-R Cal/Val Working Group oversees the development and implementation of the calibration/validation of the GOES-R instruments. Its goal, to ensure that each instrument's calibration complies with the requirements set forth in the instrument performance requirements, is referenced to recognized international standards, and conforms to "best" calibration/validation practices. The working group consist of scientists from NOAA, NASA, NIST, and the instrument manufacturers. GOES-R is NOAA's next-generation geostationary satellite with an improved Advanced Baseline Imager as the main payload. ABI has six reflective solar bands in the 0.4-2.5 mm spectral region, compared to one band for the current GOES Imager. Preliminary studies show that NASA's EO-1/Hyperion hyperspectral observations, which cover the same spectral range but with a much finer spectral resolution, are very useful for ABI calibration in characterizing the vicarious calibration targets, such as the deep convective clouds (DCC), the moon, and desert sites. Unfortunately, the Hyperion data are not acquired globally and therefore special arrangements have to be made for such studies. In addition, the operational processing of Hyperion data is not optimized for calibration purposes. Furthermore, the Hyperion sensor artifacts and impacts on calibration have to be well understood.

In addition to her research, Campbell participated in and presented research findings at professional meetings: HyspIRI Symposia at NASA/GSFC, II HyspIRI Workshop, and 2011 AmeriFlux Science Meeting & 3rd NACP All-Investigators Meeting.

Objectives for FY 11-12

Regarding the EO-1 Mission, Campbell's goals include data analysis and product generation in support of future satellite missions, developing new demonstration Level 2 science products, as prototypes for HyspIRI, assisting in the collection/generation of an EO-1 archive of research Level 0, Level 1 and 2 data, Hyperion seasonal and yearly composites over cal/val sites and targeted vegetative sites, and providing scientific support for the user community, including the HyspIRI team.

As a member of the NASA/GSFC HyspIRI group, (led by Dr. Middleton) Campbell will participate in and contribute to determining the spectroscopy requirements for the future hyperspectral mission. In preparation for HyspIRI data use, and to contribute toward the development of the mission's concepts, Campbell plans to assemble existing data sets covering both rural and urban environments from AVIRIS, MASTER, EO-1 Hyperion and ASTER. To provide confirmation for the findings, data sets for two independent locations with different regional climate, ecosystem types and functional groups will be compared. The results from the HyspIRI-like data (60 m spatial resolution) will be compared to data sets having 30 and 90 m spatial scales. By fusing spectroscopy and thermal remote sensing this study will highlight the potential of HyspIRI-like data for delineating and monitoring UHI, discriminating natural versus urban ecosystems, and assessing ecosystems diversity, health and sustainability.

She also aims to verify that the daily and seasonal changes in the sunlit and shaded canopy fractions constitute an important ecological factor in carbon balance that affect the GEP as determined for the whole ecosystem by eddy covariance methods. Investigating carbon uptake/efficiency will be extended through models for selected ecosystems utilizing several IPCC future climate scenarios that affect PAR environments such as increased cloudiness or increased diffuse/direct PAR ratios due to atmospheric aerosols. This research will support future missions (e.g., HyspIRI, DESDnyI) by providing optimal remote sensing strategies and a critical modeling tool for monitoring ecosystem stress (i.e., down-regulation of GEP) and a better understanding of the role of canopy structure in defining ecosystem carbon uptake.

Task 320: **Algorithm and Analytic Techniques via Various Sources**
(Sponsor: Jon Ranson)

Investigator: Forrest G. Hall

Description of Research

Hall's research during the past year involved five general activities. First, he was PI on a new radar/optical satellite project to combine radar and passive optical satellite data for biophysical parameter estimation. Second, he was involved in the development of a new satellite concept for direct measures of light use efficiency and gross primary production. Third, he formulated the DESDynI mission to measure vegetation 3D structure using lidar. Fourth, he participated in a climate study investigating the impact of vegetation feedbacks on climate sensitivity. Fifth, Hall was named Manager of GSFC's newly established Carbon Office.

Accomplishments in FY 10-11

Radar/Optical BioPHYS

Hall wrote and won a proposal to develop an algorithm to retrieve biophysical parameters using both radar and optical satellite data. This resulted in a rehire of Dr. Derek Peddle to JCET. A paper with one of Dr. Peddle's students, Soenen *et al.,* 2010, was the number one "Hottest Article" on SciVerse Direct for the period April to June 2010. In this radar/optical satellite project, Hall will extend a physically-based algorithm developed in past research (BioPHYS) to incorporate L-band radar data together with passive optical data to infer vegetation 3D structure in sparse to medium density forested ecosystems.

Vegetation Light Use Efficiency

The light use efficiency (LUE) effort is focused on the remote sensing of ecosystem primary production using multi-view angle 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 an international team of investigators; together, they are developing a new satellite concept and proposing a hardware build. Hall's research team has demonstrated by using tower and space-borne sensor data that multi-view angle remote sensing can retrieve vegetation LUE and gross primary production across vastly different biomes, climate zones and years. Three papers have been published (see Appendices). Hall also co-authored a review paper on the status of light use efficiency estimation from space, published in *Bioscience*. An Instrument Incubator Program Proposal was prepared and submitted to build a prototype instrument capable of making these new measurements. The proposal was not approved; other avenues are being investigated. Another proposal submitted to use the MODIS algorithm to produce regional light use efficiency data sets was also not funded.

DESDynI Mission Formulation Teams

Hall collaborated with the DESDynI mission formulation group, developing DESDynI mission requirements and participating in mission design exercises. Hall 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. He was co-editor on two special issues, now published, for DESDynI, one for the *Journal of Geophysical Research (JGR)* and the other for *Remote Sensing of Environment (RSE)*. In addition, Hall was the first author on a paper published recently in *RSE* summarizing the DESDynI mission. He has also co-authored another recent DESDynI paper published in *JGR-Biogeosciences*. The DESDynI mission unfortunately was cancelled. Hall has joined a new project, the Global Ecosystem Dynamics Mission (GEDI) to formulate a lidar mission for to fly aboard the International Space Station.

Vegetation feedback on climate

In the climate study, Hall collaborated with a small group to modify the Simple Biosphere model (SiB) to improve vegetation feedbacks. Hall and his team modified SiB to allow the vegetation forest photosynthetic rate to respond to climate changes (leaf area change) induced by doubled CO_2. The group ran SiB together with a general circulation model in a doubled CO_2 experiment. Hall co-authored a paper published in *Geophysical Research Letters* investigating the impact of vegetation on climate sensitivity. This paper "lit up the blogosphere" by showing that vegetation growth in response to doubled CO_2 would reduce the climate sensitivity by 0.6^oC.

GSFC Carbon Office

GSFC has been awarded funds to support a new applications project, the "Carbon Monitoring System". As manager of the GSFC Carbon Office, Hall coordinates carbon research, development and applications activities at GSFC. An important role of the carbon office is to coordinate technology infusion into the project. Hall prepared presentations on GSFC carbon cycle work and presented to Dr. Nicholas White, Director of GSFC Science Directorate. He also coordinated carbon research activities between the GSFC research and applications programs and GSFC's new Carbon Monitoring System applications project. Additionally, he gave several public lectures describing NASA's climate change research.

Objectives for FY 11-12

The three main activities for FY12 will be the continuation of algorithm development for biophysical variable retrievals with radar and passive optical satellite images. Hall has been funded to support the development of the GEDI mission, a lidar aboard the ISS. In 2012, he will also continue in the role of Manager of the GSFC Carbon Office. He will also continue to pursue work on photosynthesis from satellites by responding to NASA NSPIRES opportunities.

Task 79: **Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency and NASA Earth Observing-1 (EO-1) Mission, Scientific support for Hyperion data analysis and product development** ***(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, Sigma Space Corp.

Description of Research

The focus of this 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. Reflectances can be simulated with canopy reflectance models that 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 are used in models merging canopy reflectance with photosynthesis models to develop relationships linking spectral reflectance and carbon, water, and energy fluxes. These relationships are also explored at a canopy level using canopy-level reflectance measurements combined with ecosystem carbon flux measurements from flux towers and extended to wider scales using observations from the Earth Observing-1, Aqua, and Terra satellites.

Accomplishments for FY 10-11

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 work has shown that an index using two narrow spectral bands is related to light use efficiency, the rate of carbon dioxide taken up by plants for photosynthesis per unit of light absorbed by the canopy. He and his team have been studying a number of different sites with different vegetation types, where carbon fluxes between the ecosystem and atmosphere are measured. They compare optical signals detected by the satellite instruments with surface measurements of fluxes to understand the variability among sites.

To further examine vegetation spectral reflectance changes associated with stress in a more detailed manner, they conducted field experiments where they measure 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 scientists from the Smithsonian and the Department of Agriculture. They have collected hyperspectral reflectance data at multiple times diurnally in a cornfield, and these observations were compared 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, they go up in a basket suspended from a crane. These 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 in which it responds to stress conditions.

Also, Huemmrich worked with a group to develop science traceability matrices for a future satellite constellation that would collect data with high spectral, spatial, and temporal resolution to study ecosystem dynamics.

Additionally, Huemmrich is presently on the committees for five PhD students, two in the Forestry Department at Virginia Tech, one in the Geography Department at UMCP, one at the University of Idaho, and one in the Forestry Department at Laval University. He also was an external examiner for a Masters student at the University of New Hampshire.

Objectives for FY 10-11

Huemmrich will continue to work on the remote sensing of plant stress. He plans to publish the analysis using MODIS and Hyperion data to detect light use efficiency for multiple vegetation types, leading to the development of a model for ecosystem carbon uptake driven only by satellite data. He and his team will 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. They will also examine the use of narrow spectral band data to detect chlorophyll fluorescence and its relation to carbon fluxes, and work with combining thermal and spectral data to determine ecosystem water and energy fluxes along with carbon flux.

Also, he will continue to work on developing research activities on monitoring high latitude ecosystem changes, and will examine the use of high temporal frequency reflectance data in describing vegetation seasonality and temporal patterns of carbon flux.

Heliophysics & Solar System Divisions (Code 660-699)

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

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; landslide hazard and risk assessment; emergency management; 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 and has provided assistance during civil emergencies. Undergraduate classes taught have included Planetary Geology, Natural Hazards and Process Geomorphology. Process Geomorphology was taught as a 300-level course in UMBC's Department of Geography and Environmental Systems.

Accomplishments in FY 10-11

TOPOGRAPHY DATA ON MARS: OPTIMIZING ITS COLLECTION AND APPLICATION USING LASER SCANNING – NASA Mars Fundamental Research Program:

In year three of this grant, the project team has continued to make advances in their ability to identify the optimal collection parameters, analytical protocols, and supplemental data needed to resolve features on a terrestrial rocky surface. A particular focus this year has been on gaining greater understanding of the value of laser-scanned point clouds over traditional digital elevation or digital terrain models. The team has used first and last return points as well as intensity data. In addition, their thinking about future missions to Mars and other bodies considering topographic sensors has been further informed by involvement in responses to natural disasters such as the 2010 Monsoon floods in Pakistan. In their response to these events, the team has conceived of them as proxies for Mars missions. Using their experience of topography and current data collection plus analysis techniques they have provided input and recommendations to the emergency management community. They have continued to demonstrate how laser scanning-derived topography can substantially increase the interpretation of high-resolution images. Presentations on topography collection, analysis and dissemination have been given in expert and non-expert academic, government and commercial forums. Manuscripts submitted in year three continue to address issues related to characteristics of surface structures on blocky lava flows, handling of laser points clouds and dem generation, and bridging the gap between expert systems and non-expert decision makers. A variety of reports have been written predominantly focused on the natural hazards and the utility of topography data.

LANDSLIDE; TYPES, MECHANISMS, AND MODELING. CONTRIBUTED CHAPTER ON LANDSLIDES ON OTHER PLANETS - Cambridge University Press:

This two-volume book, aimed at fourth year and graduate students, contains 34 chapters. Part 1 covers Landslide Types and Mechanisms, Part 2 Geotechnical Aspects of Landslides and Part 3 Case Studies. Bulmer contributed a chapter in Part 1 entitled “Landslides on Other Planets”. In keeping with the theme of the book, the term *landslide*, which is a type of mass movement, is used to describe a movement of a mass of rock, earth or debris down a slope. In this paper, Bulmer defined mass movement as the geomorphic process by which soil, regolith and rock moves downslope under gravity. Mass movement categories include falls, topples, slides, flows and creep, each of which has its own characteristics. The process from failure to emplacement can occur over timescales of years to seconds. All slope-forming materials have a tendency to move downwards under the influence of gravity, which is counteracted by a shearing resistance. Slope failures can be triggered either by internal changes of shearing resistance or by external factors that produce an increase in shear stress. Mass movements in general, including landslides on extraterrestrial bodies, are of interest as agents of surface modification, and because their triggering and emplacement style reflects environmental conditions. Specific focus is given here to examining selected landslides on Mars, Venus and on the moon of Io orbiting Jupiter because they all have characteristics of long-run out landslides but have been triggered and emplaced in very different environments. Submitted on December 30, 2010, this chapter is currently in review.

