TWELFTH ANNUAL REPORT
JOINT CENTER FOR EARTH SYSTEMS TECHNOLOGY

A Cooperative Agreement Between:

University of Maryland, Baltimore County

and

NASA Goddard Space Flight Center

October 1, 2006 – September 30, 2007

The Joint Center for Earth Systems Technology

Twelfth Annual Report

October 1, 2006 – September 30, 2007

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Preface

This volume is the twelfth annual report describing the scientific accomplishments and status of the Joint Center for Earth Systems Technology (JCET). This Center was established July 1, 1995 to promote close collaboration between scientists at the University of Maryland, Baltimore County (UMBC) and the NASA Goddard Space Flight Center (GSFC) in areas of common interest related to developing new technologies for environmental remote sensing. The Center's objective is to conduct multidisciplinary research on advanced concepts for observing Earth and planetary atmospheres, the solid Earth and planets, and the hydrosphere, all from ground stations, aircraft, and space-based platforms. This research continues to lead to improved understanding of global processes and increased capability to predict global environmental changes. As a result of NASA's realignment to accommodate its Moon-Mars initiative, JCET has also become more involved in solar-terrestrial physics. 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. Both the Earth-Sun Division (formerly the Earth Sciences Directorate) and the Solar System Exploration Division have participated in establishing, funding, and collaborating with JCET. At UMBC, JCET is administered through the Graduate School. JCET personnel are currently associated with the university Departments of Physics, Geography and Environmental Systems, Mathematics and Statistics, and Computer Science and Electrical Engineering. JCET's administrative office is in the second building of the new technology park expansion at UMBC, which also includes space for a few faculty members and a conference room. JCET also has offices in the Physics and Academic IV-A buildings on the UMBC campus.

There are 37 JCET faculty members (listed in Section III.9), a decrease of ten percent from the previous year, partly due to faculty being promoted (Vanderlei Martins is now a tenure-track faculty member in the Physics department and now a JCET Fellow) or transferring to our sister center, the Goddard Earth Sciences & Technology Center (GEST). The number of JCET Fellows remained steady at 18 (listed in Section III.10). This newest category of JCET membership includes civil servants from NASA, other government agencies and private research institutions in addition to UMBC faculty. JCET research is also supported by two associate staff members (listed in Section III.11). Brief biographies of each JCET faculty and associate staff members are presented in Section III.8. The overall management and administration of JCET is governed by the executive board and carried out by an expert administrative staff, which also supports JCET's sister center GEST (listed in Section III.12). In the spirit of cooperation between UMBC and GSFC, the Director is also a Professor of Physics at UMBC, while the Board Chairman and an Associate Director are civil servant scientists at GSFC. The scientific management of JCET is further facilitated through four research focus groups whose titles reflect their scientific disciplines: Observation Science, Clouds and Precipitation, Atmospheric Radiation, and Interdisciplinary Science, as well as the support of an Associate Director-Academics whose position is to support the Director in linking the academic mission of the center with ongoing scientific research. Every JCET faculty and associate staff member performing research belongs to one of the focus groups. Each focus group elects a group leader (shown in Section III.13), who is responsible for the scientific leadership of the group, and these group leaders report to the Associate Director-Academics.

The body of this report (see Section II) is divided into four sections, each of which is devoted to the scientific activities of a focus group. Within each section are presented brief accounts of group members' accomplishments, provided by the respective principal investigators supported through a JCET task and/or grant from NASA or other government agencies that was active during the reporting year October 1, 2006 to September 30, 2007. Each report includes an abstract, description of the research, accomplishments for FY 06-07, and objectives for FY 07-08. 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 91 refereed papers (and 29 others submitted for review), along with 211 conference presentations and publications and nonrefereed publications (see Section III.4) comprise the principal direct contribution of JCET scientists to the Earth sciences. In addition to their current research, JCET scientists planned for the future through submission of 91 grant proposals, listed in Section III.7, a third of which have already been awarded to be administered through individual PI or Co-I assignments, while decisions remain pending on another third.

JCET scientists also contributed to education at UMBC by teaching and mentoring graduate students in the Departments of Physics and Mathematics/Statistics. The 16 different courses they taught this fiscal year are listed in Section III.5. Colloquia and seminars are an integral method to share knowledge in the academic community, and JCET researchers regularly provide such instruction, as listed in Section III.6. In addition, JCET faculty are mentoring or providing direct supervision for 10 graduate students, and providing research opportunities for a number of additional undergraduate and graduate students from UMBC and other universities.

R. E. Hartle, Associate Director September 2007
J. B. Halverson, Associate Director
R. M. Hoff, Director

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I. Executive Summary

Third in the Nation and Still Growing

Now in its 12th year, the Joint Center for Earth Systems Technology (JCET) continues to foster diverse and productive research, provide advanced degree training at UMBC, and assume international leadership roles within the Earth and space science enterprises. We are proud to report that JCET's productivity has been on a solid upward-trending curve for the past several years. This time around, the number "three" speaks broadly to JCET's accomplishments in the aforementioned arenas.

The first of the "three's" is that UMBC, based on metrics reported for 2005, nationally ranks third among all U.S. universities and colleges receiving research dollars from NASA. A large share of this accolade stems from the research independence being cultivated within JCET and GEST. During the 2007 fiscal year, JCET's faculty brought in $1.2 million in new grant research money to UMBC. The spectrum of research dollars spanned all of Earth science, ranging from studies of atmospheric trace gases and pollutants to tropical rainfall, landslide dynamics and Earth's changing sea level.

The laudable accomplishments of a few JCET faculty are highlighted here, and the details can be found within the pages of this Annual Report. Vanderlei Martins and his research team completed prototypes of a rainbow camera polarimeter and cloud scanner imaging system—both important benchmarks towards the development of a UMBC-led space mission to measure the impact of atmospheric particulates on clouds. William Olson investigated a new method for estimating the vertical profiles of falling snow using remote sensing techniques. This will help the pave the way as a new era of satellite-based, global measurement of precipitation moves out of the tropics and into the snowy mid-latitudes. Juying Warner used her expertise to design a new instrument, called a hyperspectral imager, to better detect important atmospheric trace gasses including carbon monoxide and ozone. Kevin McCann and Ray Hoff continue to make key contributions to the CALIPSO Science Team as they refine new satellite-based estimates of atmospheric particulates through careful validation studies. Marko Bulmer, on invitation from the Pakistan Geological Survey, studied landslides from a devastating 2005 earthquake and their susceptibility to monsoon rains. He did so using an ingenious method of aerial survey via remotely piloted aircraft. Simon Carn and Arlin Krueger observed sulfur dioxide emissions from several volcanic eruptions across the globe (Papua New Guinea, Alaska, Reunion, Congo, Tonga) using advanced satellite monitoring techniques, and tracked the dispersion of these gases around the globe. And Erricos Pavlis has embarked on a study to better understand Earth's geocenter and the implications of its precise measurement on Mean Sea Level. Marco Tedesco has been making significant strides in the research literature with his satellite data showing accelerating ice loss in the polar caps, research that has enjoyed widespread dissemination in the popular media.

Thanks to these scholarly achievements and the important work of many other faculty within JCET, GEST and our affiliate academic departments, UMBC now ranks third in the nation for citations in the peer-reviewed, geosciences literature for the period 2001-2005. This is a tremendous achievement for a modestly-sized, relatively young university. Our new ranking speaks to the growth, stability and maturation of JCET as a national and international leader in the study of our physical environment.

On the academic front, JCET has expanded its departmental ties beyond Physics, Geography & Environmental Systems, Mathematics & Statistics, and Computer Science & Electrical Engineering. As more of our faculty successfully obtain academic affiliation, new affiliation ties have been solidified. In the past year, we have placed faculty within the Department of Mechanical Engineering and also within the Chemistry Department. With the anticipated growth of Geography's faculty to accommodate a new graduate degree program, additional 600-level course offerings and student mentorship opportunities have been opened up to the JCET faculty.

Within these units, JCET faculty have been instrumental in the successful matriculation and career placement of graduate students. In Mathematics & Statistics, Ravi Siddani completed his PhD under the tutelage of Prasun Kundu and is now employed with a major phamaceutical company. In Physics, PhD awardees Ray Rogers, Felicita Russo and Glen Hulley have obtained positions at the NASA Langley Research Center, an Italian National Research Council position in Italy and at the Jet Propulsion Laboratory, respectively. Zhibin Sun in Mathematics & Statistics became the first-ever PhD graduate trained in the field of geomagnetic data assimilation. Many other graduate students are making excellent progress toward their advanced degrees under the guidance and financial support of JCET affiliated faculty.

In the trinity underpinning the success of academic enterprise—scholarship, research independence and teaching—JCET's contribution of "three's" in FY2007 is precisely on the mark, and mark an important milestone in the cooperative institute's continued ascent.

Raymond M. Hoff	Jeffrey B. Halverson
JCET Director and	JCET Associate Director–Academics and
Professor, Physics	Associate Professor, Geography and Environmental Systems

September 2007

Highlights of FY 05-06 Activities: Atmospheric Radiation Focus Group

The Radiation Focus Group (RFG) performs basic and applied research in atmospheric radiative transfer with applications to remote sensing and climate problems. Specific areas of group interest include cloud and aerosol radiative properties, remote sensing (i.e., satellite-, aircraft-, and surface-based techniques), in situ aerosol observations, and atmospheric and surface energy budgets. The group currently consists of fourteen members, including four faculty affiliated with the UMBC Department of Physics, one professor of the practice, three assistant research scientists, three civil servant JCET fellows, one research analyst, one staff engineer, and one UMBC Department of Physics faculty member. The following is a brief outline of major research accomplishments by RFG members.

In a *Science* paper by Drs. Yoram Kaufman and Ilan Koren the existence a direct correlation between cloud cover and aerosol column concentration, and an inverse relation between cloud cover and aerosol absorption of sunlight were identified. This is an important contribution towards the understanding of cloud0aerosol interaction processes.

Dr. Vanderlei Martins and his research team completed the first prototypes of a rainbow camera polarimeter and cloud scanner imaging systems. These are important benchmarks towards the development of an UMBC-led space mission to measure aerosol absorption, its composition and effects on clouds.

Dr. Lazaros Oreopoulus produced the most extensive estimates available to date of the plane-parallel homogeneous bias for liquid phase clouds. The reported results highlight the importance of predicting subgrid variability in GCM's and accounting for cloud-radiation interactions.

The OMI near UV aerosol data was publicly released. The Aura-OMI aerosol products include the absorbing Aerosol Index and estimates of aerosol absorption optical depth. This is an important new data set that contributes to improve the understanding of aerosol absorption effects on the Global Climate, and complements the MODIS and MISR data sets on aerosol scattering properties.
Dr. Omar Torres is the Principal Investigator of the OMI near-UV aerosol product.

Dr. Varnai presided over the third phase of the I3RC project that inter-compares cloud 3D radiative transfer models. Participant models developed by scientists around the world enabled the establishment of reference results for the comparison and analysis of a variety of modeling techniques.

Highlights of FY 05-06 Activities: Clouds and Precipitation Focus Group

Dr. Jeffrey Halverson worked with undergraduate Alex Robel from Duke University to investigate the extratropical transition of landfalling tropical cyclones in the Mid Atlantic. They identified 31 tropical cyclones making landfall during the past ten years. They then examined the North American Regional Reanalysis (NARR) fields in order to calculate various thermodynamic and dynamic forcings accompanying the evolution of the tropical cyclones. The objective is to identify the critical subset of environmental factors that determine whether a cyclone will undergo extratropical transition and intensify, maintain intensity or weaken. A second objective is to characterize severe weather generation by the population of landfalling cyclones in terms of major synoptic forcing factors, with emphasis on the freshwater flooding aspect.

Dr. Amita Mehta's worked to understand precipitation processes through retrieval, analysis, and modeling. A multi-year project carried out under this task, Cloud Dynamics and Radiation Database (CDRD), focuses on generating an extensive database using cloud resolving model simulations and calculations of microwave brightness temperatures/radar reflectivities that can be used for rain retrievals from satellite-based analogous microwave measurements. Additionally, analysis of CDRD facilitates understanding of relationships between microphysical processes and mesoscale and large-scale dynamical/thermodynamical processes in rain systems. A further goal of this task is to carry out observational analysis of TRMM rainfall measurements to understand rain characteristics over a number of regions including Gulf of Mexico - Caribbean Sea basin, Mediterranean Sea basin, Central US, and Asian monsoon region.

Dr. Prasun Kundu's research examined the statistical properties of gridded monthly averaged rainfall data gathered from satellite remote sensing measurements, such as the global multi-year data from the Tropical Rainfall Measuring Mission (TRMM). This included addressing statistical issues that arise when one attempts to compare the satellite estimates with those obtained from ground-based radar and rain gauge measurements at the established TRMM ground validation (GV) sites. In particular, an intercomparison of satellite and ground radar and rain gauge measurements presents a nontrivial problem even when the measurements are considered to be ideal, i.e. the experimental errors are neglected, because of the disparity between the space-time averaging scales in the various different measurement methods. A quantitative understanding of the scale dependence of the statistical properties of precipitation is sought in terms of the dependence of the parameters of the underlying probability distribution on the space-time scale over with the data are averaged. Current work focuses on a recently discovered probability distribution belonging to the class of infinitely divisible distributions that fully characterizes all the statistical moments of area-averaged precipitation and explains their observed power law scaling behavior.

Dr. William Olson investigated a method for estimating vertical profiles of falling snow using a combination of airborne cloud radar and higher-frequency passive microwave radiometer observations was developed and applied successfully to both synthetic data and airborne radar and radiometer observations. A comprehensive effort to improve latent heating estimates based upon spaceborne passive microwave radiometer observations led to improvements in cloud-resolving modeling, incorporation of ground-based environmental data, and changes in estimation methodology. A radar/radiometer simulator developed to support GPM ground validation activities was improved and generalized for simulations of airborne and ground-based sensor observations. Recent simulations were used to provide guidance for Canadian field campaign operations.

For Dr. Ali Tokay, measurement of precipitation in the content of physics, accuracy, and small-scale variability is the main theme of the ongoing research. In terms of physics, the characteristics of raindrop size distribution in different precipitation systems including tropical cyclones were studied through disdrometer measurements. The presence of more small and less large drops in tropical storms than in extratropical storms at a given reflectivity was one of major findings of the study. Physical aspects of the raindrop size distribution have a pronounced influence on radar and radiometer retrieval of precipitation. In that regard, a new parameterization was presented for the dual-frequency radar rainfall algorithm. The measurements of snowfall were another segment of the ongoing efforts. In terms of accuracy, the usefulness of operation rain gauges for scientific applications was tested through daily and monthly rainfall between collocated gauges. The climate reference network and fire management network gauges had a higher accuracy, while the automated weather observing system gauges had a failure. In terms of spatial variability, time height ambiguity between disdrometer and vertically pointed S- and K-band radar reflectivity was investigated. It was found that the comparison of larger volumes such as radars had a higher correlation and less biases than comparison of point measurements.

Mr. Benjamin Johnson's research focused primarily on improving multi-sensor microwave retrievals of cold-cloud precipitation. The primary goal is to obtain a higher quality retrieval of precipitation properties such s particle size distribution, particle density, precipitation rate, and particle shape. To achieve this goal, a novel, new forward model has been developed to simulate the radiative and physical properties of a steady-state 1-D column of the atmosphere and surface. A retrieval technique is also under development that utilizes co-located satellite or aircraft based dual-frequency radar observations to more accurately assess particle size distribution properties.

Highlights of FY 05-06 Activities: Observation Science Focus Group

The Observations Focus Group has initiated a number of collaborations this year along with several new multi-instrument lines of research. There have been several collaborations including those with Drs. Wallace McMillan, Leonid Yurganov, and Lynn Sparling, and their students on trace gas detection with satellite instruments and in the modeling of their dynamic evolution. In the trace gas detection arena, there has also been development on a new instrument, the Hyperspectral imager, by Dr. Juying Warner to use the instrument to detect atmospheric carbon monoxide and ozone.