In addition to the above research and textbook contribution, Bulmer continued with Staff Development efforts. He received objective, formative and summative assessments of his teaching, instructional and coaching skills. In 2010 he was awarded qualifications in Instructional Techniques, Train the Trainer, and received a certificate of coaching and motivation. He now holds an Edexcel Level 4 BTEC Professional Certificate in Teaching in the Lifelong Learning Sector and a Level 3 Award in Workplace Coaching for Team Leaders and First Line Managers from the Institute of Leadership and Management. He also developed the structure for a common collective training syllabus for a year-two reservist that be adopted across the Corps. All elements had to be mapped to certified statements of training requirements.

Objectives for FY 11-12

A Chapter Proposal entitled “Defining the Optimal Topographic Resolution for Process-Driven Studies” has been submitted for inclusion in a book entitled “Photogrammetry’ published by INTECH-ISBN 979-953-307. Additionally, proposals will be submitted to NASA Mars Data Analysis and Army Research Programs related to the manipulations of point cloud data.

III. Supporting Information

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III.1 References

Bell, T.L. and P.K. Kundu (1996), A study of sampling error in satellite rainfall estimates using optimal averaging of data and a stochastic model, *J. Climate,* **9**, 1251-1268.

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.,* doi:10.1029/2002JD002641.

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 (2010), 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.*, **10**, 977–996.

Kundu, P. K. and T.L. Bell (2003), A Stochastic Model of Space-time Variability of Mesoscale Rainfall: Statistics of Spatial Averages, *Water Resources Res.,* doi: 10.1029/2002WR001802.

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

Mehta, V. M., A. J. DeCandis, and A. V. Mehta (2006), Remote-sensing-based estimates of the fundamental global water cycle: Annual cycle, *J. Geophys. Res.,* **110**(D22), doi: 10.1029/2004JD005672.

Prados, A. I. (2010d), NASA Applied Sciences Remote Sensing Education and Training, *JCET Meeting*, Baltimore, MD, July 14.

Prados, A. I. (2010f), How to Access NASA Air Quality Imagery and Data Products, *Atmospheric Chemistry Brown Bag seminar, University of Maryland College Park*, November 5.

Prados, A. I. (2010g), How to Access NASA Air Quality Imagery and Data Products, *NOAA/NESDIS,* Camp Springs, Maryland, November 23.

Prados, A. I. (2011c), Teaching Climate Science and Policy*, Sally Ride Educator's Institute: Connecting with Climate Change 2011*, NASA Jet Propulsion Laboratory, Pasadena, CA, February 26.

Prados, A. I. (2011d), NASA Capacity Building Activities: Bridging the gap between science and policy, Invited talk, *The GAIA Climate, Climate Change and Public Health Conference*, Johns Hopkins University, Baltimore, Maryland, April 12-14.

Prados, A. I. (2011e), NASA Air Quality Capacity Building Activities: Bridging the gap between science and policy*, NASA GSFC Aerocenter Seminar*, February 15.

Prados, A. I. (2011f), NASA Air Quality Capacity Building Activities: Bridging the gap between science and policy, *NASA GSFC Atmospheric Chemistry and Dynamics Branch Seminar*, March 31.

Prados, A. I., R. Kleidman, and S. Christopher, and L. Friedl (2010c), NASA Applied Sciences Remote Sensing Education and Training, *Federation of Earth Science Information Partners, Summer Meeting*, Knoxville, TN, July 20-23.

Prados, A. I., and J. Acker (2010a), Impacts of European Atmospheric Air Pollution on Water Nutrients in the Atlantic Ocean, Baltic Sea, and Mediterranean Sea, Handbook of Satellite Remote Sensing Image Interpretation: Applications for Marine Living Resources Conservation and Management, *European Union PRESPO International Ocean Color Coordinating Group*, pp. 51-62, http://www.ioccg.org/handbook.html.

Prados, A. I., G. Leptoukh, C. Lynnes, J. Johnson, H. Rui, A. Chen, and R. B. Husar (2010b), Access, Visualization, and Interoperability of Air Quality Remote Sensing Data Sets Via the Giovanni Online Tool, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, Vol. 3, pp. 359-370.

Prados, A. I., R. Kleidman, and L. Friedl (2011b), NASA Applied Sciences Remote Sensing Education and Training, presented at the *American Association for the Advancement of Science Annual Meeting,* Washington D.C, February 17-21.

Prados, A.I. (2010e), NASA Applied Sciences Remote Sensing Education and Training, *Goddard Institute of Space Studies*, September 23.

Prados, A.I., R. Kleidman, and L. Friedl (2011a), NASA Applied Sciences Remote Sensing Education and Training, *Federation of Earth Science Information Partners, Winter Meeting*, Washington, DC, 4-6 January.

Rodgers, C. D. (2000), Inverse Methods for Atmospheric Sounding, Theory and Practice, Ser. Atmos. Oceanic Planet. Phys., 2, World Sci., Hackensack, NJ (cited by J. Warner).

Tokay, A., and P. G. Bashor (2010), An experimental study of small-scale variability of raindrop size distribution, *J. Appl. Meteor. Climatol.*, **49**, 2348-2365.

Tripoli, G. J. (1992), A nonhydrostatic numerical model designed to simulate scale interaction, *Mon. Weather Rev.,* **120**, 1342–1359.

Várnai, T. (2010), Multiyear statistics of 2-D shortwave radiative effects at three ARM sites, *J. Atmos. Sci.*, **67**, 3757–3762.

Várnai, T., and A. Marshak (2011), Global CALIPSO observations of aerosol changes near clouds, *IEEE Geosci. Remote Sens. Lett.*, **8**, 19-23.

Warner, J. X., M. M. Comer, C. D. Barnet, W. W. McMillan, W. Wolf, E. Maddy, G. Sachse (2006), A Comparison of Satellite Tropospheric Carbon Monoxide Measurements from AIRS and MOPITT During INTEX-A, *J. Geophys. Res.*, doi:10.1029/2006JD007925.

Warner, J. X., Z. Wei, L.L. Strow, C.D. Barnet, L. Sparling, G. Diskin, and G. Sachse (2010), Improved agreement of AIRS tropospheric carbon monoxide products with other EOS sensors using optimal estimation retrievals, *Atmos. Chem. Phys. Discuss.*, **10**, 11851-11883, doi:10.5194/acpd-10-11851-2010.

Yurganov, L., V. Rakitin, A. Dzhola, T. August, E. Fokeeva, G. Gorchakov, E. Grechko, S. Hannon, A. Karpov, L. Ott, E. Semutnikova, R. Shumsky, and L. Strow (2011), Satellite- and ground-based CO total column observations over 2010 Russian fires: accuracy of top-down estimates based on thermal IR satellite data, *Atmos. Chem. Phys. Discuss.,***11**, 12207-12250.

Yurganov, L., W. McMillan, C. Wilson, M. Fischer, and S. Biraud (2010b), Carbon monoxide mixing ratios over Oklahoma between 2000 and 2009 retrieved from the Atmospheric Emitted Radiance Interferometer spectra, *Atmos. Meas. Tech.*, **3**, 1319-1331.

Yurganov, L., W. McMillan, E. Grechko, and A. Dzhola (2010a), Analysis of global and regional CO burdens measured from space between 2000 and 2009 and validated by ground-based solar tracking spectrometers, *Atmos. Chem. Phys.*, **10**, 3479-3494.

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III.2 Peer-Reviewed Publications

Aumann, H.H., S. DeSouza-Machado, A. Behrangi (2011), Deep Convective Clouds at the Tropopause, *Atmos. Chem. Phys. Discuss.*, **10**, 16475-16796.

Battaglia, A., E. Rusteiemer, A. Tokay, U. Blahak, and C. Simmer (2010), PARSIVEL snow measurements: A critical assessment, *J. Atmos. and Oceanic Technol.*, **27**, 333-344.

Bounoua, L., F.G. Hall, P. J. Sellers, A. Kumar, G. J. Collatz, C.J. Tucker, and M. L. Imhoff (2010), Quantifying the negative feedback of vegetation to greenhouse warming: A modeling approach, *Geophys. Res. Lett.*, doi:10.1029/2010GL045338.

Bulmer, M.H. (2010), A geospatial approach? Pakistan Flood - Public Service Review: International Development, Issue 17, 16-17.

Bulmer, M.H. (2010), The 2010 Monsoon Flooding in South Asia: A Major Test of Resilience. *Analysis*, Royal United Services Institute, ref:C4C62742706820.

Bulmer, M.H. (2011), Worst-Case Scenario: The Tohoku-Pacific Ocean Earthquake. Royal United Services Institute, Analysis, Commentary, ref:C4D99EFC6CE5B5, dated 5 April 2011.

Bulmer, M.H., and T. Farquhar (2010), Design and Installation of a Prototype Geohazard Monitoring near Machu Picchu Peru, *Nat. Hazards Earth Syst. Sci.*, **10**, 2031–2038.

Cheng, Y.B., E.M. Middleton, K.F. Huemmrich, Q.Y. Zhang, P.K.E. Campbell, L.A. Corp, A.L. Russ, and W.P. Kustas (2010), Utilizing in situ directional hyperspectral measurements to validate bio-indicator simulations for a corn crop canopy, *Ecological Informatics,* **5**(5): 330-338.

Coops, N. C., T. Hilker, F. G. Hall, C.J. Nichol, and G. G. Drolet (2010), Estimation of Light-use Efficiency of Terrestrial Ecosystems from Space: A Status Report, *Bioscience*, **60**(10).

Corp, L.A., E.M. Middleton, P.E. Campbell, K.F. Huemmrich, C.S.T. Daughtry, A. Russ, Y.B. Cheng (2010), Spectral indices to monitor nitrogen-driven carbon uptake in field corn, *J. Applied Remote Sensing,* **4**, Article No. 043555.

DeSouza-Machado, S. G., L. L. Strow, B. Imbiriba, K. McCann, R. M. Hoff, S. E. Hannon, J. V. Martins, D. Tanré, J.L. Deuzé, F. Ducos, and O. Torres (2010), Using infrared radiances to study dust: A comparison of optical depths and heights derived for a North African dust storm using collocated A-Train and surface observations, *J. Geophys. Res. Atmos.*, **115**, D15201, doi:10.1029/2009JD012842.

Dong, X., A. Kennedy, Z. Feng, J. K. Entin, P. R. Houser, R. A. Schiffer, T. L'Ecuyer, W. S. Olson, K.-l. Hsu, W. T. Liu, B. Lin, Y. Deng, and T. Jiang (2011), Investigation of the 2006 Drought and 2007 Flood Extremes at the Southern Great Plains through an Integrative Analysis of Observations, *J. Geophys. Res. - Atmospheres*, **116**, doi: 10.1029/2010JD014776.

Finlay, C.C., A. Tangborn, *et al.* (34 authors) (2010), International Geomagnetic Reference Field: The Eleventh Generation, *Geophysical Journal International*, **183**, 216-230.

Fokeeva, E.V., A. N. Safronov, V.S. Rakitin, L.N. Yurganov, E.I. Grechko, and R. A. Shumski (2011), Influence of wildfires in July-August 2010 on carbon monoxide atmospheric pollution in Moscow and environs, emission estimates, *Physics of Atmosphere and Ocean, Bulletin of the Russian Academy of Sciences*, in press (in Russian).

Fournier, A., G. Hulot, D. Jault, W. Kuang, A. Tangborn, N. Gillet, E. Canet, J. Aubert and F. Lhuillier (2010), An introduction to data assimilation and predictability in geomagnetism, *Space Science Reviews*, **155**, 247-291.

Gamon, J.A., C. Coburn, L.B. Flanagan, K.F. Huemmrich, C. Kiddle, G.A. Sanchez-Azofeifa, D.R. Thayer, L. Vescovo, D. Gianelle, D.A. Sims, A.F. Rahman, and G.Z Pastorello (2010), SpecNet revisited: bridging flux and remote sensing communities, *Canadian Journal of Remote Sensing,* **36**, S376-S390.

Hall, F. G. (2011), PHOTOSYNSAT, Photosynthesis from space: Theoretical foundations of a satellite concept and validation from tower and space-borne data, *Rem. Sens. Env.*, doi:10.1016/j.rse.2011.03.014.

Hilker, T., A. Gitleson, N.C. Coops, F.G. Hall and A. Black (2010), Tracking plant physiological properties from multi-angular tower-based remote sensing, *Oecologia*, doi:10.1007/s00442-010-1901-0.

Huemmrich, K. F., G. Kinoshita, J.A. Gamon, S. Houston, H. Kwon, and W.C. Oechel (2010), Tundra carbon balance under varying temperature and moisture regimes, *J. Geophys Res.-Biogeosciences,* **115,** Article No. G00I02.

Jordan, N. S., J. Bacmeister, and R. M. Hoff (2010), Validation of Goddard Earth Observing System-version 5 (GEOS-5) Modern Era Re-analysis for Research (MERRA) PBL Heights Using Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), *J. Geophys. Res. Atmos.*, **115**, D24218, doi:10.1029/2009JD013777.

Kacenelenbogen, M., M.A. Vaughan, J. Redemann, R.M. Hoff, R.R. Rogers, R.A. Ferrare, P.B. Russell, C.A. Hostetler, J.W. Hair, and B.N. Holben (2011), An accuracy assessment of the CALIOP/CALIPSO version 2/version 3 daytime aerosol extinction product based on a detailed multi-sensor, multi-platform case study, *Atmos. Chem. Phys.*, **11**, 3981-4000, doi:10.5194/acp-11-3981-2011.

Kuang, W., Z. Wei, R. Holme, and A. Tangborn (2010), Prediction of geomagnetic field with data assimilation: A candidate secular variation model for IGRF-11*, Earth, Planets and Space*, **62**, 775-785.

Marks, D. A., D. B. Wolff, L. D. Carey, and A. Tokay (2011), Quality control and calibration of the dual-polarization radar at Kwajalein, RMI, *J. Atmos. Oceanic Technol.*, conditionally accepted for publication, **28**, 181-195.

Masunaga, H., T. Matsui, W.-K. Tao, A. Y. Hou, C. D. Kummerow, T. Nakajima, P. Bauer, W. S. Olson, M. Sekiguchi, and T. Y. Nakajima (2010), Satellite Data Simulator Unit (SDSU): A Multi-Sensor, Multi-Spectral Satellite Simulator Package, *Bull. Amer. Met. Soc.*, **91**, 1625-1632.

Oreopoulos L., M.J. Wilson, and T. Várnai (2011), Implementation on Landsat Data of a Simple Cloud Mask Algorithm Developed for MODIS Land Bands, *IEEE Geosc. & Rem. Sens. Lett.*, **99**, 597-601.

Peddle, D. R., S. Boon, A. P. Glover and F. G. Hall (2010), Forest structure without ground data: Adaptive Full-Blind Multiple Forward-Mode reflectance model inversion in a mountain pine beetle damaged forest, *Int. J. Remote Sensing*, **31**(8), 2123-2128.

Prados, A. I., G. Leptoukh, C. Lynnes, J. Johnson, H. Rui, A. Chen, and R. B. Husar (2010b), Access, Visualization, and Interoperability of Air Quality Remote Sensing Data Sets Via the Giovanni Online Tool, *IEEE Journal of*

Selected Topics in Applied Earth Observations and Remote Sensing, **3**, 359-370.

Shi, J., W-K. Tao, T. Matsui, R. Cifelli, A. Hou, S. Lang, A. Tokay, N-Y. Wang, C. Peters-Lidard, G. Jackson, S. Rutledge, and W. Petersen, WRF Simulations of the 20–22 January 2007 Snow Events over Eastern Canada: Comparison with in-situ and Satellite Observations, *J. Appl. Meteor. Climatol.*, **49**, 2246-2266.

Shugart, H. H., S. Saatchi, and F. G. Hall (2010), Importance of structure and its measurement in quantifying function of forest ecosystems, *J. Geophys. Res.*, **115**, G00E13, doi:10.1029/2009JG000993.

Soenen, S. A., D.R. Peddle, R.J. Hall, C.A. Coburn and F.G. Hall (2010), Estimating aboveground forest biomass from canopy reflectance model inversion in mountainous terrain, *Rem. Sen. Env*., doi:10.1016/j.rse. 2009.12.012 (*hottest article, Scopus, April to June 2010).

Tokay, A., and P. G. Bashor (2010), An experimental study of small-scale variability of raindrop size distribution, *J. Appl. Meteor. Climatol.*, **49**, 2348-2365.

Tokay, A., P. G. Bashor, and V. L. McDowell (2010), Comparison of rain gauge measurements in mid-Atlantic region, *J. Hydrometeor.,* **11**, 553-565.

Várnai, T. (2010), Multiyear statistics of 2-D shortwave radiative effects at three ARM sites, *J. Atmos. Sci.*, **67**, 3757–3762.

Várnai, T., and A. Marshak (2011), Global CALIPSO observations of aerosol changes near clouds, *IEEE Geosci. Remote Sens. Lett*., **8**, 19-23.

Warner, J. X., Z. Wei, L.L. Strow, C.D. Barnet, L.C. Sparling, G. Diskin, and G. Sachse (2010), Improved agreement of AIRS tropospheric carbon monoxide products with other EOS sensors using optimal estimation retrievals, *Atmos. Chem. Phys.*, **10**, 9521-9533, doi:10.5194/acp-10-9521-2010.

Weber, S. A., J. A. Engel-Cox, R. M. Hoff, A. Prados, and H. Zhang (2010), 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.*, **60**, 574-585.

Weldegaber, M. H., B. B. Demoz, L. C. Sparling, R. Hoff and S. Chiao (2010), Observational Analysis of Moisture Evolution and Variability in the Boundary Layer during the Dryline on 22 May 2002, *Meteor. Atmos. Phys.*, **110**, Numbers 3-4, 87-102, doi:10.1007/s00703-010-0109-5.

Winker, D. M., J. Pelon, J. A. Coakley, Jr., S. A. Ackerman, R. J. Charlson, P. R. Colarco, P. Flamant, Q. Fu, R. Hoff, C. Kittaka, T. L. Kubar, H. LeTreut, M. P. McCormick, G. Megie, L. Poole, K. Powell, C. Trepte, M. A. Vaughan, and B. A. Wielicki (2010), The Calipso Mission: A Global 3D View of Aerosols and Clouds, *Bull. Amer. Meteor. Soc.*, **91**, 1211–1229. doi: 10.1175/2010BAMS3009.1.

Yurganov, L., V. Rakitin, A. Dzhola, T. August, E. Fokeeva, G. Gorchakov, E. Grechko, S. Hannon, A. Karpov, L. Ott, E. Semutnikova, R. Shumsky, and L. Strow (2011), Satellite- and ground-based CO total column observations over 2010 Russian fires: accuracy of top-down estimates based on thermal IR satellite data, *Atmos. Chem. Phys. Discuss.,* **11**, 12207-12250.

Yurganov, L., W. McMillan, C. Wilson, M. Fischer, and S. Biraud (2010), Carbon monoxide mixing ratios over Oklahoma between 2000 and 2009 retrieved from the Atmospheric Emitted Radiance Interferometer spectra, *Atmos. Meas. Tech*., **3**, 1319-1331.

Zhang, C., J. Lin, S. Hagos, W.-K. Tao, S. Lang, Y. N. Takayabu, S. Shige, M. Katsumata, W. S. Olson, and T. L'Ecuyer (2010), MJO Signals in Latent Heating: Results from TRMM Retrievals, *J. Atmos. Sci*., **67**, 3488-3508.

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III.3 Publications Submitted for Review

Allen, D. J., K. E. Pickering, R. W. Pinder, B. H. Henderson, K. W. Appel, and A. Prados (2010), Impact of lightning-NO on eastern United States photochemistry during the summer of 2006 as determined using the CMAQ model, *Atmospheric Chemistry and Physics*, submitted.

Bulmer, M.H. (2010), Landslides on other planets, *Landslides; Types, Mechanisms and Modeling Part 1,* ed. John J. Clague and Douglas Stead, Cambridge University Press, submitted (ISBN 9781107002067).

Bulmer, M.H., S.W.Anderson, and L. S. Glaze (2010), Paradoxical Views of the Emplacement of Blocky Lava Flows at Sabancaya Volcano Provided by Morphological and Petrologic Characterization, *J. Geophys. Res.*, submitted.

Fentzke, J. T., R. Delgado, J. S. Friedman, S. Raizada, and C. A. Tepley (2011), Sporadic metal atom and ion layers and their connection to chemistry and temperature structure in the mesopause region at Arecibo, *J. Atmos. Solar. Terr. Phys.,* submitted.

Finnegan, D.C., S.A. Arcone, M. H. Bulmer, and S. W. Anderson (2010), Topographic Comparison of Rock Size Distributions Derived from High-Resolution Ground-Based LiDAR, *J. Geophys. Res.*, submitted.

Foster, J.L., G. Skofronick-Jackson, H. Meng, G. Riggs, B.T. Johnson, J. Wang, D. Hall, and S. Ngheim, (2010), Passive Microwave Remote Sensing of the Historic February 2010 Snow Storms in the Middle Atlantic Region of the U.S., *Hydrol. Proc.*, submitted.

Grecu, M., L. Tian, W. S. Olson, and S. Tanelli (2011), A Robust Dual-Frequency Radar Profiling Algorithm, *J. Appl. Meteor. and Climatol.* (in press).

Hall, F. G., K. Bergen, J. B. Blair, R. Dubayah, R. Houghton, G. Hurtt, J. Kellndorfer, M. Lefsky, J. Ranson, S. Saatchi, H.H. Shugart, D. Wickland (2011), Characterizing 3D Vegetation Structure From Space: Mission Requirements, *Rem. Sens. Env.* (in press).

Hilker, T., N. C. Coops, F. G. Hall, C. J. Nichol, A. Lyapustin, T. A. Black, M. A. Wulder, R. Leuning, A. Barr, D. Y. Hollinger, B. Munger, and C. J. Tucker (2011), Global Terrestrial Photosynthetic Light-Use Efficiency Can Be Inferred from Space, *J. Geophys. Res. Biogeosciences*, (in press).

Jiang, X., D. E. Waliser, W. S. Olson, W.-K. Tao, T. S. L'Ecuyer, S. Shige, K.-F. Li, Y. L.

Yung, S. Lang, and Y. N. Takayabu (2011), Vertical Diabatic Heating Structure of the MJO: Intercomparisons between Recent Reanalyses and the TRMM Estimates, *Mon. Wea. Rev.* (in press).

Johnson, B.T., G. Skofronick-Jackson, and S. J. Munchak (2011), Passive microwave retrievals of snowfall during the 2006/2007 CARE – C3VP field experiment, *J. Appl. Meteor. Clim.*, submitted.

Johnson, B.T., G.W. Petty, and G. Skofronick-Jackson (2010), Microwave Properties of Ice-Phase Hydrometeors for Radar and Radiometers: Sensitivity to Model Assumptions, *J. Geophys. Res. Atmos.*, resubmitted 2011.

Kundu, P. K. and R.K. Siddani (2011), Scale dependence of Spatio-temporal Intermittence of Rain I, *Water Resources Res.* (in press).

Pounder, N., R. J. Hogan, T. Várnai, and R. F. Cahalan (2011), A variational method to retrieve the extinction profile in liquid clouds using multiple field-of-view lidar, *J. Appl. Meteor. Clim.*, submitted.

Skofronick-Jackson, G., and B.T. Johnson (2010), Surface and Atmospheric Contributions to Passive Microwave Brightness Temperatures, *J. Geophys. Res. Atmos.*, submitted.

Thurai, M., W. A. Petersen, A. Tokay, C. Schultz, and P. Gatlin (2011), Drop size distribution comparisons between Parsivel and 2-D video disdrometers, *Advances Geophysics* (in press).

Wilson, E.L., Marc Neveu, W.S.Heaps, E.M. Georgieva (2011), Development of a miniaturized, low-power, low-cost gas correlation radiometer, *Measurement science & technology,* submitted.

Yang, W., A. Marshak, T. Várnai, and Z. Liu (2011), Effect of CALIPSO cloud aerosol discrimination (CAD) confidence levels on observations of aerosol properties near clouds, *Atmospheric Research*, submitted.

Yang, Y., A. Marshak, S. Palm, T. Várnai, and W. Wiscombe (2011), Cloud impact on surface altimetry from a spaceborne 532 nm micro-pulse photon counting lidar – Part I: System modeling for cloudy and clear atmospheres, *IEEE Trans. Geosci. Remote Sens*. (in press).

Zhang, H., A. Lyapustin, Y. Wang, S. Kondragunta, I. Laszlo, P. Ciren, and R.M. Hoff (2011), A Multi-Angle Aerosol Optical Depth Retrieval Algorithm for Geostationary Satellite Data over the United States, *Atmos. Chem. Phys.,* submitted.

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

Anderson, S.W., D.C. Finnegan, and M.H. Bulmer (2010), Assessment of Glassy and Vesicular Textures on Silicic Lava Domes through Analysis of Full Waveform LIDAR data, 2010 Fall AGU, San Francisco, CA, December 13-17.

Berkoff, T. A., R. Delgado, J. Compton, P. Sawamura, E. J. Welton, and R. M. Hoff (2011), Public domain lidar: entry-level network system to enable boundary layer studies for the lower troposphere, 2011 National Air Quality Conferences: Air Quality Forecasting and Mapping, Ambient Air Monitoring, Communicating Air Quality, San Diego, CA, March 7-10, 2011.

Berkoff, T. A., R. Delgado, J. Compton, P. Sawamura, J. Campbell, E. J. Welton, and R. M. Hoff (2011), Shareware lidar: an entry level network system to enable boundary layer and cloud studies for the lower troposphere, 91st American Meteorological Society Meeting, Seattle, WA, January 2011.

Bulmer, M. (2010), RUSI/SERCO Roundtable, Combined Effect: A New Approach to Resilience, The Case for a consequence-based approach to resilience and emergency planning, RUSI Whitehall, London, November 4.

Bulmer, M. (2010), The Duke of Gloucester Lecture Series on Flood Risk and the Built Environment, The International Flood Group, University of Worcester, October 20.

Bulmer, M. (2010), The Future Defence Review: Time for Trade-Offs –The Strategic Defence and Security Review 2010, RUSI Whitehall, London, June 14.

Bulmer, M. (2010), Geospatial Intelligence Special Interest Group, Ministry of Defence, Whitehall, London, November 8.

Bulmer, M. (2010), The Future of Critical National Infrastructure, The View to 2010, Royal United Services Institute, Whitehall, London, October 13-14.