One of the really exciting new developments during this year has been the availability of Level 1 and Level 2 data from the CALIPSO/CALIOP lidar, the newest addition to the A-train. Drs. Ray Hoff and Kevin McCann have been active participants on the CALIPSO Science Team and are involved with the validation of the Level 2 products. This new instrument has given us the ability to measure the altitude of clouds and aerosols. In addition to the retrievals of aerosol extinction and optical depth from this space-based LIDAR system, there has been significant collaboration between Dr. Omar Torres' OMI group and Dr. Ray Hoff's lidar group to improve the OMI retrievals of optical depth and possibly other measurements including the measurement of volcanic SO_2 plumes. In a similar manner the UMBC LIDAR group has been collaborating with the AIRS team (Drs. Larrabee Strow, Sergio DeSouza-Machado, Breno Imbiriba, Scott Hannon, and Howard Motteler) to use the altitude measurements to improve their infrared aerosol retrievals.

Dr. Bill Barnes and Dr. Strow's AIRS team have been involved with instrument calibration and the design of new instruments. These efforts have resulted in a number of publications and presentations. In a separate effort Dr. Hai Zhang has headed up an effort to look at some of the algorithms currently in use for the GOES aerosol retrievals (GASP). In addition to the improvement in these algorithms, the operational software has been ported to both UMBC and NOAA computers.

The work on GOES algorithms has added significantly to the air quality measurements and characterization currently under the direction of Dr. Ray Hoff with participation from Dr. Ana Prados and Dr. Jill Engel-Cox, the latter a recent PhD graduate from the UMBC MEES program.

The Observations Focus Group has also been very active in both teaching and student mentoring with recent PhD graduates Dr. Michele Comer (advised by Dr. McMillan) and Dr. Ray Rogers (advised by Dr. Hoff) as well as two Masters graduates, Ms. Kamonayi Mubenga and Ms. Nikisa Jordan, in the MEES program.

Highlights of FY 05-06 Activities: Interdisciplinary Science Focus Group

True to its name, the Interdisciplinary Science Focus group undertook a wide range of earth sciences research projects during 2006-07. These included solid earth, terrestrial and atmospheric processes, sometimes including all of these within a single project.

Volcanic emissions monitoring was carried out by Drs. Simon Carn and Arlin Krueger observed the long-range transport of SO_2 using the Ozone Monitoring Instrument (OMI) after volcanic eruptions at Rabaul (Papua New Guinea), Piton de la Fournaise (Reunion) and Nyamulagira (DR Congo). OMI SO_2 measurements also played a key role in diagnosing the nature of activity at Fourpeaked volcano (Alaska), during its first historical eruption in September 2006, and permitted the dating of an unwitnessed underwater eruption of Home Reef (Tonga) in August 2006.

Dr. Mark Bulmer leads landslide research at JCET. In January 2006, Dr. Bulmer was invited by the Director of the Pakistan Geological Survey, Islamabad to examine the landslides associated with the 8th October 2005 Earthquake in Pakistan. Landslides were responsible for about 20,000 of the 87,300 fatalities. Bulmer conducted a reconnaissance in January 2006, and obtained an SGER grant from NSF to examine landslide processes before and after the 2006 monsoon season in Pakistan

Satellite Laser Ranging (SLR) research was led by Dr. Erricos Pavlis. His group's accomplishments included work on the Mean Sea Level (MSL), with the goal of quantifying the accuracy our knowledge of the geocenter and it's implications for the MSL. Their first results were presented in several presentations during the 2007 European Geosciences Union general assembly. Work now focuses on the development of simulation techniques for further validation and study of the error budget associated with MSL determination and its long- and short-term variations.

Drs. Fred Huemmrich, Forrest Hall and Petya Campbell work in the area of terrestrial ecology. Dr. Huemmrich has been analyzing the short-term (less than one day) changes in hyperspectral reflectance data in cornfields to determine whether short-term changes in carbon fluxes can be observed from reflectance observations. Dr. Hall has been involved in the processing of 30 years of Landsat data with respect to surface reflectance. Dr. Campbell has continued her work on Florence in carbon cycle research, making extensive plant biophysical measurements. The purpose of this is 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.

The Geodynamo group, led by Dr. Andrew Tangborn and JCET Fellow Dr. Weijia Kuang continues to carry out a variety of numerical studies of the geodynamo as well as the Martian dynamo. This past year long term (7000 year) assimilation runs were carried out for the first time, which combine the entire human record of geomagnetic observations with the longer paleomagnetic record. During the past year Dr. Zhibin Sun successfully defended his PhD thesis in the Mathematics department, making him the first ever PhD graduate trained in the field of geomagnetic data assimilation.
Dr. Tangborn also continued work in Carbon Cycle data assimilation, incorporating measurements of Carbon Monoxide from SCIAMACHY into the GMAO constituent assimilation system.

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II. TECHNICAL VOLUME

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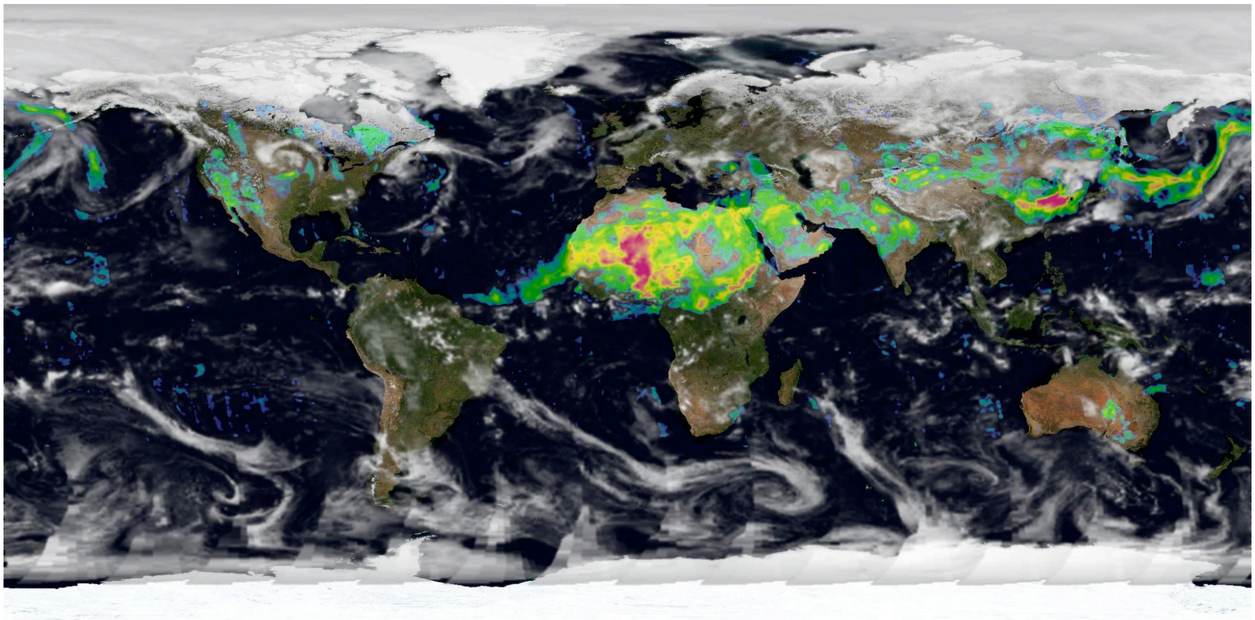
Atmospheric Radiation Focus Group



The trans-oceanic transport of desert dust across the Pacific and Atlantic Oceans as mapped in terms of the OMI Aerosol Aerosol Index, corresponding to observations on April 19, 2006. [Figure provided by Omar Torres.]

II.1 Atmospheric Radiation Focus Group: Vision

Radiative transfer in the Earth sciences is fundamentally concerned with the interaction of electromagnetic waves with atmospheric gases (molecules), particles (aerosol, cloud water droplets, and ice crystals), and land and ocean surfaces. Of primary concern is the characterization of scattering and absorption properties. Applications generally comprise two main areas: energy budget problems (*e.g.*, layer absorption and heating rates, surface and top-of-the-atmosphere radiation balance, etc.) utilizing broadband calculations, and narrow-band remote sensing applications. Both applications have obvious relevance to climate system and climate change studies. Climate is synonymous with the energy budget, while remote sensing is the only practical means for obtaining global climatologies of critical parameters.

The JCET Atmospheric Radiation Focus Group (ARFG) was organized to bring together JCET faculty with common interests in radiative transfer applications and theoretical issues. The group currently consists of fourteen members, including three faculty affiliated with the UMBC Department of Physics, one professor of the practice, one assistant research scientist, three research associates, four civil servant JCET fellows, one research analyst, and one UMBC Department of Physics faculty member. All group members are involved in major NASA-based instrument projects and research programs at GSFC. While the interdisciplinary nature of JCET ensures that the group's interests overlap with those of other focus groups, the ARFG is most closely aligned with the remote sensing activities of the Observations Science Focus Group.

Current interests of group members include remote sensing methods for obtaining global temporal and spatial distributions of major optical parameters and its vertical and horizontal variability, which, in the case of clouds, requires the use of 3-D radiative transfer. Group members are also involved in remote sensing applications for the characterization of the atmospheric aerosol load, as well as surface remote sensing applications for the determination of the oceans reflective properties. ARFG members also participate in the evaluation of these remote-sensing products by inter-comparisons between calculated and observed quantities, and in the formulation of parameterization methods of derived optical properties for GCM applications. In particular, group members analyze data from satellite-, aircraft- and ground-based measurements, and construct radiation models to retrieve atmospheric and surface parameters and to understand climate processes.

In addition to its noteworthy research efforts, the ARFG has made substantial contributions to the academic life of students in the UMBC Department of Physics. Members of the ARFG had a leading role in developing seven new graduate-level courses constituting an atmospheric physics track in the Department of Physics that were approved by the UMBC graduate council in 1998. The track was approved as a Ph.D. program a few years later. Group members have been active in the teaching four of these courses: Atmospheric Physics I & II, Atmospheric Radiation, and Atmospheric Remote Sensing. The group has also provided a great service to the department by teaching the undergraduate physics survey course (PHYS 111). Furthermore, the group has had three members serve as one of two JCET representatives at Department of Physics faculty meetings, and ARFG members serve on the GEST/JCET Advisory Board.

The NASA component of JCET often involves group member participation on local and center-wide

GSFC committees, and other such obligations not typically undertaken by university research faculty.

The ARFG envisions maintaining a strong connection with GSFC personnel through joint proposals, theoretical studies, instrument development opportunities, etc., while participating in the academic and research life of UMBC departments and developing scientific ties with fellow members of our sister center, GEST. Our vision includes graduate student support with independent external funding, although it is recognized that JCET faculty, mainly based at the GSFC campus, have fewer opportunities to interact with students than tenure-track UMBC faculty, and the financial realities of soft-money appointments rearrange funding priorities when research proposal budgets are planned.

The group values its collective expertise and believes in the value of ongoing communication among group members. Since its inception, the group has convened regular meetings used to discuss scientific papers, group research activities, and general issues of interest to the group, or sponsored seminars by speakers based close to the Capitol area. Such meetings and talks are intended to allow open sharing of ideas and the encouragement of collaborative efforts. In particular, the group would like to begin transition from collaborations established within the GSFC organizational structure to those that include interdisciplinary investigations with other group members, especially through research funding proposals.

During the period covered by this report, the ARFG has added two new members. A member of the group accepted a tenure-track position with the UMBC Physics Department. The ARFG also continues to receive significant contributions from two of its civil servant JCET fellows. Work by the ARFG towards the JCET goal of being awarded its own satellite mission goes forward. The aerosol-cloud-interaction satellite mission concept led by Dr. Martins continues to move towards that objective.

Ultimately, the JCET ARFG wants to be a recognizable semi-autonomous entity in the atmospheric radiation community via scientific and community service. This would include organizing and participating in colloquia, proposals, and conferences, and contributing to the literature by writing journal papers and assuming editorial activities. Its greatest ambition is to provide leadership in ground, aircraft, or satellite instrument development and experimental fieldwork. During the last year the JCET ARFG has made significant advances towards fulfilling many of these goals.

NASA Grant: Studies of 3D-cloud optical depth from small to very large values (NNG06GC17G)

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

Abstract

The researchers have developed the only extant surface-based passive method for retrieving cloud optical depth in a fully 3D, broken cloud situation. This method, using zenith radiance at 673 and 870 nm wavelengths, has been extensively validated and applied to a number of different instruments and observation networks. Retrievals from this method have become important in ground-based field campaigns and satellite validation experiments. We have also developed a new retrieval algorithm for cloud droplet size using zenith radiance at an additional water-absorbing wavelength. Due to its ability to simultaneously retrieve cloud optical depth and droplet size, our retrieval method can help to address the issue that retrieved cloud liquid water path from microwave radiometers tends to be too large when the clouds are thin.

Description of Research

Cloud optical depth is a fundamental optical property for computing the amount of solar radiation entering and leaving the Earth's atmosphere. It is also an important property in any cloud-resolving model. If cloud optical depth cannot be confidently and unambiguously measured, we will never be able to validate such models. Current techniques to measure this property work well for overcast clouds, but not for broken clouds. This project focuses on cloud-radiation processes in a general 3D cloud situation, with particular emphasis on cloud optical depth and effective cloud droplet size. Another focus from this research group is on ground-based zenith radiance measurements from the Department of Energy Atmospheric Radiation Measurement (ARM) program, NASA Aerosol Robotic Network (AERONET), and NASA Micropulse Lidar Network (MPLNET).

Accomplishments for FY 06-07

The JCET investigators developed a new retrieval algorithm for cloud droplet size using zenith radiance at an additional water-absorbing wavelength (1.6 micron). Preliminary validations have been conducted for measurements from the new ARM Shortwave Spectrometer (SWS) and AERONET sunphotometers. The recently deployed ARM SWS measures zenith radiance at visible and near-infrared wavelengths with a field of view of 1.4 degree and a temporal sampling rate (1–2 Hz). AERONET sunphotometers have a field of view of 1.2 degree and measure zenith radiance only when clouds block the sun. The researchers collocated SWS and one AERONET sunphotometer at the ARM Oklahoma site in order to evaluate agreement of observations in these two instruments. Non-negligible differences were found at 1.6 micron between these two, while good agreement is shown at visible wavelengths.

The ARM two-channel narrow-field-of-view radiometer (2NFOV) was deployed in the ARM Mobile Facility (AMF) Convective and Orographically-induced Precipitation Study (COPS) at the Black Forest area in March 2007. COPS is an international field campaign and aims to improve quantitative precipitation forecasting. An intensive observation phase started in an attempt to address the issue that retrieved cloud liquid water path from microwave radiometry is too large when the clouds are thin. The REDvsNIR algorithm was used to retrieve cloud optical depth and effective cloud fraction [Chiu et al. 2006]. Retrievals from 2NFOV zenith radiances are extremely important for interpreting the cloud optical path, because they provide coincident information on the cloud optical depth and its variations for surrounding areas.

The researchers calibrated solar background signals for the ARM Micropulse lidar and Raman lidar at the Oklahoma and West Pacific sites, using zenith radiance measurements from co-located AERONET sunphotometers. These calibrated signals were then used to retrieve cloud optical depth for the CLOWD (Clouds with Low Optical [Water] Depth) intercomparison. Good agreement was found between lidar retrievals and those retrieved from other different instruments/methods [Chiu et al. 2007].

Objectives for FY 07-08

The JCET investigators will continue to analyze measurements from the ARM Shortwave Spectrometer (SWS). Because SWS's fast sampling rate enables the capture of cloud-clear transitions, this data will be used to study the so-called "twilight zone," the region that is around clouds but not precisely defined as clear or cloudy. This precise separation of clear and cloudy air is important in calculations of aerosol direct forcing. In addition, the researchers plan to explore spectral signatures of 3D cloud structures from SWS high-resolution spectra.

They will also analyze all COPS data and provide retrieved cloud optical properties along with error analyses due to uncertainties from surface albedo and measurements. Validation efforts will continue for retrieved cloud optical depth and effective cloud fraction, particularly for broken clouds. Retrieved optical depth and cloud droplet size will also be used to intensively evaluate cloud liquid water path retrieved from a number of microwave radiometers.

Finally, they will continue their collaboration with AERONET and MPLNET. For AERONET, the researchers will finalize their retrieval algorithm and include their retrievals into the AERONET database. They will also continue the developments and validations of cloud droplet size retrievals for a number of AERONET sites. For MPLNET, cloud optical depths retrieved from calibrated solar background light will be provided, and those retrievals will be added to MPLNET standard cloud products.