Bulmer, M. (2010), The Risks and Opportunities of Armies Delivering Aid. International Rescue Committee, Royal Geographic Society with the Institute of British Geographers, June 14.

Bulmer, M. (2010), Water Scarcity and Hydro Politics, South Asia, RUSI, July 15.

Bulmer, M. (2011), Contribution of Satellite Earth Observation Technology to Disaster Risk Management, Earth Observation Support to World Bank Projects Services Readiness Review Meeting, World Bank Headquarters, Washington DC, April 12.

Bulmer, M. (2011), Democratization and Conflict in the Arab World: Challenges, Opportunities and Dangers, United States Institute of Peace, Washington DC, May 4.

Bulmer, M. (2011), DRAC Conference, Bovington, March 28-29.

Bulmer, M. (2011), Key Challenges in India Pakistan Relationships, US Institute of Peace, Washington, DC, May 26.

Bulmer, M. (2011), Pakistan 2020: A Vision for Building a Better Future, US Institute of Peace, Washington, DC, May 20.

Bulmer, M. (2011), Reserves in Transformation Conference Two: Defining the Relationship Between Defence, Industry and Society in an era of Persistent Conflict, Royal United Services, Whitehall, March 21.

Bulmer, M. (2011), The Great Tohoku Earthquake and Tsunami: What can it Teach us About Cascading Failure in Infrastructure?, World Bank Headquarters, Washington, DC, April 27.

Bulmer, M. (2011), Virtual Emergencies: Simulation Technology for Emergency Planning and Response, Royal United Services, Whitehall, April 8.

Bulmer, M. H. (2010), Back brief on RUSI Conference: The Future of Critical National Infrastructure: The View to 2015, Geophysical Flow Observatory, JCET, pp. 4, dated October 18.

Bulmer, M., (2010), Flooding in South Asia, Correspondence with Response to UK Ministry of Defense and Department for International Development, August 8.

Bulmer, M.H. (2010), Annual Progress Report for Year 2 of NASA Grant NNX08AT15G, “Topography Data on Mars: Optimizing its Collection and Application Using Laser Scanning”, Mars Fundamental Research Program. Period of Performance 08/01/2009 to 07/31/10, dated August 8, pp.7.

Bulmer, M.H. (2010), River Resources as a Tool of Coercion in South Asia, Water Security and Hydro Politics South Asia, RUSI, July 15 (invited).

Bulmer, M.H. (2010), The impact of hurricane Agatha on Guatemala Update, Geophysical Flow Observatory, JCET, pp 3, dated June 6.

Bulmer, M.H. (2010), The impact of hurricane Agatha on Guatemala, Geophysical Flow Observatory, JCET, pp 3, dated June 4.

Bulmer, M.H. (2010), Water Scarcity and Hydropolitics in South Asia, Geophysical Flow Observatory, JCET, pp 3, dated July 21.

Bulmer, M.H. (2011), Backbrief on Democratization and Conflict in the Arab World: Challenges, Opportunities and Dangers, Geophysical Flow Observatory, JCET, pp 4, dated May 9.

Bulmer, M.H. (2011), Geo Brief on the 11 March 2011 Earthquake in Japan. Geophysical Flow Observatory, JCET, pp 3, dated March 25.

Bulmer, M.H. (2011), Geo Brief on the 11 March 2011 Earthquake in Japan. Geophysical Flow Observatory, JCET, pp 3, dated March 24.

Bulmer, M.H. (2011), Geo Brief on the 11 March 2011 Earthquake in Japan. Geophysical Flow Observatory, JCET, pp 2, dated March 16.

Bulmer, M.H. (2011), Geo Inputs in Emergency Planning and Response. Virtual Emergencies: Simulation Technology for Emergency Planning and Response. Royal United Services, Whitehall, April 8, (invited).

Bulmer, M.H. (2010), Floods NW Pakistan, Geophysical Flow Observatory, JCET, pp. 2, dated August 1.

Bulmer, M.H. (2010), Floods NW Pakistan, Geophysical Flow Observatory, JCET, pp. 4, dated August 8.

Campbell, P., Hyperspectral Infrared Imager (HyspIRI) Science Workshop, Pasadena, CA, August 24-26.

Campbell, P.K.E, D. Lagomasino, E. Middleton, K. J. Thome, K. F. Huemmrich, L. Corp, L. Ong, N. Pollack, S. Fry and D. Landis (2010), EO-1 Hyperion Time

Series for Vegetative and Calibration Studies, presented at the EO-1 10th Anniversary Science Symposium, NASA/GSFC, November 30 to December 2.

Campbell, P.K.E, E.M. Middleton, L.A. Corp, and C. van der Tol (2010), Seasonal dynamics in solar induce fluorescence (SIF) and reflectance (R) and differences associated with nitrogen (N) availability in corn canopy, The 4th International Workshop on Remote Sensing of Vegetation Fluorescence, Valencia, Spain, November 15–17.

Chiu, J., A. Marshak, Y. Knyazikhin, W. Wiscombe, T. Várnai, and H. Wang (2011), 3D effects on spectrally invariant behavior near cloud edges: Implications for retrieving aerosol and cloud properties in these challenging regions, Second Atmospheric System Research (ASR) Science Team Meeting, San Antonio, TX, March 28-April 1.

Compton, J., R. Delgado, and R.M. Hoff (2011), Determination of PBL Heights using Lidar and Wind Profiler, Quarterly RAMMPP Meeting, Maryland Department of the Environment, Baltimore, MD, January.

Compton, J., R. Delgado, and R.M. Hoff (2011), Determining Planetary Boundary Layer Heights with Ground-based Lidar and Wind profiler on Short Spatial and Temporal Scales, UMBC 33rd Graduate Research Conference, University of Maryland Baltimore County, Baltimore, MD, April.

Compton, J., R. Delgado, and R.M. Hoff (2011), Determining Planetary Boundary Layer Heights with Ground-based Lidar and Wind profiler on Short Spatial and Temporal Scales, Thermodynamic Profiling Technologies Workshop, Boulder, CO, April.

Delgado, R., J. Compton, D. Orozco, P. Sawamura, K. Majewski, T. Berkoff, K. J. McCann, and R. M. Hoff (2011), Active Remote Sensing in the Baltimore-Washington DC Metropolitan Area: UMBC Monitoring of Atmospheric Pollution (UMAP), 2011 National Air Quality Conferences: Air Quality Forecasting and Mapping, Ambient Air Monitoring, Communicating Air Quality, San Diego, CA, March.

Delgado, R., J. Compton, D. Orozco, P. Sawamura, K. Majewski, T. Berkoff, K. J. McCann, and R. M. Hoff (2010), Active Remote Sensing in the Baltimore-Washington DC Metropolitan Area: UMBC Lidar Measurements, Quarterly RAMMPP Meeting, Maryland Department of the Environment, Baltimore, MD, October.

Delgado, R., J. Compton, and R.M. Hoff (2011), Determination of Planetary Boundary Layer Heights on Short Spatial and Temporal Scales from Ground-based Vertical Profilers”, 7th NOAA-CREST ANNUAL Symposium, Hampton University, Hampton, VA, April.

Delgado, R., S. DeSouza-Machado, A. M. Robinson, D. Orozco, L. L. Strow, O. Torres, and R. M. Hoff (2011), Synergy of A-Train sensors and in-situ air quality measurements: 3-D structure of Asian dust transported to the Mid-Atlantic United States and its impact on air quality, 91st American Meteorological Society Meeting, Seattle, WA, January.

DeSouza-Machado, S., L. L. Strow, B. Imbiriba, K. McCann, R.M. Hoff, S. E. Hannon, J.V. Martins, A. Robinson, P. Schou, D. Tanre, J.L. Deuze, F. Ducos, O. Torres, and Z. Chen (2010), Infrared retrievals of dust using AIRS: An intercomparison of optical depths and heights derived for a North African dust storm, 2nd A-Train Symposium, New Orleans, LA., October 25-28.

DeSouza-Machado, S., G.Aumann, and L. Strow (2010), Studying Deep Convective Clouds using AIRS, 2nd A-Train Symposium, New Orleans, LA, October 25-28.

DeSouza-Machado, S., L. Strow, R. Hoff, O. Torres, D. Tanre, J.V. Martins, A. Robinson, *et al.* (2010), Validating dust layer heights and optical depths from AIRS data, 2nd A-Train Symposium, New Orleans, LA, October 25-28.

Georgieva, E., W. S. Heaps, W. Huang (2010), Progress in Passive Sensors for Precision Greenhouse Gas Monitoring, AGU Fall meeting, San Francisco, CA, December.

Georgieva, E.M., W.S. Heaps, W. Huang (2010), A broad band lidar for precise atmospheric CO2 column absorption measurement from space, *Geoscience and Remote Sensing Symposium (IGARSS)*, 649–652, 2010.

Grecu, M., L. Tian, W. S. Olson, and S. Tanelli (2010), An algorithm for estimating precipitation using combined radar-radiometer observations from GPM, presented at the 2010 American Geophysical Union Fall Meeting, San Francisco, CA, December 13-17.

Hall, F. (2010), Remote Sensing of Light Use Efficiency from Space, Ag Forest Meteorology Conference, Aug 2-5.

Heaps, W., E.M. Georgieva, and W. Huang (2010), Broadband LIDAR Precision CO2 Column Measurement at 1.57 and 2.05 micron, 4th International Workshop on CO2/CH4 DIAL Remote Sensing, Oberpfaffenhofen, Germany, November.

Heaps, W. S., E. Georgieva, W. Huang, B. Baldauf, and T. McComb (2010), Ground Based Test Results for Broad Band LIDAR, AGU Fall meeting, San Francisco, CA, December.

Hoff, R. M., and G. Pappalardo (2010), The GAW Aerosol Lidar Observation Network (GALION) as a source of near-real time aerosol profile data for model evaluation and assimilation, AGU Annual Meeting, San Francisco, CA, December 13-17.

Hoff, R.M. (2011), Atmospheric Lidar: 35 Years of Changing Flashlamps is Enough, 2nd International Lidar Solutions Conference Keynote Address, Vaughan, Ontario, June 4.

Hoff, R.M., A. Huff, S. Kondragunta, and S. Christopher (2011), The GOES-R Air Quality Proving Ground, 2011 Proving Ground Annual Meeting, National Center for Atmospheric Research (NCAR), Boulder, CO, May 18.

Hoff, R., R. Delgado, T. Berkoff, K. McCann, D. Orozco, P. Sawamura, and J. Compton (2011), Comparison of EZLidar, MPL, and an elastic lidar for urban air quality applications, AMS Annual Meeting, Seattle, WA, January 25.

Huemmrich, K.F. (2010), HyspIRI Input to Models, HyspIRI Product Workshop, Greenbelt, MD, May 4-5.

Huemmrich, K.F. (2010), HyspIRI Input to Models, HyspIRI Symposium, Pasadena, CA, August 24-26.

Huemmrich, K.F. (2010), Using Imaging Spectrometer-Derived Parameters in Climate-Related Models, EO-1 Tenth Anniversary Symposium, Greenbelt, MD, November 30-December 2.

Huemmrich, K.F. (2010), Using Temporally Frequent Surface NDVI Observations to Determine Light Use Efficiency of High Latitude Ecosystems, AGU Fall Meeting, San Francisco, CA, December 13-17.

Huemmrich, K.F. (2011), Determining Ecosystem Carbon Flux from Spectral Reflectance for Multiple Sites: Implications for Global Sampling, 2011 HyspIRI Science Symposium, May 17-18.

Huemmrich, K.F., E. M. Middleton, D.Landis, T. A, Black, A. Barr, J. H. McCaughey, and F.G. Hall (2010), Remote Sensing of Ecosystem Light Use Efficiency, NASA Carbon Cycle and Ecosystems Workshop, San Diego, CA, March 15-17.

Huemmrich, K.F., L. Corp, A. Russ, E.M. Middleton, W. Kustas, J. Prueger, and Y.B. Cheng (2010), Using Spectral Reflectance to Determine Light Use Efficiency, Ecological Society of America Annual Meeting, Pittsburgh, PA, July 2-6.

Huemmrich, K.F., L. Corp, A. Russ, E.M. Middleton, W. Kustas, J. Prueger, and Y.B. Cheng (2011), Using Optical Signals to Determine Spatial and Temporal Patterns of GEP, North American Carbon Program Workshop, New Orleans, LA, January 31-February 4.

Huff, A.K., R. M. Hoff, S. Kondragunta, and S. Christopher (2011), The GOES-R Air Quality Proving Ground – Preparing the Air Quality Community for the Next Generation of NOAA Geostationary Satellites, 2011 National Air Quality Conferences: Air Quality Forecasting and Mapping, Ambient Air Monitoring, Communicating Air Quality, San Diego, CA, March 7-10.

Johnson, B.T., and G. Skofronick-Jackson (2010), Simulation Of The Microwave Extinction Properties Of Realistically Shaped Precipitation Particles, presented at International Geosciences and Remote Sensing Society (IGARSS), Honolulu, HI, July 25–30.

Johnson, B.T., and G. Skofronick-Jackson (2011), Satellite-Based Passive Microwave Retrieval of Ice-Phase Precipitation, presented at the European Geophysical Union, Vienna, Austria, April 03-08.