NASA Grant: IOP Data Collection for Improving the Understanding of the Radiative Transfer Process in Seawater

Investigators: Davide D'Alimonte, Assistant Research Scientist

Abstract

Given the increasing societal concern for the global climate, our research with ocean color remote sensing seeks to retrieve optically-active seawater constituents from space-borne radiometric measurements, one of the applicable investigative tools for studying climate change. The use of water-leaving radiance allows for an appraisal of the amount of phytoplankton on a planetary scale, which is essential for estimating the carbon flux between the atmosphere and the ocean. Within this framework, the broad goal addressed by the present research is improving our understanding of the relationships between the optically-active seawater compounds, the radiance leaving the sea surface, and the Inherent Optical Properties (IOP) of seawater. The research work consists of two principal activities: the first addresses the creation of a data base of in-situ measurements, while the second focuses on the development of bio-optical algorithms to relate radiometric and IOP data with the optically active seawater compounds.

Description of Research

This research work involves field and laboratory activities, plus the analysis of the measurement outcomes through statistical and physical models. During the fieldwork, it is the responsibility of the JCET investigator to measure the IOPs of seawater and collect ancillary data with a unified set of instruments mounted on a single frame, hereafter identified as the IOP frame. The IOP data collection is performed with an AC-9 and an AC-S meter to measure the seawater absorption and attenuation, and with a BB-9 meter to measure the backscatter. Additional measured quantities are: 1) the concentration of colored dissolved organic matter and Chlorophyll-a, taken with two WETStar fluorometers, 2) the photosynthetically available radiation (PAR), determined with a single-channel sensor, and 3) the seawater temperature and salinity, measured with a CTD.

The investigator performs laboratory experiments to calibrate the devices for measuring seawater absorption and attenuation, and to assess the precision and accuracy of related field measurements. The JCET investigator is also actively involved in the field measurement of the in-water light field properties, and the derived estimate of the radiance leaving the sea surface (which is ultimately the quantity measured by the remote sensing sensor).

On the basis of field observation and instrument characterization results, statistical and radiative transfer methodologies are applied by the investigator to model relationships between the light field and the seawater compounds. The ultimate expected outcomes of the study are the following. First, to better understand how IOP data can be optimally exploited to discern different seawater compounds (or various constituents of the same compound—e.g., different pigment of the phytoplankton component). This task will be undertaken with both an unsupervised and a supervised statistical approach (the former based on neural network regression scheme, and the second built with a novel—i.e., unpublished—constrained expectation-minimization density estimation approach to maximize the likelihood of the observations given the known spectral signature of the optically active compounds).

Secondly, the work aims to improve the accuracy of radiometric measurements on the basis of a Bayesian statistical model. Here, a correction scheme is built using a priori information on the outcomes of the numerical simulation of the radiative transfer process in the seawater (which uses IOP data as input and needs to account for the light focusing effect of the sea surface due to gravity and capillary waves).

Accomplishments for FY 06-07

The IOP frame and the laboratory facilities for the meter calibration were established during the reporting period. The JCET investigator commenced development of the software for the processing, the automatic reprocessing (when required), and the visualization of the calibration data and the field measurements. The AC-9 and AC-S calibration protocols were refined and collection of laboratory data for the instrument characterization (more than 100 calibrations) was performed. Field data collected is summarized in the table below:

CRUISE	Location	IOP Casts	Start date (GMT)	End date (GMT)
b04	Delaware Bay	22	02/07/2006	06/07/2006
d03	Chesapeake Bay	5	06/09/2006	06/09/2006
d04	Chesapeake Bay	7	28/11/2006	28/11/2006
s01	Sargasso Sea	6	25/03/2006	28/03/2006
h01	Hudson River Plume	2	05/05/2007	09/05/2007
m02	Gulf of Maine	18	26/05/2007	28/05/2007
m03	Gulf of Maine	13	06/06/2007	08/06/2007

Additionally, the JCET investigator has also been responsible for the organization of a round robin experiment (to be held on September 2007) for the inter-comparison of the AC-9 and AC-S meters. Finally, two papers relevant to the objectives of the research activity were published.

Objectives for FY 07-08

On the basis of the experimental data collected, the foreseen objectives for the FY 07-08 are: 1) Summarize preliminary results from the field data collection and instrument characterization in two separate NASA technical memorandum publications. 2) Develop the statistical methodologies for relating IOP to seawater optically active compounds;
3) Development of the water-leaving radiance correction scheme based on the IOP data and the numerical simulation of the in-water radiative transfer process; and 4) Perform new field campaigns to extend the database of in-situ observations.

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

Investigators: Ernest Hilsenrath, Professor of Practice

Abstract

Hilsenrath has an IPA position at NASA Headquarters in the Earth Science's Division Research and Analysis program, Science Mission Directorate. He nominally acts as Program Manager for the Atmospheric Composition Modeling and Analysis Program. The position also requires involvement with international space agencies for collaboration on missions and research.

Description of Research

Hilsenrath participates in the formulation and implementation of various elements NASA's Science Mission Directorate's (SMD) Earth Science Division, including the Atmospheric Composition Focus Group in collaboration with the Atmospheric Chemistry and Analysis Program, Upper Atmosphere Research Program, Tropospheric Chemistry Program and the SMD Applications Division. He participates in scientific research solicitation and selection through the ROSES program and the initiation of research grants with selected principal investigators. He also coordinates and participates with international groups consisting of representatives of international space agencies and represents NASA interests in international forums and collaborating flight missions and research programs.

Accomplishments for FY 06-07

The JCET investigator participated in the U.S. Climate Change Research Program Working Group on Atmospheric Composition. He conducted the ROSES 06 Panel Review for Atmospheric Composition Modeling and Data Analysis Program. Hilsenrath chaired the CEOS Constellation concept for international collaboration and coordination of Atmospheric Composition satellite missions and conducted its first workshop. Finally, he provided on-going support for the NASA SMD Earth Science program with Congressional and Administration inquiries and NASA strategic planning.

Objectives for FY 07-08

Hilsenrath plans to continue development of the CEOS Atmospheric Composition Constellation Concept by engaging international partners. A second workshop is scheduled to take place in September 2007. He will continue to support NASA's Atmospheric Composition Focus Area to the U.S. Climate Change Science Program. Hilsenrath will organize the ROSES 07 panel review and selection process for the Atmospheric Composition Modeling and Data Analysis Program, track the progress of NASA selected Atmospheric Composition Principal Investigators and service their grants, and continue on-going support of the NASA SMD Earth Science program for Congressional and Administration inquiries and NASA strategic planning.

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Task 80: Cloud Aerosol Interaction on the Twilight Zone

Investigators: Ilan Koren, Assistant Research Scientist

Abstract

Pollution and smoke aerosols can increase or decrease cloud cover. We have shown that aerosols over the Atlantic increase cloud fraction due to feedbacks linked to changes in the cloud droplets size and distribution. On the other hand, it was show that absorbing aerosols may reduce cloudiness by heating and stabilizing the atmosphere and reducing fluxes from the surface. This duality in the aerosol effects forms one of the largest uncertainties in climate research. To simplify the study of such nonlinear system it is customary to distinguish between “cloudy” and “cloud-free” areas and measure them separately. However, we find that clouds are surrounded by a “twilight zone”—a belt of forming and evaporating cloud fragments and hydrated aerosols extending tens of kilometers from the clouds into the so-called cloud-free zone. The gradual transition from cloudy to dry atmosphere is proportional to the aerosol loading, suggesting an additional aerosol effect on the composition and radiation fluxes of the atmosphere. Using AERONET data, we find that the measured aerosol optical depth is higher by 13% ± 2% in the visible and 22% ± 2% in the NIR in measurements taken near clouds relative to its value in the measurements taken away from clouds, and that 30%−60% of the free atmosphere is affected by this phenomenon.

Description of Research

The investigator’s research interests are focused on advancing the knowledge of the complex system formed by clouds and aerosols and the derived effects on climate. This year we focused on an area that traditionally is defined as cloud free, namely the non-cloudy pixels of a cloud field. We show that this area has special optical and microphysical properties and may hold the highest sensitivity to the aerosol properties.

We have developed a method to use AERONET observations to estimate cloud fraction (by the sampling rate) and the spacing properties between clouds. AERONET provides global and detailed aerosol information; therefore by using it we can study cloud fraction simultaneously as a function of the microphysical effect (we use the AOD as a CCN measure) and the absorption (absorbing AOD). Based on our studies of cloud aerosol interaction of the previous years we are verifying our findings.

Accomplishments for FY 06-07

In a *Science* paper co-authored with Yoram Kaufman [Kaufman and Koren 2006], the JCET investigator used solar measurements from AERONET sites around the globe to detect a direct correlation between cloud cover and aerosol column concentration, and an inverse relation between cloud cover and aerosol absorption of sunlight. The emerging rule appears to be independent of the geographical location or aerosol type, thus increasing our confidence in the understanding of these aerosol effects on the clouds and climate.

In a paper with Kaufman and Gobbi [Gobbi et al. 2007], the investigator has suggested an advanced cloud screening method for Aeronet data and a method to separate growth of the coarse mode aerosol by humidification from apparent growth due to cloud contamination.

The twilight zone between clouds and aerosols was first defined and measured in a GRL paper [Koren et al. 2007]. The sensitivity of this zone to aerosol loading was shown over several AERONET station around the globe.

Objectives for FY 07-08

The investigator plans to continue and expand the studies mentioned above while moving at the same time towards the next step that addresses the effects of aerosols on small convective clouds and on the twilight zone. The planned approach involves a combination of CALIPSO, MODIS and ground measurements with inputs from cloud microphysical models. He will also work on improving the methodology for separating the net aerosols effects on clouds.

Task 18: Studies of Aerosol Particles from Biomass Burning and its Radiative Effects

NASA Grant: Large Scale In Situ and Remote Sensing Measurements of Black Carbon and Other Aerosol Absorbers

NASA Grant: Climate Effect of Black Carbon Aerosol on Tropical Convective Clouds and Precipitation

Investigators: J. Vanderlei Martins, Associate Professor, Physics; Roberto Fernandez Borda, Assistant Research Scientist; Dominik Cieslak, Engineer; Lorraine Remer, NASA GSFC, Code 613.2

Abstract

Aerosol particles emitted by biomass burning and other sources contribute to significant changes in the radiative balance of the atmosphere, and cloud formation, lifetime and precipitation efficiency. On a local or regional scale, smoke particles can produce heating or cooling effects, depending on the albedo of the underlying surface. In biomass burning-affected areas, some of which cover several million square kilometers, the magnitude of the direct radiative forcing (DRF) can be several orders of magnitude larger (+10 to -100 W/m2) than the globally averaged DRF, potentially changing the vertical stratification of the atmosphere. Aerosols also greatly impact the formation, dynamics, and microphysical properties of clouds. Although this task mainly focuses on biomass burning emissions, the complexity of the aerosol interactions with climate and the advantages of remote sensing also give us the opportunity to study properties and effects of other aerosol sources (oceanic aerosols, dust, urban pollution, etc.), long-range transport episodes, and cloud-aerosol interactions. Major efforts are being devoted in this task for the development of new ground based, airborne, and satellite techniques to measure aerosol, clouds, the interactions of these systems, and their consequences.

Description of Research

The optical properties of aerosol particles and its effects on the radiative balance of the atmosphere, and on cloud microphysics, constitute major uncertainties in determining the anthropogenic impact on Earth's climate and weather. These two issues are addressed in this task with a variety of new techniques and methodologies. The spectral techniques applied in this project provide detailed novel information on the wide wavelength range (350-2500nm) spectral absorption efficiency for samples from several unknown regions in the globe. The impact of aerosol in clouds and precipitation is another very important topic in aerosol research. This task addresses this topic via the study of aerosol microphysical properties (including humidification and absorption), and via the measurement of cloud spectral properties using the newly developed cloud scanner spectrometer and the rainbow camera. Prototype instruments were built and are being applied to the measurement of cloud properties from the ground and from aircraft.

Accomplishments for FY 06-07

In FY06 efforts were focused on the data analysis of aerosol absorption and scattering properties, on the vertical profile of cloud effective radii using the cloud scanner concept and prototypes, on the development of calibration techniques for the retrievals of cloud droplet size distribution using the “cloud rainbow,” on the development of instrumentation for the measurement of polarized radiances, and on the measurement of near (NIR) and thermal (TIR) infrared images from the cloud side. In situ data from several field campaigns and ground stations were analyzed and are being compiled for presentations and publications. Significant efforts were made towards the development of new remote sensing concepts from aircraft and space, including the measurements of aerosol absorption, composition, and its effects on clouds. Detailed cloud 3D radiative transfer simulations were performed to allow for the interpretation of cloud side radiance measurements.

The JCET investigators have also finished the first prototype for the rainbow camera polarimeter and for the NIR cloud scanner imaging system. They have also performed a field experiment in Mount Gibbes, North Carolina, as a field test for their cloud scanner and polarimeter prototypes.

Objectives for FY 07-08

Field measurements are being planned to gather data on clean and polluted clouds in the Amazon with the new cloud scanner and rainbow polarimeter systems built in the previous FY. The researchers also intend to extend their studies on the effects of aerosol particles on cloud and precipitation. On the aerosol side, new measurements of aerosol spectral absorption and scattering properties will be performed in the laboratory and on the field. The spectral absorption techniques will be extended to shorter wavelengths in the UV allowing for more detailed information on the radiative properties of the particles, type of mixture, and chemical composition.

Task 23: Global Studies of Cloud Inhomogeneity and its Radiative Impact

Task 94: Cloud Susceptibility from MODIS for Indirect Aerosol Effect Studies

USGS Grant: Cloud Detection and Avoidance for the Landsat Data Continuity Mission

DOE Grant: Evaluation of General Circulation Model (GCM) Column Radiation Models

Investigators: Lazaros Oreopoulos, Research Associate Professor, Physics; Tamás Várnai, Research Assistant Professor, Physics

Abstract

Observational and theoretical studies of radiative perturbations due to the first indirect aerosol effect were conducted. The theoretical studies are aimed at clarifying the various dependencies and sensitivities of broadband albedo susceptibility, while observational studies explored its geographical and seasonal variations as well as the feasibility of obtaining global indirect aerosol forcing from Moderate Resolution Imaging Spectroradiometer (MODIS) Level-3 data. Application of a broadband radiative transfer (RT) model on distributions of retrieved warm cloud optical properties from this gridded MODIS dataset provided estimates of cloud albedo and shortwave cloud radiative forcing bias due to neglect of horizontal inhomogeneity. The prospective cloud detection capabilities of a future Landsat sensor without thermal bands were investigated with the aid of extensive MODIS cloud mask data and a sizeable collection of Landsat-7 scenes. An initial assessment of the Goddard Space Flight Center (GSFC) and Community Atmospheric Models (CAM) Column Radiation Models was completed using Atmospheric Radiation Measurement (ARM) program Broadband Heating Rate Profile (BBHRP) data. Finally, the investigator continued coordinating the soon to be launched first phase of the Continuous Intercomparison of Radiation Codes (CIRC).

Description of Research

The PI's research focuses on development of new efficient cloud-radiation parameterizations for inhomogeneous atmospheres suitable for implementation in GCMs, intercomparison of GCM RT models, and analysis of satellite, airborne, and ground-based measurement for studies of cloud masking, cloud variability, and cloud-aerosol interactions. The common goal of all the above research endeavors is to advance our understanding of the complex nature of clouds and their impact on the propagation of radiation in terrestrial atmospheres, the atmospheric and surface energy budgets, and, ultimately, global climate.

Accomplishments for FY 06-07

The PI, in collaboration with JCET Fellow Steven Platnick, has adopted an approach where satellite retrievals can be used to estimate the radiative response or sensitivity to some specified change in warm cloud droplet number ("cloud albedo susceptibility"). They have expanded the calculations of cloud susceptibility to encompass the entire solar spectrum, to include surface albedo and atmospheric effects, and more importantly, to account for changes in the cloud droplet asymmetry parameter and single scattering albedo in addition to changes in cloud extinction. An alternative method to calculate albedo perturbations based on relative (rather than fixed) changes in cloud droplet number density was also introduced. Four months of Level-3 (1° gridded) and selected MODIS Level-2 (orbital swath) cloud optical thickness and effective radius data were used to estimate susceptibility. It was found that a uniform droplet number density increase of 10% under constant liquid water conditions would yield a susceptibility forcing (increase in reflected solar flux at the top of the atmosphere) of about 1.5 W m-2.

The PI has also completed the most extensive hitherto estimates of the plane-parallel homogeneous (PPH) bias for warm (liquid phase) clouds. Specifically, he produced global distributions of broadband flux bias based on MODIS (Terra and Aqua) liquid water cloud retrievals, aggregated as a Level-3 product, and radiative transfer calculations with a modified version of the Chou et al. [1998] model. For the two months studied (July 2003 and January 2004), global values of albedo bias close to 0.03 were found, which corresponds to roughly 8% of the global warm cloud albedo. This albedo bias translates to ~3-3.5 Wm^{-2} of bias in the diurnally averaged global shortwave cloud radiative forcing. The substantial magnitude of the plane-parallel bias stresses the importance of predicting subgrid variability in GCMs and accounting for its effects in cloud-radiation interactions.

The GSFC and CAM RT algorithms were modified to accept input from ARM observations similar to the way the Rapid Radiative Transfer Model (RRTM) is implemented within the BBHRP effort. Preliminary results show that that GSFC and CAM are only slightly inferior to the more sophisticated RRTM algorithm, but a detailed breakdown of performance for different types of atmospheric conditions is still pending. The cases for Phase I of CIRC were selected and the bulk of the reference radiative transfer calculations completed. Work on the CIRC website is underway.

Finally, the JCET investigators have examined the performance of simplified versions of Landsat-7's Automated Cloud Cover Assessment (ACCA) algorithm on ~200 Landsat-7 scenes with cloud truth available from a supervised subjective imaging analysis. They showed that considerable cloud detection skill still remains even without thermal data. Using a full year of MODIS cloud mask data (~55,000 granules) they investigated the frequency of cloud detection by the 1.38 µm band (to be available in the next Landsat) as well as the performance of visible threshold cloud masking tests versus the full cloud mask. Over land during daytime about 70% of clouds can be detected with only visible channels.

Objectives for FY 07-08

The susceptibility work will be enhanced to include a GCM modeling component with Georgia Tech collaborators provided that a relevant proposal submitted to NASA is funded. The DOE research evaluating GCM column radiation models will be expanded to include the Goddard Institute of Space Studies (GISS) and the Geophysical Fluid Dynamics Laboratory (GFDL) models. Also relevant to DOE efforts will be a collaborative work with GEST faculty member Peter Norris on a new method of building joint distributions of cloud water content for GCMs, and the continuation of the CIRC initiative. The Landsat work will focus on testing new cloud detection schemes on available Landsat-7 scenes, but also on MODIS granules where results can be compared with the native MODIS cloud mask algorithm. At the same time the PI will participate in the activities of the Landsat Science Team "Product" and "Long Term Acquisition Plan" focus groups.

Task 103: **Retrieval of Aerosol Properties from Aura-OMI Observations**

Task 106: **Validation of OMI-Aerosol Measurements**

NASA Grant: **A Long Term Dataset on Aerosol Absorption from TOMS, MODIS, MISR, and AERONET (NNG04GG90G)**

NASA Grant: **Assessment of NPOESS Aerosol Algorithm Enhancement using VIIRS and OMPS Observations (NNG04GE08A)**

JPL Contract: **A High-Accuracy Spectro-Polarimetric Camera for Aerosol Remote Sensing from Space**

Investigators: Omar Torres, Research Associate Professor, Physics

Abstract

The investigator carries out research on several aspects of aerosol retrieval from near UV measurements in space. Research activities include radiative transfer analysis, algorithm development, as well as validation and scientific analysis of satellite data on aerosol properties. Research work during the reporting period covered different aspects of space-based aerosol remote sensing. A series of activities to assess the performance of the Ozone Monitoring Instrument (OMI) near UV algorithm were carried out. These included direct comparison to ground-based observations of aerosol optical depth as well as comparison to other satellite products, and comparison to model calculations. As a result of the aerosol product evaluation, a series of algorithmic modifications are being considered. A new version of the OMI Level1b radiance data (Collection 3) has been made available by the OMI calibration team. Evaluation of the impact of the new Level1b data in the aerosol retrieval algorithm has started. The long-term aerosol record from the Total Ozone Mapping Spectrometer (TOMS) observations was completed during the reporting period. The evaluation of the NPOESS-VIIRS aerosol algorithm continued. During the reporting period the investigator contributed to five peer-reviewed publications, and was awarded funding for two proposals.

Description of Research

The investigator is currently a member of the OMI, NPOESS Preparatory Project (NPP), and CALIPSO science teams. Research activity is currently carried out in three areas: 1) aerosol retrievals from OMI observations; 2) combined use of TOMS, MODIS, MISR and AERONET observation for the development of a long-term data set on aerosol absorption; and, 3) evaluation and analysis of the NPP-VIIRS aerosol algorithm.

The PI is responsible for the development, implementation and validation of the OMI near UV aerosol algorithm. In this algorithm, observations of backscattered near UV radiation are inverted to characterize the atmospheric aerosol load in terms of aerosol extinction optical depth and single scattering albedo. The first public release of the OMI near UV aerosol product took place in December 2006. An overview of the OMI aerosol products and details of the retrieval algorithm are discussed by Torres et al. [2007a]. Results of preliminary evaluation of the OMI aerosol product by comparison to ground-based observations [Torres et al. 2007b], and to other satellite products [Ahn et al. 2007], were completed.

The multi-year long TOMS record (1978-1993, 1996-present) of near-UV observations has been used to construct the longest available research data set on aerosol optical depth over the oceans and the continents. The TOMS retrieval method produces extinction optical depth and single scattering albedo. The combination of these two quantities yields the aerosol absorption optical depth. The TOMS aerosol record has been reprocessed with an upgraded version of the retrieval algorithm fully consistent with the OMI aerosol algorithm.

The VIIRS sensor is part of the payload of the NPP and NPOESS satellites to be deployed in the next few years. As a member of the NPP science team, the PI is involved in the evaluation of the VIIRS aerosol algorithm. This task involves the determination of whether the accuracy of the VIIRS derived environmental and climatic data records (EDR's and CDR's) on aerosols is suitable for science applications. VIIRS aerosol algorithm evaluation activities also include overall analysis of algorithm performance as well as formulation of recommendation and advise regarding calibration-validation plans.

Accomplishments for FY 06-07

The OMI near UV aerosol data was publicly released on December 2006. Four publications on the OMI aerosol product were produced during the FY 06-07 period.

As part of the evaluation of the VIIRS aerosol algorithm, the evaluation of upgrades to the 6S radiative transfer code (i.e., addition of polarization) code was completed. A manuscript on the results of the analysis is under preparation.

Five peer-reviewed articles were published or accepted for publication. The investigator also participated as PI or Co-I in seven research proposals submitted to NASA. Two proposals submitted to NASA were funded during the reporting period.

Objectives for FY 07-08

Research objectives for FY 07-08 include the re-processing of the OMI UV aerosol product using Collection 3 Level1b data. Validation efforts and algorithm refinement activities will continue.

As a result of newly approved research projects, activities dealing with the combined use of A-train sensor for aerosol studies will be carried out in the next year. OMI and Aqua-MODIS aerosol data will be used to attempt aerosol characterization in term of scattering and absorption properties. In the same way OMI and CALIPSO observations will be synergistically used to create a more accurate measurement of aerosol absorption.

Task 72: **Retrieval of Cloud and Sea Ice Properties from THOR Lidar Measurements**

NASA Grant: **I3RC Workshops and 3D Community Tools Applied to Assessments and Improvements of Cloud Retrievals from Terra, Aqua, and THOR Offbeam Data (621-30-86 and 622-42-57)**

Investigators: Tamás Várnai, Research Assistant Professor, Physics

Abstract

This research investigates several aspects of the three-dimensional (3D) radiative processes that occur in clouds, snow, and sea ice. Analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) data revealed that 3D interactions cause systematic view angle-dependent biases in satellite retrievals of cloud optical thickness, and cause additional uncertainties in retrievals of cloud droplet size. It was found that combining observations taken from multiple view directions can reduce optical thickness retrieval uncertainties. In addition, the researchers explored the potential for determining snow and sea ice thickness using Thickness from Offbeam Returns (THOR) lidar observations, based on the observed 3D spreading of lidar pulses. Finally, the third phase of the Intercomparison of 3D Radiative Codes (I3RC) project was advanced. This work included new intercomparisons of 3D radiative transfer models and the development of on-line resources for the research community.

Description of Research

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

Accomplishments for FY 06-07

The researchers continued statistical analysis of a yearlong global dataset of MODIS cloud observations and completed the process of publishing the first results [Várnai and Marshak 2007]. This work included examining the influence of 3D radiative effects in the latest version (Collection 5) of MODIS cloud products. While such data analysis could detect the influence of 3D effects, fully estimating these effects required a combination of observations with 3D radiative simulations. Therefore they started combining statistics of observed cloud inhomogeneity with theoretical simulations for a wide variety of cloudy scenes. Early progress was reported at an international conference.

The JCET investigator also examined whether simultaneous observations from multiple view directions (e.g., by the Multiangle Imaging Spectroradiometer [MISR] on board the Terra satellite) can improve cloud optical thickness retrievals. Results indicate that initial estimates based on overhead views can be improved by adding information from oblique backscatter observations, whereas information from forward scattering views is less helpful.

Exploration continued on the benefits of offbeam multiview lidars that can detect photons returning from increasingly wide rings around a spot illuminated by a laser beam. This year's focus was on the potential for airborne THOR lidar observations of snow and sea ice thickness. Simulations indicate that after some minor upgrades to the current instrument built for cloud observations, THOR can be expected to provide observations suitable for snow and sea ice thickness measurements [Várnai and Cahalan 2007].

Finally, the JCET investigator advanced the third phase of I3RC project. 3D radiative simulations were performed for the test cases developed last year, and the simulation results that participants submitted to us were compared. One set of test cases is for simulations of solar radiative transfer in broken clouds, and the other set is for multiple scattering of lidar signals in thick clouds. The results from 12 participating models from around the world enabled the researchers to establish reference results when numerous models agreed, and also to analyze some differences between various modeling techniques. Initial results from this intercomparison were discussed at an international conference attended by many participants. Finally, the I3RC web site (http://i3rc.gsfc.nasa.gov) was expanded and its on-line resources on 3D radiative transfer were improved, including a publication database, a collection of links to publicly available 3D radiative models, and a new version of the I3RC community model for 3D radiative simulations.

Objectives for FY 07-08

Next year the JCET investigator plans to continue work on combining satellite data analysis with theoretical simulations of 3D radiative transfer. He will use the simulations to establish relationships between easily observable features, such as cloud texture, and 3D influences on measured radiances. While the initial focus is on stratiform clouds, expanding this work to cumuliform clouds is planned as well. He also plans to explore ways for correcting the influence of 3D effects on satellite retrievals of cloud droplet size.

Exploring THOR's potential for measuring vertical profiles of cloud microphysical properties can expand the scope of THOR lidar measurements. The researcher hopes to further explore THOR's potential for snow and sea ice thickness measurements in a field experiment.

Finally, he plans to complete the analysis of the currently ongoing third phase of I3RC intercomparison experiments and to further improve the I3RC website, including an online 3D radiative transfer calculator and a model checker.

Clouds and Precipitation Focus Group

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II.2 Clouds and Precipitation Focus Group: Vision

The underlying research theme for the Clouds and Precipitation Focus Group is to improve our understanding of the global hydrological cycle and regional climate variability. The goals of our research activities are to understand the physics and dynamics of cloud and precipitation processes, from individual cloud particles to organized convective systems, and to determine the aggregate impact of precipitation systems on the Earth's climate. We examine the fundamental physical processes of precipitating systems through analyses of observational data sets and output from numerical model simulations. We develop improved surface- and space-based retrievals of precipitation, and evaluate the assimilation of these improved precipitation estimates in larger-scale models. We also produce global, multi-year data sets of precipitation for climatological monitoring of the atmospheric hydrological cycle. The expertise in our group is in atmospheric thermodynamics, cloud physics, mesoscale dynamics, tropical meteorology, radar meteorology, radiative transfer applications in active (radar) and passive microwave remote sensing from space, high-resolution numerical modeling of clouds, and measurements of precipitation from surface-based instruments.

A continuing focus of the group is to provide quality data sets to validate spaceborne precipitation algorithms and high-resolution numerical models. This involves collecting and analyzing data from field campaigns (physical validation), and developing multi-year precipitation data sets from specific validation sites (climatological validation). Since the four-dimensional structure of clouds and precipitating systems is tremendously complex, both approaches provide important scientific insights and independent validation of numerical and remote sensing models. In physical validation, coincident measurements from surface platforms (e.g., scanning radars, rain gauges, disdrometers, vertical profilers, lidars, radiosondes, tethersondes, and surface meteorological instruments) are combined with those from aircraft and satellites (e.g., in situ microphysical data sets, active radar and passive microwave remote sensing measurements) to better understand the fundamental physical processes of precipitating systems. This methodology focuses on improving our understanding of the complex physical processes within clouds, and using this information to improve various types of physical models. Group members play leadership roles in the application of this research to such major NASA efforts as the Tropical Rainfall Measuring Mission and the follow-on Global Precipitation Mission.

Surface rainfall has always been a primary indicator of regional climate, and the recent integration of satellite and rain gauge estimates has provided a time series of global rainfall distributions spanning the last decade. Climate models cannot always predict the magnitude and duration of significant rainfall anomalies; therefore, statistical models— based upon the global rainfall record—represent an important first step in understanding rainfall variability. Group members will continue to collaborate with NASA scientists to develop and analyze this important data source, and help to deduce the large-scale mechanisms responsible for rainfall variability.

On shorter space and time scales, severe weather events can have devastating human and economic impacts, and the roles of convection in intense weather systems—such as mesoscale convective complexes and tropical cyclones—will be a continuing area of collaborative research within the group. Research on the dynamics and evolution of precipitation systems, their surrounding environment, and their variability in the regional climate system provides the foundation for testing assumptions in satellite-based precipitation retrieval algorithms.

The theoretical basis for satellite remote sensing of precipitation in convective systems has evolved from the earlier era of crude radiative models and simple inversion schemes to an era of three-dimensional cloud/radiative models and physically consistent retrieval techniques. Implementing the methods of the new era will involve close collaboration between cloud modelers and remote sensing algorithm developers; both types of specialists are represented in the Clouds and Precipitation Research Group. The ultimate utility of remote sensing measurements of clouds and precipitation may depend on how well the data can be assimilated into global simulations of the Earth's climate. The success of such assimilation experiments will also depend on how well cloud processes are represented in the global models.

The Clouds and Precipitation Focus Group is committed to fostering undergraduate and graduate education in the Earth and environmental sciences at UMBC. Group members, affiliated with the Department of Geography and Environmental Systems and the Department of Physics, have developed and are teaching several courses. These include undergraduate courses on weather and climate, climate change, El Niño/hurricanes and related societal impacts, and a graduate course on atmospheric dynamics. Our faculty members serve as mentors for undergraduate students to inspire them to pursue graduate study. Members of the Clouds and Precipitation Focus Group will be taking an active role in developing graduate-level courses and mentoring graduate students in the new Graduate Studies Program being implemented by the Department of Geography and Environmental Sciences.

NASA Grant: Use of TRMM and Combined Satellites to Study Tropical Cyclone Rainfall Over Oceans and During Landfall (NNG04GE97G)

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

Abstract

In the past year, the PI continued to work with NASA program managers to develop and lead a major high altitude aircraft field experiment off Senegal, Africa, for the purpose of investigating tropical cyclogenesis in the eastern Atlantic. He is also involved in efforts to underwrite the scientific justification for a follow-on mission during the 2009-2010 timeframe. Professor Halverson taught two introductory courses (weather and climate, and physical geography) in the Department of Geography and Environmental Systems. He supervised the research of five undergraduates and one grad student, investigating the processes of extratropical transition of tropical cyclones in the Mid Atlantic with emphasis on heavy rain production, and also a climate study of the Mid Atlantic region.