Johnson, B.T., and G. Skofronick-Jackson (2010), Physically-Based Snowfall Retrievals Using CloudSat Radar Reflectivities, presented at the A-Train / CloudSat Science Team Meeting, New Orleans, LA, October 25-29.

Johnson, B.T., and G. Skofronick-Jackson (2010), Precipitation Remote Sensing Using Combined Passive and Active Microwave Observations, presented at the American Geophysical Union, 2010 Fall meeting, San Francisco, CA, December 13–17.

Johnson, B.T., W.S. Olson, and G. Skofronick-Jackson (2010), Melting Layer Model Development for the GPM Combined Algorithm, presented at the PMM/GPM Science Team Meeting, Seattle, WA, November 1-5.

Kacenelenbogen, M. S., M. Vaughan, J. Redemann, R. M. Hoff, R. Rogers, R. A. Ferrare, P. B. Russell, C. A. Hostetler, J. W. Hair, and B. Holben (2010), CALIOP/CALIPSO: Improvement in the retrieval algorithm and a few applications), 2nd A-Train Symposium, New Orleans, LA, October 25-28.

Kacenelenbogen, M. S., M. Vaughan, J. Redemann, R. M. Hoff, R. Rogers, R. A. Ferrare, P. B. Russell, C. A. Hostetler, J. W. Hair, and B. Holben (2010), CALIOP/CALIPSO: Improvement in the retrieval algorithm and a few applications, AGU Annual Meeting, San Francisco, CA, December 13-17.

Kleidman, A. I. Prados, and S. A. Christopher (2010), Applied Remote Sensing Education and Training (ARSET): Opportunities to shorten the learning curve in use of NASA Satellite Data Products, 2010 Fall AGU Meeting, San Francisco, CA, December 13-17.

Kleidman, R. and A. Prados (2011), ARSET: NASA's Applied Remote Sensing Education and Training Program*, EPA AirNow National Air Quality Conference,* San Diego, CA, March 7-10.

Kleidman, R. and A. Prados (2011), ARSET: NASA's Applied Remote Sensing Education and Training Program, George Wright Society Conference on Parks, Protected Areas, and Cultural Sites, New Orleans, LA, March 13-16.

Kundu, P. K. and J. R. Travis (2010), A Unified Description of the Statistics of Radar and Gauge Rainfall Data in terms of a Stochastic Dynamical Model, Paper No. H21E-1095, Poster presentation at the 2010 AGU Fall Meeting, San Francisco, CA, December 13-17.

Kuo, K.-S., T. Clune, C. Pearson, W. S. Olson, G. S.-Jackson, J. Gravner, and D. Griffeath, (2010), Role of non-convexity in characterizing single-scattering properties for ensembles of non-spherical precipitation particles, American Geophysical Union Fall Meeting, San Francisco, CA, December 13-17.

Marshak, A., T. Várnai, G. Wen, W. Yang, and R. Cahalan (2010), CALIPSO observations of aerosol properties near clouds, NASA A-train symposium, New Orleans, LA, October 25-28.

McComb, T. S., W. S. Heaps, E. M. Georgieva, E. C. Cheung, B. K. Baldauf, P. A. Thielen, and J. G. Ho (2010), Spectrally tailored pulsed thulium fiber laser system for broadband lidar CO2 sensing, SPIE, Orlando, Florida.

McQueen, J.T., C. M. Tasson, M. Tsidulko, Y. Zhu, L. Cucurull, G.S. Manikin, G. DiMego, B. Lapenta, M. Simpson, W. Pendergrass, C, Vogel, E. J. Welton, E. L. Joseph, M. Hicks, B. Demoz, R. M. Hoff, R. Delgado, and J. Compton (2011), An Ad-Hoc PBL variability experiment over the Washington, DC area, 91st American Meteorological Society Meeting, Seattle, WA, January 2011.

Middleton, E. M., D. J. Mandl, P.K.E. Campbell, L. Ong, S. W. Frye, and S. G. Ungar (2010), Ten-Year Summary of NASA's Earth Observing One (EO-1) Mission, Proc. of ESA's *Hyperspectral Workshop* 2010, ESA/ESRIN, Frascati (Rome), Italy*,* March 17-19.

Olson, W. S., T. S. L'Ecuyer, G. Gu, M. Grecu, and M. G. Bosilovich (2010), Atmospheric diabatic heating distributions derived from a combination of satellite sensor data, 2010 American Geophysical Union Fall Meeting, San Francisco, CA, December 13-17.

Olson, W. S., T. S. L'Ecuyer, G. Gu, M. Grecu, and M. G. Bosilovich (2010), Atmospheric diabatic heating distributions derived from a combination of satellite sensor data, the American Meteorological Society 17th Conference on Satellite Meteorology and Oceanography, Annapolis, MD, September 27-30.

Orozco, D., R. Delgado, and R. M. Hoff (2011), Direct Aerosol Radiative Forcing Variations Over The Mid-Atlantic Region, UMBC 33rd Graduate Research Conference, UMBC, Baltimore, Maryland, April.

Pappalardo, G., and R. M. Hoff (2010), GALION: The GAW Aerosol Lidar Observation Network, 26th International Laser Radar Conference, St. Petersburg, Russia, July 4-7.

Pickering, K., A. Prados, E. Celarier, R. Pinder, and S. Kondragunta (2010), Monitoring Air Quality Changes Resulting from NOx Emission Regulations over the United States Using OMI and GOME-2 Data, Community Modeling and Analysis System Annual Conference, Chapel Hill, NC, October 11-13.

Pickering, K., A. Prados, R. Pinder, D. Allen, E. Celarier, J. Gleason, and S. Kondragunta (2010), An Update on Tropospheric NO2 Trends over the United States Using OMI and GOME-2 Data, Aura Science Team Meeting, Boulder, CO, September 27-29.

Prados, A. I., R. Kleidman, and L. Friedl (2011a), NASA Applied Sciences Remote Sensing Education and Training, Federation of Earth Science Information Partners, Winter Meeting, Washington, DC, January 4-6.

Prados, A. I., R. Kleidman, S. Christopher, and L. Friedl (2010c), NASA Applied Sciences Remote Sensing Education and Training, Federation of Earth Science Information Partners, Summer Meeting, Knoxville, TN, July 20-23.

Prados, A. I., and J. Acker (2010a), Impacts of European Atmospheric Air Pollution on Water Nutrients in the Atlantic Ocean, Baltic Sea, and Mediterranean Sea, Handbook of Satellite Remote Sensing Image Interpretation: Applications for Marine Living Resources Conservation and Management, European Union PRESPO International Ocean Color Coordinating Group, pp. 51-62, http://www.ioccg.org/handbook.html, September.

Prados, A. I. (2011), NASA Capacity Building Activities: Bridging the gap between science and policy, The GAIA Climate, Climate Change and Public Health Conference, Johns Hopkins University, Baltimore, MD, April 12-14 (invited).

Prados, A. I., R. Kleidman, and L. Friedl (2011), NASA Applied Sciences Remote Sensing Education and Training, presented at the American Association for the Advancement of Science Annual Meeting, Washington, DC, February 17-21.

Prados, A. I. (2011), Teaching Climate Science and Policy, Sally Ride Educator's Institute: Connecting with Climate Change 2011, NASA Jet Propulsion Laboratory, Pasadena, CA, February 26.

Rakitin, V., A. Dzhola, E. Grechko, E. Fokeeva, R. Shumsky, and L. Yurganov (2011), CO pollution anomaly over Moscow and rural area in summer 2010, July- August, *Geophysical Research Abstracts*, Vol. 13, EGU 2011-617, presented at the European Geosciences Union General Assembly, April 5.

Szykman, J., R. Mathur, T. Plessel, M. Freeman, M. Silverman, H. Paulsen, R. Hoff, D. Mangosing, C. Praderas, E. Masuoka, P. Rinsland, L. Remer, and C. Trepte (2010), The Use of A-Train data sets within the EPA Remote Sensing Information Gateway (RSIG)/3-D Air Quality System (3-D AQS) for CMAQ Evaluation, 2nd A-Train Symposium, New Orleans, LA, October 25-28.

Szykman, J., R. Mathur, T. Plessel, M. Freeman, M. Silverman, H. Paulsen, R. Hoff, D. Mangosing, C. Praderas, E. Masuoka, P. Rinsland, L. Remer, and C. Trepte

(2011), Use of Satellite Data sets via the EPA Remote Sensing Information Gateway (RSIG)/3-D Air Quality System (3-D AQS) for CMAQ Evaluation, 2011 National Air Quality Conferences: Air Quality Forecasting and Mapping, Ambient Air Monitoring, Communicating Air Quality, San Diego, CA, March 7-10.

Tangborn, A. (2010), Ensemble estimation of Error statistics in Geomagnetic data assimilation, 2010 AGU Fall Meeting, San Francisco, CA, December 13-17.

Várnai, T. and J. Harrington (2011), Parameterization of shortwave horizontal photon transport effects, 2nd Atmospheric System Research (ASR) Science Team Meeting, San Antonio, TX, March 28-April 1.

Várnai, T., A. Marshak, G. Wen, W. Yang, and R. Cahalan (2010), Analysis of co-located CALIPSO and MODIS observations near clouds, NASA A-train symposium, New Orleans, LA, October 25-28.

Várnai, T., A. Marshak, R. Cahalan, F. Evans, G. Wen, and W. Yang (2011), Aerosol properties near clouds, MODIS-VIIRS Science Team Meeting, University College, May 18-20.

Várnai, T., A. Marshak, W. Yang, G. Wen (2011), Synergy of co-located CALIOP, WFC, and MODIS aerosol observations near clouds, CALIPSO Science Team Meeting, Montreal, Canada, June 15-17.

Várnai, T., and J. Y. Harrington (2010), Influence and estimation of 2-D solar radiative processes in clouds, Atmospheric Systems Research Cloud-aerosol-precipitation Interactions Working Group meeting, Boulder, CO, October 11-14.

Warner, J. *et al.* (2010), AIRS CO V5+ to V6-, AIRS Fall Meeting, Greenbelt, MD, November 1-5.

Warner, J., *et al.* (2010), Variability Analysis of Tropospheric Carbon Monoxide data Records from AIRS and Ground Measurements, American Geophysical Union Annual Meeting, San Francisco, CA, December 13-17.

Warner, J., *et al.* (2011), AIRS V6 CO Validation, AIRS Spring Meeting, Pasadena, CA, April 26-29.

Warner, J., *et al.* (2011), Tropospheric CO in the Arctic Region Measured by AIRS in the Last Decade, American Meteorological Society Annual Meeting, Seattle, WA, January 23-27.

Yang, W., A. Marshak and T. Várnai (2011), CALIPSO observations of dust aerosol properties near-cloud, CALIPSO Science Team Meeting, Montreal, Canada, June 15-17.

Yurganov, L. (2010), CO from the Russian Fies-2010 observed by AIRS, MOPITT and ground-based instruments, presented at the NASA Sounder Science Team Meeting, Greenbelt, MD, November 4.

Yurganov, L. (2010), Monitoring of tropospheric methane from space: Problems and solutions, presented at the 2nd Scientific Work Group Meeting & 3rd Management Committee Meeting, COST Action ES0902 PERGAMON, Brussels, Belgium, October 18.

Yurganov, L. (2011), An ability of space-based IR sensors to monitor the entire tropospheric depth: the Russian fires case, presented at the JCET All Hands Meeting, UMBC, Baltimore, MD May 11.

Zhang, H. A., R. M. Hoff, S. Kondragunta, A. Huff, M. Green, S. A. Christopher, B. Pierce, and B. Gross (2011), GOES-R Air Quality Proving Ground, 91st AMS Annual Meeting, Seattle, WA, January 23-27.

Zhang, H., R. M. Hoff, S. Kondragunta (2010), IDEA as a template for an Air Quality Proving Ground (AQPG) for GOES-R, 17th Conference on Satellite Meteorology and Oceanography, September 27–October 1, Annapolis, MD.

III.5 Courses Taught

FYS103N: *First Year Seminar, Earth Sciences* — This course provides students with an opportunity for early exposure to the Earth Sciences by learning how earth satellite monitoring is currently utilized in environmental and societal applications. The course structure will be a combination of in-class lectures, directed web-based hands-on activities, and student presentations, and taught at a computer lab on UMBC's campus. The course curriculum will primarily rely on NASA imagery and tools to teach 1) basic earth system science principles, climate variability and atmospheric chemistry and 2) environmental and societal implications of climate change, stratospheric ozone depletion, and air pollution. (Taught by A. Prados, Spring 2011)

GES 311: *Weather and Climate* — This course offers an introduction to the physical processes that control weather and climate. Topics covered include 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 J. Halverson, Fall 2010)

GES 400: *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 2011)

GES 400A: *Severe Storms & Their Socioeconomic Impact* — Part of Selected Topics in Geography (Taught by J. Halverson, Fall 2010)

GES 415: *Climate Change* — This course deals with the question of climate change and variability. Topics covered include changes in climate in different time scales, 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 A. Mehta, Spring 2011)

PHYS 122: *Introductory Physics II* — This course emphasizes electricity, magnetism, heat and thermodynamics. Topics include Coulomb's law, Gauss's law, electric fields and electric potential, currents, simple circuits and Kirchhoff's laws, generation of magnetic fields by charges in motion, electromagnetic induction, magnetic materials, oscillatory circuits, temperature, heat and the laws of thermodynamics. (Taught by S. Desouza-Machado, Summer 2010)

PHYS 224: *Physics of Waves* — This course emphasizes vibrations, wave motion and optics. Topics include mathematical characterization of vibrations and waves, sound, superposition of standing waves, geometrical and physical optics, diffraction, interference and polarization of light. (Taught by S. Desouza-Machado, Spring 2010)

PHYS 450: *Individual Study* (Jaime Compton) — Mr. Compton studied methods to retrieve planetary boundary layer heights from lidar data and wrote a class report on the method. (Advisor: R.M. Hoff, Fall 2010 and Spring 2011)

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, A. Tokay, Spring 2011)

PHYS 622: *Atmospheric Physics II* — This class covers introductory radiative transfer, aerosol formation processes and light scattering, and introductory cloud physics. (Taught by R.M. Hoff, Spring 2011)

PHYS 741: Inverse Methods (Physics) — This course provides an overview of the mathematical methods used in inverse problems of remote sensing and in atmospheric data analysis. Methods based on estimation theory and variational principles will be presented. Topics include conditional mode and conditional mean estimation, linear and nonlinear least squares and applications to remote sensing and atmospheric data analysis. (Co-taught by J. Warner and E. Maddy, Fall 2010)

PHYS 898: *Pre-candidacy Research* — Worked with candidates Patricia Sawamura, Thishan Darshana Karandana-Gamalathge, Daniel Orozco, and Lijun Diao (R. M. Hoff, Fall 2010 and Spring 2011)

III.6 Colloquia and Seminars

Hall, Forrest (2011), *Howard County Legacy Leadership Institute: The Global Carbon Cycle*, GSFC, February 2011.

Hall, Forrest (2011), *The world view from Newton to Einstein*, Seminar to the Montgomery College Round Table, March 3.

Huemmrich, K.F. (2011), *Climate and Vegetation*, Goddard Space Flight Center, Greenbelt, MD, April 6.

Prados, A. I. (2010), *NASA Applied Sciences Remote Sensing Education and Training*, JCET Meeting, Baltimore, MD, July 14.

Prados, A.I. (2010), *NASA Applied Sciences Remote Sensing Education and Training*, Goddard Institute of Space Studies, September 23.

Prados, A. I. (2010), *How to Access NASA Air Quality Imagery and Data Products*, Atmospheric Chemistry Brown Bag seminar, University of Maryland College Park, November 5.

Prados, A. I. (2010), *How to Access NASA Air Quality Imagery and Data Products,* NOAA/NESDIS*,* Camp Springs, Maryland, November 23.

Prados, A. I. (2011), *NASA Air Quality Capacity Building Activities: Bridging the gap between science and policy,* NASA GSFC Aerocenter Seminar, February 15.

Prados, A. I. (2011), *NASA Air Quality Capacity Building Activities: Bridging the gap between science and policy*, NASA GSFC Atmospheric Chemistry and Dynamics Branch Seminar, March 31.

Johnson, B.T., and G. Skofronick-Jackson (2011), *Satellite-Based Passive Microwave Retrieval of Ice-Phase Precipitation,* presented at the European Geophysical Union, Vienna, Austria, 03 – 08 April.

Mehta, A. (2010), *Extreme Rainfall Events over the US Great Plains during the Last Decade*, Mesoscale Atmospheric Processes Branch, NASA-GSFC, October 7, and JCET All Hands Meeting, UMBC, October 13.

Mehta, A. (2011), *Earth's Climate System, Multidisciplinary Field of Science Webinar*, Indian Center for Climate and Societal Impacts Research, January 23.

Olson, W. S. (2010), *An algorithm for estimating precipitation using combined radar-radiometer observations from GPM*, presented at the Jet Propulsion Laboratory, Pasadena, CA, November 15.

Warner, J. X. (2010), *Measurements of Atmospheric Composition from Space: Importance for the Climate and Air Quality Studies*, Department of Geography and Environmental Systems, University of Maryland Baltimore County, Baltimore, MD, October 6.

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
Lower Atmospheric Research Using Lidar Remote Sensing	DOD		Hoff	Awarded
Aerosol modulating tropical convection: A missing link in tropical dynamics and climate modeling?	DOE		Várnai	Not Funded
Characterization of 3D cloud variability, and the analysis and parameterization of its radiative impacts	DOE	Várnai		Not Funded
Direct Measurement of Global Photosynthesis from Space: Technology Development and Airborne Demonstration	INSTRUMENT INCUBATOR PROGRAM		Hall	Not Funded
A prerequisite for modeling future trends in methane: A credible simulation of methane's observed trends and variability (1980-2010)	NASA		Warner	Not Funded
A Proposal For The Continued Research In The Earth System Sciences (the JCET Cooperative Agreement; PI receives no funds)	NASA	Hoff		Awarded
AIRS and IASI Near---real Time Measurements and Data Analysis in Support of the SEAC4RS Campaign	NASA	Warner		Pending
Aqua and Terra MODIS New Data Products for fAPARchl	NASA		Huemmrich	Not Funded
Assimilation of CO from AIRS, MOPITT and other instruments for estimating and eliminating instrument and model bias	NASA	Tangborn	Warner (JCET), Ott (GEST)	Not Funded
Characterizing Uncertainties in Large-Scale Atmospheric Heating Distributions Derived from TRMM Observations and Reanalysis Datasets	NASA	Olson		Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Correction of lidar altimetry data for range delay due to the effects of cloud forward scattering and snow-ice penetration	NASA		Várnai	Not Funded
GEST Cooperative Agreement	NASA	Hoff		Awarded 2000-2011
GESTAR: Enabling the Next Generation of NASA Earth Science	NASA	Hoff		Not Funded
Improvements Of Passive And Active Microwave Precipitation Retrieval Algorithms For Mixed-Phase Precipitating Clouds	NASA		Johnson	Awarded
Mapping Ecosystem Light Use Efficiency Using Aqua and Terra MODIS Data	NASA	Huemmrich		Not Funded
MODIS aerosol properties in the vicinity of clouds	NASA		Várnai	Awarded
NASA Air Quality Satellite Trainings Year III	NASA	Prados		Awarded
NASA Water Resources Management Satellite Trainings Year I	NASA	Prados	Mehta	Awarded
Observing system simulation experiments to optimize the assimilation of high resolution CO_2 measurements from space	NASA	Ott (GEST)	Tangborn	Awarded
Quantifying particle size distributions in support of GPM combined precipitation retrieval algorithms	NASA		Tokay	Awarded
Studying Land Cover Through Spectral Dynamics in The Anthropogenic Biosphere	NASA	Huemmrich		Not Funded
UMBC Participation in Discover AQ	NASA	Hoff		Awarded
Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency II: Syn-	NASA - ROSES		Campbell, Huemmrich	Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
thesis and Integration				
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		Not Funded
Climate Scholars: Educating Undergraduate Students in Using NASAs Earth Science Data and Information in Global Climate Change Applications	NASA IGCCE 2011		Prados	Pending
Analysis of global CO interannual variations based on validated and reconciled AIRS, MOPITT and IASI measurements	NASA ROSES	Yurganov		Not Funded
Beautiful Earth: Experiencing and Learning Science in a New and Engaging Way	NASA ROSES	Casasanto	Prados	Awarded
Extending the Vertical Dimension in Air Quality Studies	NASA ROSES	Hoff		Not Funded
Measurements of the hydrometeors size distribution through surface based instruments	NASA ROSES	Tokay		Awarded
Quantitative Error Characterizations of TRMM and GPM Rainfall Products for Climate Studies and Validation	NASA ROSES		Kundu	Awarded
Satellite Derived Trends in Atmospheric Methane	NASA ROSES	Yurganov		Not Funded
Interferometric NIR Receiver for ASCENDS Lidar	NASA ROSES ACT		Georgieva	Pending
Low cost laser heterodyne radiometer for highly sensitive detection of CO_2, CH_4, O_2, and	NASA ROSES ACT		Georgieva	Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
aerosols for OCO2, ASCENDS, and GOSAT validation				
Diagnosing Moisture, Clouds, and Dust Characteristics Associated with Mediterranean Rain Systems using AIRS and MODIS Retrieval Products from the Aqua Satellite	NASA TERRA AQUA	Mehta		Not Funded
Multi-Sensor Retrieval of Vegetation 3-D Structure and Biomass using Physically-Based Algorithms	NASA TERRA AQUA	Hall		Awarded
Mapping Ecosystem Light Use Efficiency Using Aqua and Terra MODIS Data	NASA TERRA AQUA		Hall	Not Funded
Solar Excited Chlorophyll Fluorescence System for the Assessment of Vegetation Photosynthetic Function	NASA/GSFC IRAD 2010		Campbell	Awarded
Predictability and Prediction of Decadal Climate and its Societal Impacts in the Missouri River Basin with Climate, Hydrology, Crop Yield Earth System, and Economic Land Use Models	NIFA-USDA		Mehta	Awarded
Air Quality Proving Ground (NA10NES4280016)	NOAA	Hoff		Awarded 2010-2011
An Air Quality Proving Ground (NA09NES4400022)	NOAA	Hoff		Awarded
City University of New York Research Foundation (subcontract)	NOAA	Hoff		Awarded 2006-2011
GOES-R air quality data distribution system	NOAA NESDIS	Zhang		Pending
Collaborative Research: Hydrological and thermal regimes as drivers of ecosystem change in Alaskan tundra: the 2nd generation manipulation	NSF		Huemmrich	Pending

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.

Mr. Timothy Berkoff is an Assistant Research Engineer with the Joint Center for Earth Systems Technology, University of Maryland, Baltimore County. He has more than 20 years of experience with optical instrumentation and measurement analysis, and currently serves as the instrument manager for NASA's Micro-Pulse Lidar Network (MPLNET), a global network of lidar systems to provide long-term observations of aerosols and clouds. His background includes lidar, fiber-optic sensing techniques, interferometry, spectroscopic gas detection, tunable diode lasers, optical design, opto-electronics, and optical diagnostics. He has more than 15 peer-reviewed publications, numerous conference proceedings, and is an inventor on two patents in the field of optical sensing. Mr. Berkoff obtained a B.S. in Optics from the University of Rochester in 1988.

Dr. Huisheng Bian received a B.S. in atmospheric science from Nanjing University in 1985, a M.S. in 1988, and a Ph.D. from University of California, Irvine in 2001. From 1988 to 1995, she worked at the Chinese Meteorological Academy as an assistant researcher, where her research interest was regional air quality modeling. Her Ph.D. work focused on improving, validating, and applying UCI global chemistry transport model for tropospheric ozone simulation, as well as on developing a module (Fast-J2) to accurately simulate stratospheric photolysis in global chemistry models. Upon graduation, Dr. Bian became interested in atmospheric aerosols, their distribution and their photolytic and heterogeneous impacts on tropospheric chemistry. Her current major research interest involves improving and applying multiple CTMs to the atmospheric chemistry studies and providing mission planning and mission support.

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 has16 years of experience in pure and applied fields of geology, remote sensing, GIS, emergency management plus instrument design. He has taught undergraduate and graduate courses in Natural Hazards, Geomorphology and Planetary Geology. He is an expert in geophysical flows combining field-derived measurements with remotely sensed data and emergency management. He has led or participated in over 30 major field tests, campaigns and responses to natural disasters working on land (volcanoes, mountains, deserts and glaciers), at sea, or in the air, and he has experience as project and team leader, chief instructor, assessor and planner. He has worked in real, synthetic and simulated environments. In the field, he has worked in Nepal, Taiwan, Italy, Spain, Peru, New Zealand, Pakistan, Morocco, Iceland, North America and the UK. This has involved collaborations with government and international agencies (e.g. UNHCR, DFID/UKAID, USAID, World Bank) and non-government organizations (e.g. Red Cross, Oxfam, CRS, MercyCorps). Dr. Bulmer has installed prototype hazard monitoring systems on the Hubbard Glacier in Alaska, in the Sierra Nevadas in USA, mountain slopes in eastern Nepal, around Muzaffarabad in Pakistan and in the Peruvian rain forest. He has an on-going collaboration with emergency medical teams to examine the nature and survivability of injuries sustained in landslide disasters.

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 Natural Resources Management / 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 a NRC associate and worked at GSFC 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 and measurement techniques) for vegetation stress assessments and land cover change detection. Dr. Campbell started working in this direction as a post-doctoral research associate of Dr. Middleton at NASA/GSFC, and later continued as a Prime Investigator on an NSF project for the "*Evaluation of vegetation Solar Chlorophyll Fluorescence properties*". Of high interest to this end is the FLEX mission currently under development at ESA, which targets the assessment of solar exited ChlF. At GSFC she participates in the NASA's "*Light Use Efficiency and Carbon Science*" research led by Dr. Middleton and has participated in developing the satellite hyperspectral mission/s *Flora/SpectraSat/HyspIRI* for vegetation assessment. Currently, she participates 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 UMBC, Dr. Campbell teaches the class "Introduction to Remote Sensing for Environmental Applications" for undergraduate and graduate students at the Department of Geography and Environmental Systems (GES).