Description of Research

Halverson studies the dynamics and thermodynamics of severe storms including tropical cyclones, nor'easters and thunderstorms. Additionally, he does much to promote the popularization of NASA research on severe weather through frequent appearances on television, radio and newspaper interviews. He also serves as a writer and scientific consultant for popular books describing severe storms and pens a monthly column in *Weatherwise Magazine*.

Accomplishments for FY 06-07

During the past year Halverson was able to engage a number of undergraduate students in the study of Mid Atlantic climatology and meteorology. Undergraduates Shelly Stone, Emily Puls and Maggie DeLauncey worked with him to analyze and map patterns of precipitation and temperature variation across the Mid Atlantic region and relate these features to the orography and physiography of the region during the warm and cold seasons. Undergraduate Chris Hughes began an internship under Halverson's supervision to examine the time and space distribution of summertime severe weather events across Maryland, and to relate the occurrence of these events to synoptic scale weather systems.

Undergraduate Alex Robel from Duke University interned with Halverson during the early summer to investigate the extratropical transition of landfalling tropical cyclones in the Mid Atlantic. The researchers identified 31 tropical cyclones making landfall during the past ten years. They then examined the North American Regional Reanalysis (NARR) fields in order to calculate various thermodynamic and dynamic forcings accompanying the evolution of the tropical cyclones. The objective is to identify the critical subset of environmental factors that determine whether a cyclone will undergo extratropical transition and intensify, maintain intensity or weaken. A second objective is to characterize severe weather generation by the population of landfalling cyclones in terms of major synoptic forcing factors, with emphasis on the freshwater flooding aspect.

UMBC graduate student Ross Dixon began working with Halverson and Professor Lynn Sparling in the Fall to pick up where Alex Robel left off during his summer internship. Ross is computing the Hart and Evans phase space for the 31 cases of landfalling storms, following the trajectory of extratropical transition through warm core asymmetry and transition from warm to cold upper tropospheric circulation. This effort will help categorize patterns or modes of extratropical transition in the Mid Atlantic.

Objectives for FY 07-08

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

Two manuscripts are under preparation. The first, a paper devoted to the climate of the Mid Atlantic region, will report on the research and analyses conducted by the undergraduate interns. The second, which will detail the process of extratropical transition of tropical cyclones making landfall in the Mid Atlantic, will build on the work started by Alex Robel and being continued by Ross Dixon.

Work is also underway to establish a mesoscale research framework for assessing the impact of severe summer storms (thunderstorms containing heavy rain, damaging wind, hail and lightning) in the D.C.-Baltimore urban corridor. UMBC has partnered with the NASA Marshall Space Flight Center to install sophisticated lightning detection equipment as part of the D.C. Lightning Mapping Array (LMA). The LMA will allow high time and space resolution assessment of severe storm generation, evolution and movement as well as detailed 3D mapping of lightning strikes. This dataset will be paired with precipitation intensity mapping provided by the regional network of NWS and FAA Doppler weather radars. Favored locations of storm genesis, movement and intensification will be placed in the context of terrain-induced surface boundaries such as those generated by the urban "heat island" effect, Chesapeake Bay and mountain-valley circulations. The JCET investigator hopes to build a consortium of institutes in the Washington-Baltimore region, including UMBC, GSFC, USGS, VDOT, MDOT, EPA, NWS Sterling and Howard University, for the purpose of using combined assets (upper air observations, surface networks, Doppler radars, King Air research aircraft, mobile lidars) to construct a state-of-the-art mesonet to further meteorological research in the region.

Task 87: **High Frequency Passive Microwave Retrievals of Frozen and Melting Precipitation-sized Hydrometeors**

NASA Grant: **Retrieval Algorithm Development for Precipitating Snow Detection and Estimation using High Frequency Observations (NNH06ZDA001N-PMM)**

NASA Grant: **Retrievals of Precipitating Snow and Light Rain Using Synergistic Multi-Sensor Active and Passive Observations (NNH05ZDA001N-CCST)**

Investigators: Benjamin T. Johnson, Research Associate; Gail Skofronick-Jackson (PI), NASA GSFC, Code 614.6; James W. Wang, NASA GSFC, Code 614.6; William Olson, Research Associate Professor, Physics; Mircea Grecu, GEST

Abstract

In the mid- to high-latitudes, the spatial structure and microphysics of clouds and precipitation differ significantly from that of tropical and warm-cloud precipitation. The variety of precipitation particles, low precipitation rates, surface snow-cover, and low freezing level heights has historically contributed to large uncertainties involving passive microwave (PMW) precipitation retrievals. The present research seeks to simultaneously improve knowledge of both the physical and radiative properties of precipitation types consistent with mid- to high-latitude climates. By using co-located multi-frequency passive and active microwave sensors along with improvements in simulations, the researchers are able to constrain retrievals to a much larger degree than previous research. The knowledge obtained from this research can then be propagated into other areas such as 3-D cloud resolving models, operational retrieval algorithms, and future retrieval algorithms such as those used for the upcoming Global Precipitation Mission (GPM).

Description of Research

Johnson's research has focused primarily on improving multi-sensor microwave retrievals of cold-cloud 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. To achieve this goal, a novel, new forward model has been developed to simulate the radiative and physical properties of a steady-state 1-D column of the atmosphere and surface.

A retrieval technique is also under development that utilizes co-located satellite or aircraft based dual-frequency radar observations to more accurately assess particle size distribution properties. As an additional constraint to the above retrieval technique, passive microwave brightness temperature simulations, using the forward model, are compared to co-located observations of passive microwave brightness temperatures. This allows for a relatively fine-tuned selection of retrieved precipitation properties that are consistent with the entire set of observations and physical relationships present in simulations.

Accomplishments for FY 06-07

The forward model provides a basis for simulating passive microwave brightness temperatures (TBs) and radar reflectivities for a 1-D vertical precipitation profile. The two primary components of the forward model are the: 1-D physical model and radiative transfer model. The parametric, one-dimensional physical model described in Petty [2001b] was employed with modifications. A number of reasonable constraints were applied to limit the number of free parameters describing the 1-D column of precipitation. Novel features such as variable cloud liquid water height, variable particle density profiles, variable environmental lapse rate, and an explicit melting layer model were added. The hydrometeor model is part of the radiative transfer model. Precipitation hydrometeors are most commonly modeled as homogeneous dielectric spheres, so that standard Mie codes may be utilized to compute local radiative transfer properties, such as single scattering albedo, asymmetry parameter, and mass extinction coefficient. These quantities are computed as integrations over a prescribed particle size distribution. The distribution of particle sizes is the exponential distribution, given by $N(D) = N_0 \exp[-\Lambda D]$, where Λ is the slope of the distribution and N_0 is the number density per unit diameter. This model also introduces the ability to compute a symmetric 3-component dielectric constant (e.g., ice, water, and air) for the simulated hydrometeors. The radiative transfer model used for this research is the plane-parallel, fully polarized, adding-doubling radiative transfer model, RT4 [Evans1995]. It incorporates surface scattering/emission, and multiple independent layers. New ocean surface emissivity models from Meissner and Wentz [2004] have also been incorporated. Surface wind speed effects on the ocean emissivity are also modeled, and are valid for wind speeds up to about 25 meters per second. The primary accomplishment of the forward model development is the creation of an end-to-end solution for simulating both the physical and radiative properties of a 1-D column of the atmosphere containing various types, shapes, and sizes of precipitation.

The precipitation retrieval algorithm is designed to retrieve the vertical profile of precipitation using a combined radar / radiometer algorithm. This differs from previous studies in that a dual-wavelength radar (Ku and Ka Bands) and co-located passive microwave radiometer (at 89, 150, and 220 GHz) are the basis for the retrieval. Dual-wavelength radar retrievals of particle size distribution (PSD) parameters are performed using the “dual wavelength ratio” (DWR) methods of Meneghini et al. [1997]. However, by itself the DWR method is highly ill posed. To rectify this, the forward model was employed to compute passive microwave brightness temperatures (TB) for each profile in the candidate set obtained from the DWR method. By comparison with observed TBs, the initial set of retrievals is reduced. The resulting profiles selected are consistent with observations and simulations. From there, parameterizations based on the retrievals are made and can be employed in other retrieval and simulation schemes. The primary accomplishment here is the development of a robust and reasonably well-posed retrieval algorithm capable of retrieving snowfall and rainfall. Currently the technique is limited to over ocean retrievals.

Objectives for FY 07-08

Johnson plans to undertake additional rainfall and snowfall case studies in the coming year. He will test an optimal-estimation technique to improve retrieval and error characterization. By replacing spherical particles with more realistic shape model & properties (e.g., DDA) he hopes to improve the results. Other possible research includes simulating conically scanning passive microwave radiometer geometry issues vs. nadir looking radar (i.e., GMI \& DPR on GPM) and improving land surface emissivity, radar cross-sections, and understand terrain influences on over-land retrievals. Overall, Johnson plans to develop a GPM-era combined GMI/PR2 radar retrieval algorithm(s) for light rain and snow over both land and ocean.

Task 89: **Modeling of Rainfall Statistics from Satellite and Ground Based Remote Sensing Measurements**

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

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

Abstract

Research efforts under this task involved an intensive study of the statistical properties of gridded monthly averaged rainfall data gathered from satellite remote sensing measurements, such as the global multi-year data from the Tropical Rainfall Measuring Mission (TRMM). This included addressing statistical issues that arise when one attempts to compare the satellite estimates with those obtained from ground-based radar and rain gauge measurements at the established TRMM ground validation (GV) sites. In particular, an intercomparison of satellite and ground radar and rain gauge measurements presents a nontrivial problem even when the measurements are considered to be ideal, i.e., the experimental errors are neglected, because of the disparity between the space-time averaging scales in the various different measurement methods. A quantitative understanding of the scale dependence of the statistical properties of precipitation is sought in terms of the dependence of the parameters of the underlying probability distribution on the space-time scale over with the data are averaged. Current work focuses on a recently discovered probability distribution belonging to the class of infinitely divisible distributions that fully characterizes all the statistical moments of area-averaged precipitation and explains their observed power law scaling behavior.

Description of Research

There are four major goals of the research performed under this task: 1) developing mathematical models of rainfall statistics; 2) applying these models to describe statistical behavior of precipitation data sets from a variety of sources including satellite and ground based remote sensing measurements as well as rain gauge networks; 3) a detailed study of statistics of precipitation data obtained from low earth-orbiting satellites, such as TRMM and Special Sensor Microwave/Imager (SSM/I); and 4) a quantitative generalization of the commonly used least-squares method of determining the coefficients of a linear regression of satellite vs. ground data in connection with the validation problem for satellite measurements that takes into account the spatio-temporal correlation between the two variables.

Accomplishments for FY 06-07

In his Ph.D. dissertation, Ravi Siddani, a graduate student at JCET under the PI's mentorship, studied the gridded radar data from the Tropical Ocean Global Atmosphere - Coupled Ocean-Atmosphere Response Experiment (TOGA-COARE). This study has led to the discovery of a new family of probability distributions belonging to the general class of the so-called infinitely divisible distributions that accurately describes the scale dependence of the full hierarchy of moments of spatially averaged rain rate field. In this respect it supersedes the previously used stochastic dynamical model [Bell and Kundu 1996; Kundu and Bell 2003, 2006], which is limited to the second moment statistics. The moments of the rain rate data aggregated at various spatial scales was found to exhibit nontrivial power law scaling, known as multiscaling or multifractal behavior. The scaling exponents describing this observed power law dependence of the moments agree well with those estimated from the probability model. A full-length paper on the subject is in press in *Journal of Geophysical Research-Atmospheres.* The new distribution is currently being applied to describe the statistics of spatially averaged radar data as well as time averaged rain gauge data from the TRMM ground validation site in Melbourne, Florida.

Objectives for FY 07-08

In the coming year, Kundu's immediate goals are to: 1) apply the new distribution to examine the scale dependence of time averaged rain data from the multi-year rain gauge data set available at the TRMM ground validation (GV) sites and to try to get a combined space-time description of rain statistics; 2) seek a physical basis for the new distribution in terms of an underlying stochastic process that leads to clustering of rain at various scales; 3) examine spatial statistics of TRMM PR (Precipitation Radar) derived rain data and test the predictions of the model with regard to the multiscaling behavior ; and finally 4) pursue the problem of generalizing the standard least-squares formulation of the linear regression of satellite vs. ground radar or rain gauge estimates by properly taking into account both the individual variances of the dependent and the independent variables as well as their mutual covariance described by the stochastic dynamical model [Bell and Kundu 1996].

Task 28: Research Support For Precipitation Science

Investigators: Amita V. Mehta, Research Assistant Professor, Physics

Abstract

The objective of this task is to understand precipitation processes through retrieval, analysis, and modeling. A multi-year project carried out under this task, the Cloud Dynamics and Radiation Database (CDRD), focuses on generating an extensive database using cloud resolving model simulations and calculations of microwave brightness temperatures/radar reflectivities that can be used for rain retrievals from satellite-based analogous microwave measurements. Additionally, analysis of CDRD facilitates understanding of relationships between microphysical processes and mesoscale and large-scale dynamical/thermodynamical processes in rain systems. A further goal of this task is to carry out observational analysis of TRMM rainfall measurements to understand rain characteristics over a number of regions including the Gulf of Mexico - Caribbean Sea basin, the Mediterranean Sea basin, the Central U.S., and the Asian monsoon region.

Description of Research

The focus of this research task has been on precipitation retrieval, analysis, and modeling. A major ongoing project, the Cloud Dynamics and Radiation Database System (CDRD), carried out in collaboration with G. Tripoli (University of Wisconsin), and A. Mugnai (CNR/ISAC, Italy), is designed to create an extensive database that can be used for improved rain retrievals from microwave radiometers and radars flying onboard current and future satellites. This project includes simulations of various rain systems with the University of Wisconsin Nonhydrostatic Modeling System (UW-NMS simulations), a cloud-resolving model. The simulated rain-rates and associated microphysical, thermodynamical, and dynamical profiles are archived in the CDRD database. There are two regions chosen for creating and testing the CDRD database: the Gulf of Mexico - Caribbean Sea (GM-CS) basin and the Mediterranean Sea (Med) basin. For these regions, generation and detailed statistical analysis of the CDRD data and their use in rain retrievals form the core of this project. Additional research activities include analysis of TRMM-based rainfall over the central U.S., GMCS, Med, and Asian monsoon regions.

Accomplishments for FY 06-07

During the last year the CDRD database systems covering the GMCS and Med regions were created by carrying out a number of UW-NMS simulations of various rain systems. The simulations included several major hurricanes over the GMCS and various rainstorms over the Med region. The CDRD database is still being populated with more simulations covering multi-seasonal rain systems over these regions to ensure that the database includes a large range of microphysical, and dynamical/thermodynamical processes. The simulated microphysical and thermodynamical profiles were further used to calculate brightness temperatures (TBs) at TRMM, AMSR, and SSMIS radiometer frequencies. The calculated TBs are also included in the CDRD database. An experimental Bayesian algorithm was developed which used a subset of the CDRD database to obtain rain retrieval solutions from TRMM TB measurements over the GMCS region. A paper based on this study is under preparation for submission to the *Journal of Atmospheric and Oceanic Technology*.

In addition to the CDRD project, a flood-inducing heavy rainfall event over the western part of

India was investigated by using TRMM observations and UW-NMS simulation. The heavy rain event occurred on August 6th 2006. TRMM observations showed that a series of squall lines originated in central India and propagated westward over western India bringing large amount of rainfall. The model simulation of this event indicated that the propagating mesoscale systems also intensified local convective activity over western India, which resulted in intense rainfall inducing devastating floods. Results of this study were presented at two international Conferences.

A new project was initiated that included analysis of NCEP reanalysis and TRMM merged precipitation product (3B42) to study possible connection between moisture transport from the GMCS and Atlantic Ocean region and rain systems over the Med region. Preliminary results show that the moisture originates in the tropical Atlantic region that is first transported northward and then carried over the Med region by mid-latitude westerly winds.