Dr. D. Allen Chu received a BS in Atmospheric Sciences from the National Taiwan University in 1982 and a Ph.D. in Atmospheric Sciences from Georgia Institute of Technology. In 1989, he joined ISAMS (Improved Stratospheric and Mesospheric Sounder) team at NASA Langley Research Center where he worked on the ozone and nitric acid retrievals using ISAMS measurements as well as radiance simulations using line-by-line/broadband radiative transfer models. In 1996, he was recruited by MODIS (Moderate Resolution Imaging Spectroradiometer) aerosol team at NASA Goddard Space Flight Center to work on MODIS aerosol retrieval and lead quality assurance for the MODIS atmosphere products. In 2004, he joined JCET/UMBC as an associate research scientist. Since then, he has been heavily involved in a number of projects including the application of MODIS AOD to air quality, evaluation of aerosol radiative forcing in a number of field campaigns (INTEX-NA, INTEX-B, NAMMA, and ARCTAS), study of dust radiative and microphysical process on precipitation and energy budgets over the tropical Atlantic Ocean, and intercomparison of model (e.g., GOCART, GEOS-CHEM, and CMAQ) and MODIS-derived aerosol properties. In 2007, he joined the GEST to continue his researches. He served as a PI of NASA INTEX-B, NAMMA, and ARCTAS programs, and EPA AMI pilot project.

Dr. Marcianna P. Delaney received her B.S. in Marine Biology with a concentration in Physics at the University of North Carolina in Wilmington in 1994. She earned her M.Sc. and Ph.D. in Biological Oceanography at Memorial University of Newfoundland in St. John's, Newfoundland. Her graduate research for both degrees focused on the effects of small-scale turbulence on the marine microbial food web of a cold-ocean environment. She has turned her love of science into a career with the GSFC Office of Education as a scientist on staff. Dr. Delaney currently serves as the GSFC Digital Learning Network Team (DLN) Lead, in which she designs STEM content for interactive videoconferencing, actively teaches to students and teachers across the United States, and establishes partnerships across NASA for additional STEM collaboration on projects for e-Education. In addition to her extensive experience with teacher professional development, she is currently designing an on-line synchronous and asynchronous STEM PD course with blendedschools.net utilizing NASA science and engineering content. Most recently noted is the effort Dr. Delaney made on behalf of NASA Education in its relationship with Disney/Pixar, in which she secured the WALL·E partnership in the Space Act Agreement for the NASA DLN this past year.

Mr. Ruben Delgado is a Faculty Research Assistant in JCET. He received a Chemistry B.S and M.S from the University of Puerto Rico in 1995 and 2004, respectively. He expects to receive his Ph.D. in 2011, also from the University of Puerto Rico, for his dissertation work entitled "Observations and Modeling of Sporadic Metal Layers over the Arecibo Observatory". He joined JCET as a Research Associate in November 2006. 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.

Dr. Sergio DeSouza-Machado obtained a B.A. 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 CO2 P/R linemixing and water continuum corrections. His current research work is on retrievals of dust heights and optical depths, radiative transfer codes and trace gas retrievals. He also actively participates in teaching Physics classes, at both the undergraduate and graduate levels.

Dr. Elena M. Georgieva received her PhD in physics in 1998 from the University of Sofia. She was a research associate at Lasers and Optical characterization Laboratory, Georgetown University where she worked on nanoparticles characterization and correlation spectroscopy (2000-2001). Georgieva also was a research associate at NIST Center for neutron research and Johns Hopkins University (2001-2002). For four years, she was a Senior Systems Scientist/Engineer at Science systems and Applications, and worked at Goddard Laser and Electro-optics branch on instrument development for measurement of atmospheric species (2002-2006). She has research experience in remote sensing, data analysis and validation, instrument development, spectroscopy, interferometry, 3-D imaging laser radar system and polarimetry. Previous positions held by Georgieva include Assistant Professor at the Institute of Applied Physics, Technical University of Sofia; Bulgaria (1995 - 1999); Graduate Research Assistant, Department of Physics, University of Sofia (1988 - 1994); Research Associate, Institute of Applied Mineralogy, Bulgarian Academy of Sciences, Sofia (1987-1988). She has authored 28 refereed publications and is a member of the Optical Society of America and The International Society for Optical Engineering (SPIE). In July 2010, she transferred from GEST to JCET.

Dr. Forrest Hall a physicist, currently with the University of Maryland, Baltimore County, is located at the Goddard Space Flight Center, in the GSFC/UMBC Joint Center for Earth Systems Technology. Since 1980, Dr. Hall has been active in global change research using earth-observing satellites to monitor human-induced and natural changes to the earth's land ecosystems and the effects those changes have had on the earth's climate. He has authored or co-authored 60 scientific papers on satellite monitoring, the global carbon cycle and climate change. In addition to many other awards, in 2009 Dr. Hall received the William T. Pecora Award, which recognizes outstanding contributions toward understanding the Earth by means of remote sensing, and the Career Achievement Award from the Canadian Remote Sensing Society. Dr. Hall has a BS in Mechanical Engineering from the University of Texas, and an MS and PhD 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. His 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. 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. Shin-Chan Han received a Ph.D. (2003) and a MS (2000) in Geodetic Science from Ohio State University (OSU), Columbus, OH, and a BS (1998) in Earth Science from Seoul National University, Seoul, Korea. His MS thesis is on absolute point positioning from Global Positioning System (GPS) and his Ph.D. dissertation is on the global and regional gravity recovery from satellite tracking data and geophysical applications. He worked for two years as a Postdoctoral Research Associate at the Space Geodesy and Remote Sensing Laboratory at OSU and for one year as a Research Scientist at the School of Earth Sciences as OSU. During this period, he gave several invited talks on Earth gravity field at Technische Universiteit Delft, University College London, University of Toronto, Texas A&M University, and Université Laval. In 2006, he joined the Planetary Geodynamics Laboratory at NASA Goddard Space Flight Center and the Goddard Earth Sciences and Technology Center at UMBC as a member of the research faculty. His main research interest is global and local, static and temporal gravity field determination of the Earth and planets and earthquake monitoring and modeling with the gravity observations. He has been publishing papers on gravity estimation theory, coseismic and postseismic deformation, hydrological mass variation over the large river basins, ocean tides in polar regions, GPS/INS, and gravity gradiometry. In 2011, he joined JCET.

Mr. Scott Hannon received his BA and MS in physics at UMBC, and stayed on as a research assistant with Dr. Strow since 1991. His work has primarily focused on the development of fast radiative transfer algorithms for AIRS and other infrared spectrometers.

Dr. Susan Hoban is a Senior Research Scientist at JCET, and formerly with GEST. She received her Ph. D. in astronomy from the University of Maryland in 1989. She conducted research in cometary science at NASA Goddard Space Flight Center, first as a National Research Council fellow, then as part of USRA Visiting Scientist Program, from 1989 - 1993. In 1993, she began working on information systems for science and education. In 1996, Dr. Hoban received the NASA Special Service Award for her work on web-based educational outreach. She joined the University of Maryland Baltimore County in the Computer Science and Electrical Engineering Department in 1996 as part of the Center of Excellence in Space Data and Information Science (CESDIS) at Goddard. From 1998-99 Dr. Hoban served as Acting Associate Director of CESDIS and from 1999 through the conclusion of CESDIS in 2000 as Acting Director. Her interests include scientific information systems, and information technologies for science, technology, engineering and mathematics (STEM) education. Dr. Hoban is the PI on the NASA's BEST Students (Beginning Engineering, Science and Technology) project that provides professional development for educators and curriculum support resources with a space exploration theme for engineering clubs for elementary and middle school students. The project also hosts engineering challenges and two-week summer bridge programs centering on lunar exploration for middle and high school students. She has a particular interest in contributing to our nation's educators' understanding of STEM subjects. She serves on the STEM Council at UMBC and on the STEM Advisory Council for Anne Arundel County Public Schools.

Dr. R. M. Hoff is a Professor of Physics at the University of Maryland, Baltimore County. He is the Science Advisor for the Joint Center for Earth Systems. Dr. Hoff has 37 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 Raman, 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 99 journal articles and book chapters, 97 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. He was a member of the Science Advisory Group on Aerosols to the Commission of the Atmospheric Sciences of the World Meteorological Organization. He served on a National Academy of Sciences/National Research Council Panel on Mesoscale Meteorological Observations for Multiple National Needs. He is the Chair of the NASA Applied Sciences Advisory Group and is a member of the Earth System Science Advisory Panel for the agency. Recently, he has become an external science committee member on the European Commissions ACTRIS project. 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. In 2008, he became a Fellow of the American Meteorological Society.

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, 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 was born in Belem, Brazil. He received his B.Sc. degree in 1997 from the Universidade Federal do Para (UFPA) - Belem, Brazil, and his M.Sc. degree in Theoretical Physics from the Instituto de Fisica Teorica (IFT) - Sao Paulo, Brazil in 1999. In 2007, Dr. Imbiriba received his Ph.D. in Physics from the University of Maryland (UMD) at College Park, MD. Since Fall 2006, he has been a Research Associate at the Joint Center for Earth Systems Technology (JCET) at University of Maryland Baltimore County (UMBC) in Baltimore, MD. His research interests include remote sensing studies on climate change, and numerical modeling.

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 Measurement (GPM) and ongoing CloudSat missions. He is a member of the GPM radiometer algorithm team, combined radar/radiometer algorithm team, and is a member of several working groups, including the International Precipitation Working Group (IPWG), and is actively involved in developing improved retrieval algorithms for measuring falling snow using passive microwave and radar remote sensing methods.

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 and subsequently 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, a 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 problem. 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. J. Vanderlei Martins received a Bachelor's degree in physics in 1991, a Master's degree in physics/nuclearapplied 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 in international conferences, the most recent being on the spectral absorption properties of aerosol particles, on the measurement of the vertical profile of cloud microphysical and thermodynamic properties, and on the development of new instrumentation for the measurement of aerosol and cloud particles. He served as elected member of the International Radiation Comission from 2001-2008. In 2006 he assumed an Associate Professor position in the Department of Physics of the UMBC, while keeping his affiliation with JCET.

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. Her interest 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 distributions into global models. His current work involves the development of combined radar-radiometer methods for estimating precipitation and latent heating vertical structure, and the creation of a satellite-based, atmospheric diabatic heating record for evaluating climate models and closing the atmosphere’s energy budget.

Dr. Ana I. Prados is a Research Assistant Professor at the Joint Center for Earth Systems Technology, University of Maryland Baltimore County. She has a Ph.D in Chemistry and is also currently a candidate in Public Policy at the University of Maryland, College Park. Her main research expertise is the application NASA imagery for monitoring air pollution and the development of web-tools for access to NASA Earth Science data. Dr. Prados also currently coordinates and conducts remote sensing education and public outreach workshops for the NASA Applied Sciences Program, where she teaches the application of satellite imagery to environmental decision-making activities related to air quality, water resources management, and climate.

Mr. Adam Robinson is an undergraduate student at the University of Maryland, Baltimore County, double majoring in physics and math. He is currently working on retrieving dust heights and optical depths. He has improved the AIRS dust flag, an algorithm to determine where there is dust, over ocean and is working on making it work over land.

Mr. Paul Schou received a B.A. from Michigan Technology University in Physics in 2006 and currently is working on finishing his M.S. in Atmospheric Physics at UMBC. His research interests include retrieving atmospheric profiles from 600 mb to the surface from various skydiving sites, as well as collocating AIRS and IASI radiance data with ECMWF geophysical fields.

Dr. Chung-Lin Shie, originally from Taiwan, R.O.C., received a B.S. in atmospheric sciences from National Taiwan University, then a M.S. in meteorology from Pennsylvania State University, and a Ph.D. in meteorology from Florida State University. He started working at NASA/GSFC as a research scientist since February 1993, affiliated first with SSAI (as Research Meteorologist till February 1997, then Senior Research Meteorologist till March 2001), and then Associate Research Scientist with UMBC/GEST (since April 2001) and joined UMBC/JCET in May 2011. During his early career, he mainly worked on the development and improvement of an EOF (Empirical Orthogonal Functions) model for surface humidity retrieval over the global oceans using the SSM/I precipitable water data. He later helped produce a global (2x2.5 grid) daily air-sea surface flux product (GSSTF1) for a 7.5-year period, which was archived and distributed by the Goddard DISC. Since April 1997, he joined a research project involving numerical simulations using the GCE model, and scientific analysis to study radiative-convective systems and their interactions with large-scale environment. He has recently further extended the scope of his multi-tasking research works. His current research also involves research projects such as EOS, NEWS, and NAMMA. He recently won a MEaSUREs funded proposal to resume the air-sea flux production that he had helped establishing during 1993-1997. In 2006, he won a “Meritorious Service Award” from COAA for his genuine performance serving as one of the COAA Board Directors during 2003-2004. He also won the “Annual Outstanding Performance Award” of Mesoscale Atmospheric Processes Branch, NASA/GSFC in both 2000 and 2004, as well as won an “Outstanding Mentoring Award” from UMBC/GEST in 2003. During his association with SSAI for 1993-2000, he had won Annual Performance Awards eight years in a row.

Dr. Christopher A. Shuman joined GEST in May 2007 as Associate Research Scientist. He is currently working with Dr. David J. Harding, Planetary Geodynamics Branch, NASA GSFC, on enhanced laser altimetry concepts for cryospheric science. From 2001-2007, he was a Physical Scientist with the Cryospheric Sciences Branch, and the Deputy Project Scientist for the ICESat Mission (2001-2005), as well as an Adjunct Research Faculty, ESSIC, University of Maryland, College Park (UMCP). From 1999-2001 he was an Assistant Research Scientist, Earth System Science

Interdisciplinary Center, UMCP. For fours years he worked with Dr. Robert Bindschadler at NASA GSFC's Oceans and Ice Branch, first, from 1994-1996 as a Resident Research Associate through the National Research Council; second, from 1996-1998 as a Visiting Research Fellow with the Universities Space Research Association. From 1992-1994, he was a Research Associate at the Earth System Science Center and Department of Geosciences of The Pennsylvania State University, working with Dr. Richard B. Alley. Dr. Shuman received his Ph.D. in Geosciences in 1992 and his M.S. in Geology in 1987 from The Pennsylvania State University, and his B.S. in Geology in 1982 from Moravian College. Dr. Shuman has authored or co-authored research papers on laser altimetry and its combination with other remote sensing data to define subglacial lakes in Antarctica, on the accuracy of early ICESat-1 data, on composite temperature records derived from AWS passive microwave data from SMMR and SSM/I and IR data from AVHRR, as well as correlating those records through stratigraphic correlation with stable isotope ratio profiles in shallow snow layers. He has worked extensively in Greenland and Antarctica, and began his cryospheric career helping to date the GISP2 ice core. He is currently the longest serving (surviving?) member of PoDAG (http://nsidc.org/daac/podag.html) and is also on the Executive Committee of the Cryospheric Focus Group of AGU http://www.agu.org/focus_group/cryosphere/membership.html#exec).

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 the B.S. degree in physics from University of Maryland, Baltimore County in 1974, and the M.S. and Ph.D. degrees from the University of Maryland at College Park in 1977 and 1981 respectively. He is currently a Professor with the Department of Physics, UMBC. His research interests include molecular spectroscopy, especially spectral line shapes, and atmospheric remote sensing. He is a member of the AIRS Science Team.

Dr. Michael Studinger joined GEST in 2009 as Associate Research Scientist, working in the Cryospheric Sciences Branch and moved to JCET in May 2011. He received his M.S. in Geophysics in 1993 at Ludwig Maximilians University, Munich, Germany, and his Ph.D. in Geophysics in 1998 from the Alfred Wegener Institute and University of Bremen in Germany. He has served on several committees and participated in many workshops. Additionally, he has extensive field experience, most recently in Antarctic and Greenland.

Dr. Andrew Tangborn received undergraduate degrees from the University of Washington In Mathematics and Mechanical Engineering and MS and PhD 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. He is the PI on grants from the National Science Foundation on geomagnetic data assimilation and is Co-I on a NASA Modeling, Analysis and Prediction (MAP) grant on carbon cycle data assimilation. In addition to his collaboration with scientists at NASA, he has been active in advising graduate students at UMBC and METEO-France. He has taught several different graduate courses at UMBC and has given invited lectures in graduate courses in the atmospheric sciences department at the University of Maryland College Park for the past 6 years.

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 National Research Council Fellowship between 1993 and 1995. He then joined to Saint Louis University as assistant professor in 1995 and to University of Maryland Baltimore County (UMBC) as a research assistant scientist in 1997. He was later promoted to research assistant professor and became research associate professor in 2007. Dr. Tokay was a principal investigator during a series of field campaigns under NASA Tropical Rainfall Measuring Mission. He has been taught a number of undergraduate and graduate courses in both Saint Louis University and UMBC. He was an advisor of a MS student who graduated in 1998, and he also mentored 14 undergraduate and 8 graduate students. Dr. Tokay is an affiliated associate professor of Department of Geography and Environmental Sciences and research associate professor of Joint Center for Earth Systems Technology at UMBC. He is a member of NASA precipitation science team, and he was the co-chair of the 34^{th} AMS radar meteorology conference and he is a member AMS radar meteorology committee.

Dr. Tamás 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 to 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 considering 3D radiative effects in satellite retrievals of cloud and aerosol properties, focusing mostly on the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite instrument, the CALIPSO satellite, and the airborne 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 Atmospheric Chemistry Division until she joined the University of Maryland Baltimore County at the Joint Center for Environmental Systems Technology in 2004. During her career after 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 25 refereed papers on the analyses of the atmospheric composition and remote sensing algorithms and techniques and received four 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. Michael Wilson joined JCET in May 2011 after being with GEST since August 2009. He received his Ph.D. in Atmospheric Sciences from the University of Illinois, Urbana-Champaign, where his work at Illinois involved separating clouds from ice and snow in satellite imagery, mostly using the MISR instrument. He also has compared Arctic and Antarctic MISR retrievals to radiative transfer model simulations. As part of his work at Goddard, he is working on finding cloud shadows in Landsat imagery.

Dr. Tianle Yuan received a B.S. in both Atmospheric Science and Computer Science from the Peking University in 2001 and a Ph.D. in atmospheric and oceanic sciences in 2008 from the University of Maryland, College Park. His major interests are cloud physics, radiation, and aerosol science. In 2008, he joined JCET as a research associate. His research interests include aerosol radiative forcing, aerosol-cloud interactions, and aerosol-chemistry-climate interaction.

Dr. Leonid Yurganov, a Senior Research Scientist with UMBC's Physics Department, has been with JCET since 2006. His 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). During 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 43 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. He carried out 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. In 2011, he was promoted to Assistant Research Scientist.

Dr. Zhibo Zhang received a Ph.D. in Atmospheric Sciences (2008) and a MS (2004) from the Texas A&M University and a BS in Meteorology (1998) from the Nanjing University, China. His Ph.D. thesis is on the satellite-based remote sensing of ice clouds. In January 2009, he joined the Goddard Earth Sciences and Technology Center at the University of Maryland, Baltimore County, where he worked with the MODIS cloud science team led by Dr. Steven Platnick on the development of infrared cloud property retrieval algorithm. In 2011, he joined JCET.

III.9 Table 1: JCET Faculty (as of July 31, 2011)

NAME	TITLE	AFFILIATION
Dr. William Barnes	Senior Research Scientist	Research Faculty
Dr. Huisheng Bian	Associate 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. Allen Chu	Associate Research Scientist	Research Faculty
Dr. Marcianna Delaney	Assistant Research Scientist	Research Faculty
Mr. Ruben Delgado	Research Associate	Research Faculty
Dr. Sergio deSouza-Machado	Research Assistant Professor	Physics
Dr. Elena Georgieva	Associate Research Scientist	Research Faculty
Dr. Forrest Hall	Senior Research Scientist	Research Faculty
Dr. Jeffrey Halverson	Associate Professor	Geography and Environmental Systems
Dr. Shin-Chan Han	Associate Research Scientist	Research Faculty
Mr. Scott Hannon	Research Assistant	Research Faculty
Dr. Jay Herman	Senior Research Scientist	Research Faculty
Dr. Susan Hoban	Senior Research Scientist	Research Faculty
Dr. Raymond Hoff	Professor	Physics
Dr. K. Fred Huemmrich	Research Associate Professor	Geography and Environmental Systems
Dr. Breno Imbiriba	Research Associate	Research Faculty
Dr. Ben Johnson	Research Associate	Research Faculty
Dr. Ilan Koren	Assistant Research Scientist	Research Faculty
Dr. Prasun Kundu	Research Associate Professor	Physics
Dr. Amita Mehta	Research Assistant Professor	Geography and Environmental Systems

NAME	TITLE	AFFILIATION
Dr. William Olson	Research Associate Professor	Physics
Dr. Ana Prados	Research Assistant Professor	Chemistry
Dr. Chung-Lin Shie	Associate Research Scientist	Research Faculty
Dr. Christopher Shuman	Associate Research Scientist	Research Faculty
Dr. Michael Studinger	Associate Research Scientist	Research Faculty
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	Physics
Dr. Zigang Wei	Assistant Research Scientist	Research Faculty
Dr. Michael Wilson	Research Associate	Research Faculty
Dr. Tianle Yuan	Research Associate	Research Faculty
Dr. Leonid Yurganov	Senior Research Scientist	Research Faculty
Dr. Hai Zhang	Research Associate	Research Faculty
Dr. Zhibo Zhang	Assistant Research Scientist	Research Faculty

III.10 Table 2: JCET Fellows (as of July 31, 2011)

NAME	AFFILIATION
Dr. Robert Cahalan	NASA GSFC
Dr. Belay Demoz	Hampton
Dr. Jill Engel-Cox	Battelle Memorial Institute
Dr. Richard Hartle	NASA GSFC
Mr. Ernest Hilsenrath	NASA GSFC (retired)
Dr. Weijia Kuang	NASA GSFC
Dr. Thorsten Markus	NASA GSFC
Dr. Alexander Marshak	NASA GSFC
Dr. Vanderlei Martins	UMBC Physics
Dr. Harvey Melfi	Emeritus
Dr. Lazaros Oreopoulos	NASA GSFC
Dr. Steven Platnick	NASA GSFC
Dr. Lynn Sparling	UMBC Physics
Dr. David Starr	NASA GSFC
Dr. Larrabee Strow	UMBC Physics
Dr. Marco Tedesco	NASA GSFC
Dr. David Whiteman	NASA GSFC

III.11 Table 3: JCET Associate Staff (as of July 31, 2011)

NAME	TITLE
Mr. Timothy Berkoff	Assistant Research Engineer
Mr. Dominic Cieslak	Research Engineer
Mr. Keith Evans	Research Analyst
Mr. Paul Schou	Research Analyst

III.12 Table 4: JCET Administrative Staff (as of July 31, 2011)

NAME	TITLE
Ms. Valerie Casasanto	Program Coordinator
Ms. Mary Dawson	Business Manager
Ms. Danita Eichenlaub	Director
Dr. Franco Einaudi	Chair, Executive Board
Dr. Jeffrey Halverson	Associate Director
Dr. Raymond Hoff	Science Advisor
Ms. Amy Houghton	Communications Specialist
Ms. Camilla Hyman	Accountant I
Ms. Brizjette Lewis	Executive Administrative Assistant
Ms. Cathy Manalansan	Administrative Assistant II
Ms. Katie Nguyen	Business Specialist
Ms. Nina von Gunten	Administrative Assistant I
Ms. Margo Young	Business Manager

Acronyms and Abbreviations

ACARS	Aircraft Communications Addressing and Reporting System
AERI	Atmospheric Emitted Radiance Interferometer
AERONET	Aerosol Robotic Network
AGU	American Geophysical Union
AIRS	Advanced Infrared Sounder
ALEX	Atmospheric Lidar Experiment
ALG	Atmospheric Lidar Group
AOD	Aerosol Optical Depth
ARM	Atmospheric Radiation Measurement
BOREAS	Boreal Ecosystem Atmosphere Study
BRDF	Bidirectional Reflectance Distribution Function
C3VP	Canadian Cloudsat/CALIPSO Validation Project
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CDRD	Cloud Dynamics and Radiation database
CMAQ	Community Multiscale Air Quality
CRESST	Cooperative Center for Remote Sensing Science and Technology
CrIS	Cross-Track Infrared Sounder
CRM	Cloud Resolving Model
DAAC	NASA Data Active Archive Center
DOE	U.S. Department of Energy
ELF	Elastic Lidar Facility
EOS	Earth Observation System
ESA	European Space Agency
EUMETSAT	European Organization for the Exploration of Metrological Satellite
GALION	Global Atmosphere Watch Atmospheric Lidar Observation Network
GASP	GOES Aerosol and Smoke Product

GEDI	Global Ecosystem Dynamics Mission
GEST	Goddard Earth Sciences and Technology Center
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
GRIP	Genesis and Rapid Intensification Processes
GSFC	Goddard Space Flight Center
GV	Ground Validation
I3RC	Intercomparison of 3-D Radiation Codes
IASI	Infrared Atmospheric Sounding Interferometer
IDEA	Infusing satellite Data into Environmental Applications
IEEE	Institute of Electrical and Electronics Engineers
IGAC	International Global Atmospheric Chemistry Project
IGARSS	IEEE International Geoscience and Remote Sensing Symposium
LaRC	Langley Research Center
LIDAR	Light Detection and Ranging
LITE	Lidar In-Space Technology Experiment
LUE	Light Use Efficiency
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MC3E	Midlatitude Continental Convective Cloud Experiment
MDSA	Multi-Sensor Data Synergy Advisor
MISR	Multiangle Imaging SpectroRadiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
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

NIFA	National Institute for Food and Agriculture
NLLJ	Nocturnal Low Level Jet studies
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NSF	National Science Foundation
OMI	Ozone Monitoring Instrument
PMF	Positive Matrix Factorization
SiB	Simple Biosphere
SIF	Solar Induce Fluorescence
SSM/I	Special Sensor Microwave/Imager
THOR	Thickness from Offbeam Returns
TMI	TRMM Microwave Imager
TOMS	Total Ozone Mapping Spectrometer
TIROS	Television Infrared Observation Satellite
TRMM	Tropical Rainfall Measuring Mission
UMBC	University of Maryland, Baltimore County
USDA	U.S. Department of Agriculture
UWNMS	University Wisconsin Non-hydrostatic Modeling System
VIEWS	Visibility Exchange Web System
WMO	World Meteorological Organization