Furthermore, diurnal propagation of rain systems was studied over the central U.S. by using TRMM 3B42 and TRMM PR 2A25 rain products, and North American Regional Reanalysis dataset. Results show that the Rocky Mountains play a dominant role in downwind propagation of convective systems that extend all the way to the eastern U.S. Similar diurnal propagation of rain systems were noted along other mountain slopes, including the Andes, Himalaya, and Ethiopian High Land. A paper describing these results is being prepared for submission to a special issue of the *Journal Of Climate*.

Objectives for FY 07-08

The main objectives for the next year include continuing work on the CDRD in its last phase before making it operational and available to interested users for rain retrievals. Specifically, the CDRD database formation over the GMCS and Med will be completed and Bayesian retrieval algorithm will be tested. Analysis of the CDRD will be carried out to understand the water budget of the GMCS basin and its influence on the warm season rainfall over the central U.S. and its variability. Finally, the relationship between the GMCS and Atlantic basin water budget and that of Mediterranean basin will be studied through observations, operational reanalysis datasets, and UW-NMS model simulations.

NASA Grant: **Global Retrieval of Precipitation and Latent Heating Distributions from Spaceborne Radiometer/Radar Observations**

NASA Grant: **Characterization and Mitigation of Errors in Passive Microwave Precipitation/Latent Heating Estimates Used in Data Assimilation and Large-Scale Analysis Applications (NNG04GP24G)**

NASA Grant: **Assimilation of Precipitation Information from Spaceborne Sensors to Enhance Weather Forecast and Climate Diagnostic Capabilities (622-32-99)**

NASA Grant: **A Prototype Satellite Simulator Model for Combined Radar-Radiometer Precipitation Estimation (806-55-01)**

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

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

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

Investigators: William S. Olson, Research Associate Professor, Physics; Robert Adler, GSFC, Code 613.1; Wei-Kuo Tao, GSFC, Code 613.1; Mircea Grecu UMBC/GEST; Chung-Lin Shie, UMBC/GEST; Song Yang, GMU; Arthur Hou, GSFC, Code 610.1; Xiaowen Li, UMBC/GEST; Gail S. Jackson, GSFC, Code 614.6

Abstract

A method for estimating vertical profiles of falling snow using a combination of airborne cloud radar and higher-frequency passive microwave radiometer observations was developed and applied successfully to both synthetic data and airborne radar and radiometer observations. A comprehensive effort to improve latent heating estimates based upon spaceborne passive microwave radiometer observations led to improvements in cloud-resolving modeling, incorporation of ground-based environmental data, and changes in estimation methodology. A radar/radiometer simulator developed to support GPM ground validation activities was improved and generalized for simulations of airborne and ground-based sensor observations. Recent simulations were used to provide guidance for Canadian field campaign operations.

Description of Research

The emphasis of this research has begun to shift from the support of the Tropical Rainfall Measuring Mission (TRMM) to the Global Precipitation Measurement (GPM) mission. Thus, methods for calibrating precipitation and latent heating estimates from multiple microwave radiometers using combined spaceborne radar-radiometer data are being studied in anticipation of the GPM constellation of microwave instruments. In parallel with these activities, the role of ground-based instrumentation in the physical validation of spaceborne precipitation and latent heating estimates is also being evaluated.

Accomplishments for FY 06-07

In collaboration with Dr. Mircea Grecu of GEST, a method for estimating vertical profiles of falling snow using a combination of airborne cloud radar and higher-frequency passive microwave radiometer observations was developed and applied successfully to both synthetic data and airborne radar and radiometer observations. The method uses covariances statistics derived from ensembles of candidate solutions to search for new solutions that are more consistent with sensor observations. Substituting lower-frequency radar, such as the TRMM or GPM radar, for cloud radar yields estimates of falling snow that have almost the same accuracy.

A comprehensive effort to improve latent heating estimates based upon spaceborne passive microwave radiometer observations focused on improvements in cloud-resolving modeling, incorporation of ground-based environmental data, and changes in estimation methodology. Since cloud-resolving model simulations underpin the latent heating estimation method, biases in estimates were reduced by increasing the resolution of the model and improving the representation of model precipitation processes. A further reduction of latent heating errors was achieved by limiting the sensitivity of the estimation method to residual biases in the cloud-resolving model simulations. Environmental conditions derived from ground-based data were classified using projections of the data onto empirical orthogonal functions- cloud model simulations belonging to these environmental classes can now be identified and incorporated into the estimation methodology in a consistent way.

The radar/radiometer simulator developed to support GPM ground validation activities was improved and generalized for simulations of airborne and ground-based sensor observations. Recent simulations were used to illustrate the advantages and disadvantages of upward- and downward-looking higher-frequency airborne passive microwave observations of falling snow, in support of Canadian field campaign operations.

Objectives for FY 07-08

The radar/radiometer method for estimating falling snow will be adapted to spaceborne observations. Using specific CRM simulations as a guide, the microwave radiometer precipitation/latent heating estimation method will be generalized and refined. Analyzed temperature/humidity/wind fields will be incorporated into the method to improve latent heating estimation. Work will continue on the development of the generalized radar/radiometer simulator, and coupled with cloud-resolving model simulations, the simulator will be used to demonstrate what sets of field campaign observations may best be used to improve our understanding of precipitation physical properties.

NASA Grant: Measurements of the Hydrometeor Size Distribution for the NASA Precipitation Measurement Mission (NAG 5-13615)

NASA Grant: Measurements of the Hydrometeor Size Distribution through Surface-Based Instruments (NNX 07AD71G)

Task 34: A Proposed Mid-Latitude Coastal Ground Validation Site for the NASA Precipitation Measurement Mission

Investigators: Ali Tokay, Research Associate Professor, Geography and Environmental Systems

Abstract

Measurement of precipitation in the context of physics, accuracy, and small-scale variability is the main theme of the ongoing research. In terms of physics, the characteristics of raindrop size distribution in different precipitation systems including tropical cyclones were studied through disdrometer measurements. The presence of more small and less large drops in tropical storms than in extratropical storms at a given reflectivity was one of major findings of the study. Physical aspects of the raindrop size distribution have a pronounced influence on radar and radiometer retrieval of precipitation. In that regard, a new parameterization was presented for the dual-frequency radar rainfall algorithm. The measurements of snowfall were another segment of the ongoing efforts. In terms of accuracy, the usefulness of operation rain gauges for scientific applications was tested through daily and monthly rainfall between collocated gauges. The climate reference network and fire management network gauges had a higher accuracy, while the automated weather observing system gauges had a significant failure. In terms of spatial variability, time height ambiguity between disdrometer and vertically pointed S- and K-band radar reflectivity was also investigated. It was found that the comparison of larger volumes such as radars had a higher correlation and less biases than comparison of point measurements.

Description of Research

The leading objective of this research is to provide better validation products for the Precipitation Measurement Mission in which the inconsistency between the radar and radiometer based precipitation retrieval algorithms is often attributed to the lack of knowledge about the physics of the precipitation. In that regard, the measurements of the particle size distribution in rain, snow, and mixed regime can be analyzed for different precipitation systems. The mathematical form of the size distribution may then be extracted for a particular precipitation system. For snow, the density of the particles or at least bulk density should be known. The ongoing research deals with these physical aspects of precipitation including its small-scale variability and measurement accuracy.

Accomplishments for FY 06-07

Considering the time height ambiguity between the precipitation measuring instruments, the ground-based disdrometer reflectivties were compared to the vertically pointing S- and K-band radar reflectivities. The agreement between the radars was better than the comparison of collocated disdrometers. The size of the measuring volume plays an important role in rainfall statistics. The vertical variability of reflectivity was also studied in the content of variations in coefficients and exponents of reflectivity rain rate (Z-R) relations where rainfall was determined from disdrometer and reflectivity was taken from radar measurements. This study was conducted with Peter Hartmann of Bonn University, Germany. Hartmann received his diploma in January 2007.

The performance of operational rain gauges was determined through comparison of collocated gauge daily and monthly rainfall totals. As part of the Tropical Rainfall Measuring Mission satellite validation program, dual or triple rain gauges were operated at 20 sites in eastern Virginia, Delmarva, and northeast North Carolina. The operational gauges under the Climate Reference Network and Fire Management performed quite well, while the Automated Weather Observing System gauges had poor results. The co-op gauges were found to be acceptable for monthly totals but not for daily rainfall. The automated surface observing system gauges were also reasonable for monthly measurements but could also be accepted for daily rainfall at some sites. The state agency gauges had poor performance most of the time. The selection of tipping bucket gauge was indeed a factor for each site. This research was conducted with Victoria McDowell of Susquehanna University. Dowell received her Bachelor degree in May 2007.

Characteristics of raindrop size distribution in eight tropical cyclones were studied through disdrometer measurements in Wallops Island, Virginia and two other sites [Tokay et al. 2007]. More small and less large drops were found in tropical cyclones than in extratropical systems at a disdrometer-calculated reflectivity of 40 dB. The extratropical stage of the cyclone occurs when the cyclone merges with a mid-latitude frontal system. Interestingly, the size distribution in the Central Pacific Ocean had similar characteristics to tropical cyclones but the former had even more small drops.

The role of Z-R variability to the flood prediction was studied through a disdrometer gauge network over a small watershed in Southern Louisiana. Chari Malakpet of the University of Louisina-Lafayetter conducted this study under the guidance of Dr. Emad Habib. The investigator collaborated with Habib and was a committee member on the thesis defense of Malakpet, who graduated with a Master’s degree in May 2007.

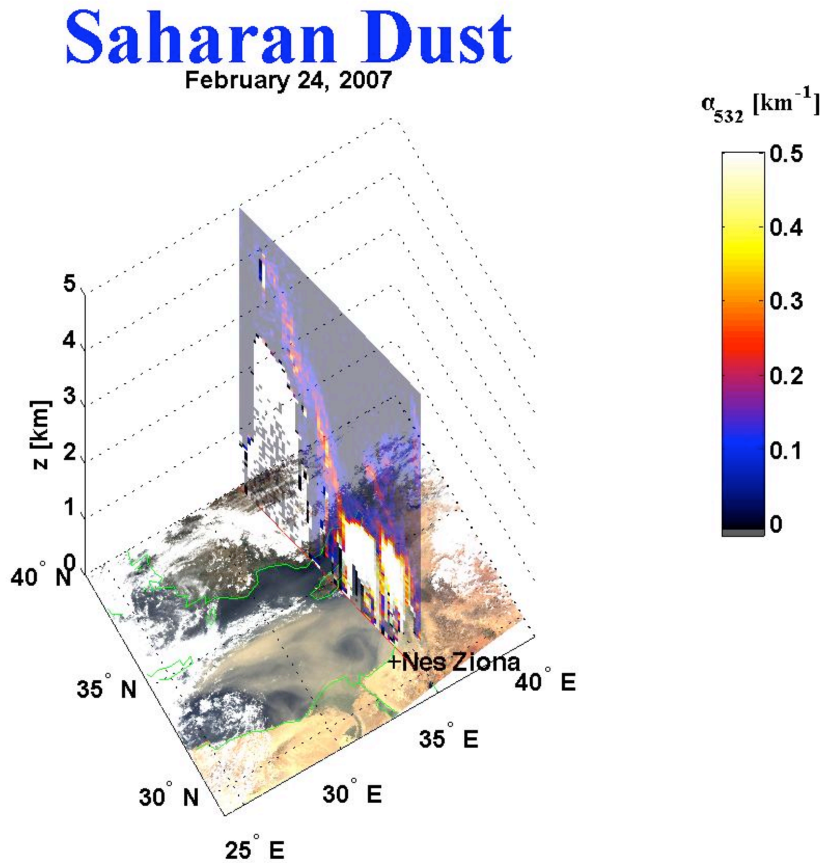
The investigator participated in the Canadian Cloudsat/CALIPSO validation project field campaign in winter 2006-07. He was the principal investigator for the parsivel laser-optical disdrometer. The preliminary analysis revealed that there were 34 snow and 20 rain events during the six-month-long field campaign. The analysis of the data is underway and early results have been presented in an international conference. Interestingly, the snow size distribution follows exponential distribution and bulk density of snow is lower (less than 0.1 g cm-3) than what the models anticipate in the presence aggregated crystals at < -5° C.

Objectives for FY 07-08

The performance of NOAA’s multi-sensor precipitation estimation (MPE) products has been validated against rain gauges in eastern Virginia and Delmarva. The accuracy of gauge measurements has been determined and the comparison of gauge and MPE rainfall was done from one hour to monthly time scale. Given the fact the Hydrometeorological Testbed (HMT) East field campaign will focus on coastal effect on precipitation measurements and field campaign will start in 2009, the ongoing study can provide useful input for the field.

As an ongoing study, the characteristics of raindrop size distribution will be investigated in Kwajalein atoll in Central Pacific Ocean, and Central Florida. Both sites have two disdrometers and are part of the TRMM satellite validation network.

Observations Science Focus Group



A Dust Storm from the Sahara. The figure shows a three dimensional representation of the optical extinction vs. altitude from the CALIPSO lidar onboard the CALIOP satellite as it orbited over the eastern end of the Mediterranean Sea. The data are overlayed on a two-dimensional true-color image from the MODIS instrument onboard the AQUA satellite. MODIS channels 1,4, and 3 were used to construct the RGB image. (Figure courtesy of Kevin McCann)

II.3 Observations Science Focus Group: Vision

The Observations Science Focus Group (OSFG) within JCET is a team of UMBC tenure-track faculty, NASA/Goddard civil servants, JCET research faculty, postdoctoral fellows, and graduate students. The backgrounds of the group members are varied, but all have specific expertise in both active and passive remote sensing. Our primary fields of interest include lidar instrumentation and sensors, radiometry, microwave sensing, spectroscopy and molecular physics, satellite instrumentation, and data analysis. Although we make use of other forms of remote detection such as radiosondes, the techniques employed by our group are, for the most part, measurements of the electromagnetic spectrum from the far infrared to the ultraviolet.

The overarching objective of the members of the OSFG is to measure and understand atmospheric processes at both the local and global scale, and to provide new insights and measurements that bear on the composition, dynamics and evolution of the atmosphere. Toward this end several members of OSFG have recently become involved with air quality measurements as well. We are actively engaged in the development and use of state-of-the-art ground- and satellite-based instruments. OSFG members have laboratories in the Physics Building on the UMBC campus and at NASA's Goddard Space Flight Center (GSFC). These laboratories are used to conduct studies and measurements of atmospheric pollution, atmospheric aerosols, cloud physics, atmospheric water vapor, and to track air quality.

In addition to these remote sensing efforts, our group is also actively engaged in the development of processing techniques that allow the measurement of atmospheric properties. Toward this end, our group is also involved in the study of the radiative properties of atmospheric molecules including trace gases. These studies include spectroscopic studies in the laboratory that help to identify those wavelengths that are most useful in the study of the various atmospheric gases. Our group is also involved in instrument calibration and the development of signal processing techniques to improve the overall quality and quantity of our measurements. The OSFG has significant expertise in the modeling and retrieval of infrared atmospheric radiation, which includes the modeling of spectral line-shapes, and in the utilization and analysis of high spectral resolution measurements from satellites, aircraft, and mountaintops as well as moderate resolution measurements and other instruments. As a result of the expertise resident within our group, several of our members serve as principal investigators and science team members for NASA programs and satellite missions.

In addition to our research efforts, our group is heavily involved in the education of the next generation of atmospheric scientists. Our members are involved in both undergraduate and graduate teaching within the Physics department. We have helped to develop and teach courses in instrumentation, remote sensing technology, and the physics and chemistry of the atmosphere as well as the core courses in physics. Our members also serve as thesis advisors to approximately 10 graduate students in Physics and the MEES program.

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Task 55: MODIS Calibration and Characterization Support (CV-5828)

Investigators: William L. Barnes, Senior Research Scientist

Abstract

The Moderate Resolution Imaging Spectroradiometer (MODIS) is currently operated aboard NASA's Earth Observing System (EOS) Terra and Aqua spacecrafts launched on December 18, 1999 and May 04, 2002, respectively. This work supports the ongoing calibration and characterization of both MODIS sensors and the documentation of seven years of on-orbit performance.

Description of Research

MODIS, a complex imaging radiometer, was designed for EOS to extend and enhance the global observations of several heritage sensors and to support the development of climate data records. It collects data in 36 spectral bands covering wavelengths from 0.41 to 14.4μm. Observations are made at three different (nadir) spatial resolutions: 250m (bands 1-2), 500m (bands 3-7) and 1km (bands 8-36). In addition to improved spatial and spectral resolution, the MODIS calibration requirements are more stringent than those of its heritage sensors. Both Terra and Aqua MODIS went through extensive radiometric, spatial, and spectral calibration and characterization activities pre-launch. In order to enable continuous on-orbit characterization and calibration, the MODIS design includes a complete set of onboard calibrators.

The MODIS calibrated and geo-located L1B data is the primary input for more than 40 products generated by the MODIS Science Team. It is critical to mission success that the L1B data is of the highest quality possible and that this quality is maintained for the life of the mission. The MODIS Calibration Support Team (MCST) has the responsibility for generating and maintaining the L1B algorithms and for monitoring sensor performance. It is important that the MCST efforts be documented in both the scientific literature and internal documents available to the MODIS users. This effort is not only important for the present and future user community, but serves as a critical input to follow-on sensors such as the NPOESS/VIIRS.

Accomplishments for FY 06-07

Major accomplishments during the last year are principally in the areas of publication development and presentations at scientific conferences. The documents described below all have Dr. Barnes as lead author or co-author. They were developed in collaboration with Vincent Salomonson, MODIS Science Team Leader; Jack Xiong, MCST Leader; and the members of the MCST.

At the request of the editors, four book chapters describing the MODIS system were submitted for inclusion in *Earth Science Satellite Remote Sensing*, a two-volume set published by Tsinghua Univ. Press and Springer-Verlag. The two-volume set was released in the fall of 2006.

Refereed journal articles for 2006-2007 include two manuscripts published in *IEEE Transactions on Geoscience and Remote Sensing* and a third paper that has been accepted by the same journal. A manuscript has been submitted to the *Journal of Advances in Space Research* and two book chapters have been submitted to the editors of *Land Remote*

Sensing and Global Environmental Changes: NASA's Earth Observing System and the Sciences of ASTER and MODIS which is slated for publication by Springer-Verlag in 2007.

There have been fifteen MODIS related papers published in conference proceedings during the last year. The papers were presented at symposia in San Diego (7/06), Boulder (7/06), Denver (7/06), Bejing, China (7/06), and Stockholm, Sweden (9/06) Dr. Barnes is a co-author on all of these and made presentations at San Diego, Denver and Stockholm.

In addition to the extensive publication tasks described above, Dr. Barnes (who resides in Texas) provided support to the MCST at a MODIS Science Team meeting in Baltimore, Maryland, participated in bi-weekly calibration telecoms, and represented the MODIS Team at a meeting in Santa Barbara, California.

Objectives for FY 07-08

The MODIS calibration team plans to continue monitoring sensor performance and generating documentation to keep the user community abreast of the latest developments. Presentations are planned for IGARSS'07 in Barcelona, Spain, Optics and Photonics in San Diego and Remote Sensing/Europe in Florence, Italy. Work will continue on the submitted book chapters and refereed journal articles as deemed appropriate.

NASA Grant: NASA African Monsoon Multidisciplinary Activities (NNH05ZDA001N-NAMMA)

Investigators: Sergio DeSouza-Machado, Research Assistant Professor, Physics; D. Allen Chu, GEST; Chung-Lin Shie, GEST; Ruei-Fong Lin, GEST

Abstract

A suite of instruments utilizing the synergy of NASA's A-train is used to study dust storms on planet Earth. AIRS thermal infrared radiance data makes this possible day and night, over ocean and land. Together with MODIS (daytime) data, we plan to use the two datasets to constrain the dust height. Data from the NAMMA experiments will be used. Preliminary studies of dust storms off the coast of West Africa in late August and early September 2006 have been done. The studies indicate that the straight line relationship between the MODIS and AIRS retrieved optical depths vary systematically with placement of the dust layer, but there is no clear indication of where the dust actually is.

Description of Research

Desert dust storms play an important, yet not completely understood role in climate radiative forcing. The infrared dust forcing can be studied more accurately if there is information about the altitude of the dust cloud. We will use this research to try to extract information about the height placement using AIRS thermal infrared radiances and ancillary information. The extra information could include MODIS retrieved optical depths and CALIPSO height information.

Accomplishments for FY 06-07

This research was initiated at the end of the current reporting period and first results will be reported in next year's annual report.

Objectives for FY 07-08

The JCET investigators will use the in-situ radiosonde and lidar data taken during the NAMMA 2006 field campaign to constrain the AIRS retrievals, and compare the results against the generic AIRS retrievals done using ECMWF model fields and climatology for dust height.

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Cooperative Remote Sensing Science and Technology (CREST) Center (SBCT49100-0001B)

Investigators: Rubén Delgado, Research Associate; Raymond Hoff, JCET Director and Professor, Physics; Nikisa S. Jordan, Graduate Student, UMBC; Kamonayi Mubenga, Graduate Student, UMBC

Abstract

The University of Maryland, Baltimore County (UMBC) contributed to NOAA's Cooperative Remote Sensing Science and Technology Center (CREST) in the Trophospheric Remote Sensing and Air Quality thrust area. Lower tropospheric profiling with lidar as part of the Regional East Aerosol Lidar Mesonet and the use of subsidiary passive information from instruments such as MODIS on Terra and Aqua, OMI on Aura, and GOES-12 imager on GOES-12. UMBC maintains internal databases of UMBC generated data and contributes to NOAA and NASA distribution of data through the U.S. Air Quality Smog Blog and through the GASP product distribution.

Description of Research

Remote sensing of atmospheric aerosols and water vapor, in the lower troposphere, that affect the Earth's radiative budget were carried out at the University of Maryland, Baltimore County (UMBC) by the Atmospheric Lidar Group. Elastic (532 nm) and Raman (355, 386, 407 nm) lidar measurements by the Elastic Lidar Facility (ELF) and the Atmospheric Lidar Experiment (ALEX), respectively, support the Regional East Atmospheric Lidar Mesonet (REALM), 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 (GALION), and CALIPSO/OMI instruments on the NASA's A-Train, and the Water Vapor Variability – Satellite/Sondes (WAVES) campaign. Synergistic observations from instruments from the A-Train were used to identify the horizontal and vertical extent of these atmospheric scatterers.

Accomplishments for FY 06-07

The Elastic (ELF) and Raman (ALEX) lidar, operated by the UMBC Atmospheric Physics Group, ran for 146 days between June 1, 2006 and June 30, 2007 in support of REALM activities. Aerosol backscattering and extinction time series for these days are available on our website, http://alg.umbc.edu/REALM. Comparisons have been carried out between GASP and MODIS AOD below the planetary boundary layer with AOD derived from the Elastic lidar extinction product. Analysis of GASP aerosol optical depth continues with NESDIS support. Master degrees were awarded to our MEES students Nikisa S. Jordan and Kamonayi Mubenga for their thesis work on "Estimating Smoke Emissions over the U.S. Southern Great Plains Using Moderate Resolution Imaging Spectroradiometer (MODIS) Satellite Fire Radiative Energy (FRE) Measurements" and "GASP and MODIS Surface Reflectance Comparison for the Baltimore MD/Washington DC Area (2004-2005)," respectively.

Objectives for FY 07-08

REALM will be part of the NOAA IDEA transition from Wisconsin to NESDIS, which is paid for by the leveraged NASA funding. A sulfate particulate analyzer, supplied by an EPA AMI Project (Fred Dimmick, PI) became operational by the end of FY 06-07, and will be used to correlate in time the variation in the vertical distribution of aerosol scatterer to sulfate concentrations recorded at UMBC, as part of the EPA Air Quality System. Active measurements from ELF and ALEX will support the North American Global Atmospheric Watch: Aerosol Lidar Observation Network (GALION), and CALIPSO/OMI instruments on the NASA's A-Train. Passive measurements from NASA and NOAA satellites and EPA monitoring networks will be evaluated to compare and determine their impact in the aerosol optical depth (AOD) retrieval.

NASA Grant: Simultaneous Validation of OMI and Calipso Using Ground-Based Lidar, Aeronet, and Satellite Optical Depth Measurements (AURA/04-0000-0045 under NNH04ZYS004N)

Investigators: Rubén Delgado, Research Associate; Omar Torres, Research Associate Professor, Physics; Raymond Hoff, JCET Director and Professor, Physics; Zhu Li, Graduate Student, UMBC; Paul Schou, Graduate Student, UMBC; Raymond R. Rogers, Graduate Student, UMBC

Abstract

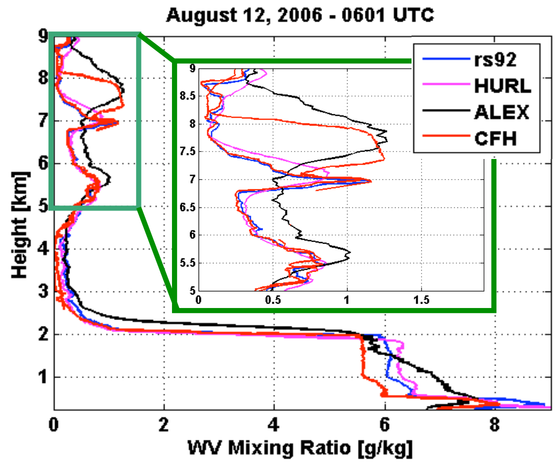
The University of Maryland, Baltimore County (UMBC) contributed to the Water Vapor Experiment Studies (WAVES) in the determination of accurate profiles of water vapor for comparison from AURA and AQUA. Coordinated lidar measurements by UMBC's Elastic Lidar Facility (ELF) and Atmospheric Lidar Experiment (ALEX), and the other lidar systems at Goddard Space Flight Center (GSFC) and Howard University's Raman Lidar (HURL) were carried out to evaluate aerosol extinction and scattering profiles and aerosol water vapor concentrations in the troposphere. These results should aid the understanding of mesoscale variability in atmospheric water and aerosols, at the sub-pixel scale, from the distributed Raman lidar measurements and Weather Research and Forecasting (WRF) modeling of regional meteorological events. As part of the CALIPSO validation during 2006, we compared specific OMI aerosol optical depth and aerosol absorption optical depth products with UMBC Raman and Elastic lidar profiles.

Description of Research

The UMBC Elastic and Raman lidar was operated during the WAVES experimental period of July and August 2006. During the summer (from June 14 to September 14) over 402 hours of coincident lidar data was taken with the elastic lidar system, which corresponded, to AURA and CALIPSO overpasses. Observations were carried out to assess the relative and absolute accuracy of balloon-borne and ground-based lidar measurements of water vapor and temperature. Instrumentation involved: Cryogenic Frostpoint Hygrometer, ATM+Sippican, Vaisala RS-92 and RS-80, Intermet, Raman lidar (NASA, Howard, UMBC). Lidar intercomparison allows characterization of water vapor and aerosol variability on the sub-pixel scale using ground-based Raman lidar systems stationed at UMBC, Beltsville and GSFC. Active measurements from ELF and ALEX also support the Regional East Atmospheric Lidar Mesonet (REALM), 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 (GALION), and Nocturnal Low Level Jet studies, sponsored by the Maryland Department of the Environment.

Accomplishments for FY 06-07

The UMBC lidar group took on two areas of focus during WAVES. The first is the mesoscale variability in the water vapor concentrations between Beltsville and UMBC. Figure 1 below shows that the sites can see very different amounts of water vapor aloft. HURL and the CFH are in good agreement to 7.5 km but UMBC's ALEX system has better agreement with the CFH in a layer above that height. The second area of focus is hygroscopic growth of the aerosol in the boundary layer. This research is the doctoral thesis of Mr. Raymond Rogers, who is combining research from the UMBC, HU, SRL and ARM CART water vapor lidar



systems. The approach is to simultaneously measure profiles of relative humidity and aerosol extinction from the Raman lidar systems and to plot humidograms of growth from these two independent measurements. The technique requires a well-mixed boundary layer (determined from a constant water vapor mixing ratio with height) and there are limited numbers of these cases during the WAVES project.

Figure 1. Intercomparison of ALEX (UMBC), HURL (HU) and two sonde types (CFH-frostpoint hygrometer and rs92 - Vaisala radiosonde). Agreement with ALEX and CFH above 8 km.

In July 2006, northern Canadian forest fire event led to an elevated smoke plume that arrived over the eastern U.S. Observed in the UMBC lidar data and reported on the UMBC Smog Blog (http://alg.umbc.edu/usaq), it drew the attention of Dr. Torres who had also detected the plume in OMI's AAOD product. The AAOD values were elevated and inconsistent with the AOD reported by MODIS. Analysis of the data from the UMBC lidar and the CALIPSO browse images indicated that the initial plume height assumption used by OMI underestimated the plume height (10-12 km); and therefore, overestimated the AAOD. Subsequent reprocessing of the data reduced the AAOD and led to a single scatter albedo, which is more consistent with aged fire plumes.

Objectives for FY 07-08

The team plans CALIPSO, OMI, MODIS and UMBC elastic lidar comparisons for validation of the OMI AAOD product, especially for elevated fire plumes. They will participate in the WAVES 2007 experiment with a revised detector package on the UMBC ALEX Raman Water Vapor system and evaluation of sub-pixel variability in the water vapor fields in the Baltimore/Washington area using WRF. Lastly, a retrieval of aerosol extinction at 355nm will be performed using ALEX during WAVES for OMI extinction comparison.

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

Investigators: Raymond Hoff, JCET Director and Professor, Physics; Kevin McCann, Research Associate Professor, Physics; Rubén Delgado, Research Associate; Zhu Li, Graduate Student, UMBC; Paul Schou, Graduate Student, UMBC

Abstract

The JCET/Physics LIDAR Group at UMBC has taken a large number of ground-based aerosol measurements for comparison with and validation of the CALOIPSO/CALIOP satellite-based LIDAR system. In addition, the JCET researchers have been involved in multi-instrument measurements made in conjunction with the OMI and AIRS instruments. These efforts have led to the detection of dust and aerosol plumes and the improvement of the passive aerosol optical depth retrievals.

Description of Research

The two primary research areas have been the validation of the CALIPSO spaceborne LIDAR and a multi-instrument approach to the measurement of aerosol optical depth (AOD) in conjunction with the passive instruments OMI and AIRS. In the validation portion of the work a significant amount of data has been collected by the ground-based systems during times of CALIPSO overpasses. These data have been used to help understand the CALIPSO data. The group's work with the OMI and AIRS instruments has provided their respective retrieval algorithms with the altitude structure of aerosol plumes. This has led to a significant improvement in the retrieval of aerosol properties by the passive instruments.

Accomplishments for FY 06-07

The elastic lidar (ELF), operated by the UMBC Atmospheric Physics Group, was run for 146 days between June 1, 2006 and June 30, 2007. Aerosol backscattering and extinction time series for these days are available on a website, http://alg.umbc.edu/REALM, and have been used to compare with measurements made by CALIPSO during overpasses.

The JCET researchers have examined several cases of dust and smoke plumes and have retrieved aerosol optical depths for these cases. These data have also been compared with optical depth measurements made by MODIS and AERONET.

Objectives for FY 07-08

A manuscript is in preparation that documents the AIRS/CALIPSO optical depth retrievals.

Significantly improving the accessibility of CALIPSO data is planned in the coming year. This will be done by archiving the data on a UMBC server and by providing a GUI interface that allows the subsetting and averaging of the data.

The group will work closely with researchers at NASA/Langley to continue validation and improvement of the aerosol optical depth retrieval algorithms.

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MDE Grant: **Measurements of Nocturnal Jets with UMBC ELF Lidar (U00R6200819 and U00R7201032)**

Investigators: Kevin McCann, Research Associate Professor, Physics; Rubén Delgado, Research Associate; Raymond Hoff, JCET Director and Professor, Physics; Michael Woodman, MDE; Zhu Li, Graduate Student, UMBC; Paul Schou, Graduate Student, UMBC

Abstract

The University of Maryland, Baltimore County (UMBC) contributed to the Maryland Department of the Environment (MDE) effort to understand the transport of particulates and air pollutants (natural and anthropogenic sources) and their impact to the regional variability of ozone (O_3) and fine particulate matter ($PM_{2.5}$). Upon identification of meteorological conditions by MDE, that favored the formation of nocturnal low-level jets, elastic (532 nm) lidar measurements were carried out with the UMBC Elastic Lidar Facility (ELF) to measure vertical profiles of air quality based on aerosol content. Comparison between ELF and MDE's Beltsville wind field measurements, under the direction of Michael Woodman, were made to show the effect of aerosol production during low-level jet events.

Description of Research

During 2006-2007 lidar measurements were carried out to monitor the vertical distribution of aerosols over the Baltimore-Metro region for days on which the O_3 and $PM_{2.5}$ Air Quality Index levels ranged from Good to Unhealthy for Sensitive Groups. Nighttime observations were carried out to support fieldwork of MDE meteorologists at the Howard University Beltsville site, when nocturnal low-level jets were favored by atmospheric conditions. Active measurements from ELF and ALEX also support the Regional East Atmospheric Lidar Mesonet (REALM), 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 (GALION), and CALIPSO/OMI instruments on the NASA's A-Train. Passive measurements from NASA and NOAA satellites and EPA monitoring networks have been evaluated to compare and determine their impact in the aerosol optical depth (AOD) retrieval.

Accomplishments for FY 06-07

The elastic lidar (ELF), operated by the UMBC Atmospheric Physics Group, was run for 146 days between June 1, 2006 and June 30, 2007. Aerosol backscattering and extinction time series for these days are available on our website, http://alg.umbc.edu/REALM. Time series of lidar data are useful for looking at the air as it advects over the lidar system and to determine the height and intensity of particulate matter in the atmosphere as well as observing the dynamics of the atmospheric boundary layer. Lidar measurements were made on 12 occasions (132 hours of observations) in support of low-level jet research. There was clear confirmation on August 3, 2007, with both lidar and wind measurements, of the formation of a low level jet.

Objectives for FY 07-08

A manuscript is in preparation that documents the lidar/wind profiler measurements of low level jet (LLJ) made in a joint effort by UMBC and MDE. This document will be submitted by December 2007.

In an effort to improve aerosol measurement capabilities at altitudes less than 0.5 km, UMBC is investigating the use of a charge-coupled device (CCD) camera based detection system modeled on the work of Dr. John Barnes at NOAA. The plan is to investigate the feasibility of using the CCD camera as a way to obtain high-resolution aerosol measurements between the surface and 1.0 km above the ground.

In a separate effort, depolarization and attenuated color ratios from observables of the elastic and Raman lidar systems will be calculated to aid in the identification of aerosol speciation and characterization. Synergistic observations from instruments from the A-Train will be used to identify the horizontal and vertical extent of these atmospheric scatterers.

NASA Grant: AIRS Carbon Gas Measurements (NAG5-11653)

NASA Grant: AIRS Trace Gas Retrievals for INTEX-A and INTEX-B (NNG06G B06G)

NOAA Grant: Ground-based Trace Gas Monitoring (NA04AOAR4310095)

NASA Grant: AIRS Trace Gas Retrieval Validation and Analysis (NNG04GN42G)

Investigators: W. Wallace McMillan, JCET Fellow, Associate Professor, Physics, UMBC; Leonid Yurganov, Senior Research Scientist; Michele McCourt, Ph.D. Graduate Student, UMBC; Chris Wilson, Ph.D. Graduate Student, UMBC; Debra Wicks, Ph.D. Graduate Student, UMBC; Tony Salemi, Undergraduate Student, UMBC

Abstract

The main research foci of the group continue as: (1) validation of satellite retrieved products (AIRS and Aura), (2) analysis and interpretation of satellite trace gas retrievals (A-Train), and (3) BBAERI trace gas retrieval algorithm development and subsequent analysis and interpretation. Analysis and interpretation of AIRS concentrates on temperature, water vapor, and trace gas products from the AIRS BBAERI Ocean Validation Experiment (ABOVE02 and ABOVE03) and NASA's INTEX-A and INTEX-B, and the NOAA TexAQS2006 field experiments. Initial validation and analysis of INTEX-A observations appear in two manuscripts published and two still under revision for the INTEX-A special issue of JGR. Leonid Yurganov has extended his analysis of MOPITT CO measurements with the inclusion of AIRS CO retrievals with a manuscript recently submitted to JGR. His research validating AERI CO retrievals continues. Michele McCourt Comer successfully defended her dissertation and graduated in December 2006. Third year graduate students Chris Wilson and Debra Wicks are progressing towards defending thesis proposals in the Fall of 2007. Tony Salemi graduated in May 2007 after completing a senior research project studying pyrocumulus events with AIRS data.

Description of Research

McMillan's research has spearheaded the use of infrared spectra of atmospheric thermal emission for retrievals of tropospheric CO and Ozone. Consulting with ABB Bomem of Quebec, Canada, McMillan equipped his Atmospheric FTIR Laboratory (AFL) with the first commercial prototype FTIR atmospheric sounding system, the Baltimore Bomem AERI, BBAERI. Through participation in the MOPITT Correlative Measurements Team, AIRS Validation Team, and AIRS Science Team, McMillan's group has provided products for validation of satellite CO measurements and is developing tropospheric CO climatologies from archived airborne and ground based FTIR spectra. As leader for the AIRS Science Team Minor Constituents Focus Group, McMillan has overseen validation and optimization of AIRS CO retrievals and its inclusion as a new publicly accessible operational standard product available starting the end of July 2007.

Accomplishments for FY 06-07

Validation, optimization, analysis, and interpretation of AIRS CO retrievals continued to dominate the group's research activities in 2006-2007. Two co-authored studies involving analysis and validation of INTEX-A data were published in the INTEX-A special issue of JGR. An additional lead-authored and another co-authored manuscript remains under revision for this special issue of JGR. McMillan contributed AIRS CO maps and interpretation as a co-author on two papers published in ACP in early 2007. At the request of NOAA colleagues, NASA Tropospheric Chemistry and ACMAP Programs provided support for McMillan and Juying Warner to serve as AIRS field scientists during the 2006 Texas Air Quality Experiment (TexAQS2006) August-September 2006 centered on Houston, Texas, providing near real-time AIRS CO and O3products. Analysis of INTEX-B and TexAQS2006 AIRS data continues as part of an integrated investigation of tropospheric chemistry and dynamics utilizing the extensive capabilities of NASA's A-Train satellite constellation. Wicks has joined with the integrated analysis effort in her examination of stratosphere-troposphere exchange as viewed by AIRS. Reprocessing of AIRS data with the now operational v5.0 algorithm is underway in support of this integrated analysis and in collaboration with the INTEX-B and TexAQS2006 science teams.

Michele McCourt Comer completed her optimization and validation of the AIRS CO retrieval algorithm with the successful defensive of her Ph.D. dissertation. The improved CO algorithm has been incorporated as a new standard product in the next Product Generation Environment (PGE) of AIRS data processing, which will begin operation in July 2007.

Leonid Yurganov joined the research group to lead analysis and interpretation of AERI and BBAERI trace gas retrievals and incorporate them into validation and analysis of AIRS retrievals. Yurganov has extended his analysis of MOPITT CO measurements with the inclusion of AIRS CO retrievals in a manuscript recently submitted to JGR. His research validating AERI CO retrievals has grown to include Chris Wilson who is examining CO_2 and CH_4 retrievals from BBAERI. In August 2006, the JCET group took delivery of the BNAERI instrument originally intended for autonomous operation in Hawaii. Yurganov has taken responsibility for identifying opportunities for field deployments of BNAERI and BBAERI.

Objectives for FY 07-08

The coming year will see final validation and continued analysis of the new AIRS CO standard product produced by the NASA GES DISC. The JCET investigators will continue collaborative analysis of INTEX-A, INTEX-B, and TEXAQS data, as well as extending the range of trace gas studies to the Arctic through involvement with the ARCTAS experiment. The researchers will be contributing to several additional papers featuring analysis of AIRS CO, and will be pursuing new correlation studies of AIRS CO, CH_4, H_2O and O_3. Yurganov will continue analysis of AERI archive data as well as BBAERI data with publication of validation of the AERI CO retrieval algorithm. Wilson will continue work on improving AERI trace gas retrievals as part of his dissertation research. Wicks will continue her integrated analysis of AIRS products with other A-Train observations as part of her dissertation research. Additional proposals will be submitted for new field deployments of BBAERI and BNAERI.

NOAA Contract: Support NOAA/NESDIS in Area of Satellite Retrievals (DG133E0SSE6814-1)

Task 107: Air Quality Support for Giovanni

Investigators: Ana I. Prados, Assistant Research Scientist; Raymond Hoff, JCET Director and Professor, Physics; Shobha Kondragunta, NOAA NESDIS

Abstract

This work supported the development and adaptation of the existing GOES-12 Aerosol/Smoke Product (GASP) Aerosol Optical Depth (AOD) retrieval algorithm for the GOES-11 (west) imager, testing and validation of the code and assistance with the implementation of the code at NOAA/NESDIS in near-real time. It also supports testing and improvements to the existing GOES-12 AOD algorithm. As part of the Three-Dimensional Air Quality System (3D-AQS) project, this work supports collocation of satellite, LIDAR and surface aerosol measurements in time and space and the determination of boundary layer heights based on LIDAR observations. It also includes weekly contributions to the UMBC Air Quality Web Blog. As part of the Giovanni task this work supports the acquisition and integration of EPA $PM_{2.5}$ observations into Giovanni, NASA Goddard's web-based tool for Earth science remote sensing data.

Description of Research

The goal of this research was to apply the existing GASP algorithm to the western GOES-11 imager in order to provide increased geographical coverage of Aerosol Optical Depths over Canada and the Pacific and the capability to track pollution plumes in those regions at high temporal resolution. The purpose of the GASP algorithm improvements was to increase their accuracy and thus the ability to monitor U.S. air pollution and transport. Although AOD is a total column measurement, it has been shown to be correlated to surface aerosol concentrations affecting human health and the environment. LIDAR data can enhance our ability to use satellite AODs for air quality purposes because it contains vertical information and can be used to better interpret the satellite data and its relationship to aerosol conditions at the surface.

Accomplishments for FY 06-07

Building on previous work with the GOES-10 imager, Prados adapted the GASP AOD retrieval algorithm for the GOES-11 imager. The algorithm included the currently available calibration and a newly created LUT based on the GOES-11 spectral function. The primary motivation for adding GOES-11 AODs was to increase coverage over North America further north into Canada, where fires can lead to significant amounts of smoke aerosols, particularly in summer. Smoke from fire activity in Canada can be transported into the U.S. where it can have an adverse impact on air quality. The current GOES-12 imager only includes a very small portion of southern Canada. The GOES-11 imager also adds coverage in the Pacific. Near-real time GASP-west imagery was provided to the internal NOAA/NESDIS/STAR GASP web page that was maintained through this project. This enabled easy visual inspection and comparisons to the concurrent GOES-12 GASP imagery. Good agreement was found in regions of overlap over the western U.S. and with less noise in the retrieved product when compared with GOES-10 retrievals (its predecessor). The GASP-West imagery became publicly available at NOAA/NESDIS in experimental mode on July 31st and was used to help with flight planning in the TEXAS-AQS Air Quality campaign in the summer of 2006.

Prados also provided improvements to the GASP AOD mask currently used in the GOES-12 retrievals and found that the agreement between the AERONET and GASP AOD improved when using stricter spatial variability tests in the retrieved GASP AOD and in the required number of cloud free pixels around a given pixel.

A GASP AOD validation paper was submitted in August 2006and will be published in August 2007 [Prados et al. 2007]. The validation was based on comparisons to MODIS and AERONET AODs for the years 2004 and 2005. The main findings from this work were that the GASP AOD can be used quantitatively to monitor air quality over the eastern U.S., where the mean correlation between the GASP and AERONET AOD was 0.79. There was also reasonable agreement between both datasets in the diurnal and seasonal variability of the AOD.

3D-Air Quality System (3D-AQS) is a UMBC led effort incorporating satellite and LIDAR data into EPA decision support systems, specifically their air quality databases. Prados collocated GASP, UMBC LIDAR and AERONET AODs in time and space for preliminary analysis and comparison to surface EPA $PM_{2.5}$ concentrations at 5 sites in the Baltimore-Washington metro area. $PM_{2.5}$ refers to particles with aerodynamic diameter less than 2.5 microns. It is a criteria pollutant regulated by the U.S. EPA that has been linked to adverse cardiac and respiratory health effects. The AOD/$PM_{2.5}$ correlations can be potentially improved by using only the AOD below the Planetary Boundary Layer (PBL), which is more representative of surface aerosol conditions than the total column AOD product. To this end, Prados used visual inspection of the UMBC LIDAR data in 2005 to determine PBL heights and calculate below PBL AODs. The subsequent analysis (performed at Battelle) has shown moderate improvement in the AOD/$PM_{2.5}$ correlations.

Giovanni is a web-based tool for analyzing and displaying Earth science remote sensing data at NASA GSFC. In June 2007, Prados began preliminary work in creating an Air Quality capability in Giovanni that will include the ability to easily compare NASA earth science data to EPA surface aerosol observations.

Objectives for FY 07-08

For the next fiscal year, support will continue to be provided to the 3D-Air Quality System (3D-AQS) project including the incorporation of satellite and LIDAR data into EPA’s database. Prados also expects to make regular (weekly) contributions to the UMBC Air Quality Web Blog. An Air Quality instance will be developed in NASA’s Giovanni web based tool for earth science data. As a first task, in-situ ozone and aerosol data and CALIOP aerosol observations will be integrated into the Giovanni system. This will provide the air quality research community with fast and easy access to remote sensing and surface data for visualizing and analyzing the spatial variability and transport of air pollutants in the U.S.

Task 47: **Statistical Analysis of Geophysical Variability**

NASA Grant: **Validation of Non-coincident Trace Species Measured by AURA Using Trajectory Mapping and Statistical Analysis (NNX07AD87G)**

UMBC DRIF: **Investigations of TC Inner Core Dynamics and Its Impact on Storm Intensity**

Investigators: Lynn Sparling, JCET Fellow, Associate Professor, Physics, UMBC; Sam Trahan, PhD Graduate Student, UMBC; Eric Hughes, Undergraduate Student, UMBC

Abstract

Two papers on the statistical properties of atmospheric trace gases that are relevant for measurement and validation have been published, and research on methods for non-coincident validation is continuing. A multi-sensor and trajectory analysis of volcanic SO2 and aerosols for Aura validation has been initiated. Several modeling projects have been initiated using the non-hydrostatic mesoscale Weather Research and Forecast (WRF) model. A new research project on tropical cyclone inner core dynamics has been initiated. Collaborative projects with UMBC computer science faculty on visualization of tropical cyclones are continuing.

Description of Research

The research under this task is aimed at an understanding of the dynamical, chemical, and transport processes in the atmosphere that contribute to the observed variability in chemical tracers and meteorological fields over a wide range of spatial and temporal scales. Satellite observations of chemical tracers are used to investigate the statistical properties of large-scale dynamical processes, while high resolution aircraft and balloon observations are used to obtain a statistical view of smaller scale mixing and dissipative processes. The observations are interpreted using a combination of theory and comparisons with numerical models and Lagrangian transport models. This research is also applied to some practical problems related to the impact of subgrid/subpixel scale geophysical variability on satellite validation.

Accomplishments for FY 06-07

Research on the two-point statistics of trace gas variability is ongoing. This work shows that the small-scale increment statistics are Weibull and that the distribution seems to be universal, a result that can be used in data validation to interpret differences between non-collocated measurements. A publication is in preparation. Another method being developed utilizes the asymptotic properties of two-point statistics in the limit as the spatial and temporal separation approaches zero [Sparling et al. 2006]. This method is being applied to trace gas data from the AURA satellite and correlative aircraft measurements.

Progress has been made during the past year in atmospheric modeling at UMBC. Student Mengs Weldegaber is continuing with WRF (Weather Research and Forecast) [Michalakes et al., 2004] modeling of convective initiation along a southern Great Plains dryline for his Ph.D research. Other modeling work included an undergraduate research project in which 8 km resolution WRF simulations of low level winds were compared to wind measurements at

UMBC during March April 2007. The model representation of the diurnal cycle was poor with inconsistent agreement in wind speed. Additional studies of low-level winds at other locations in Maryland are being planned.

New tropical cyclone research was initiated in collaboration with Scott Braun (GSFC) and Jeff Halverson. Ph.D. student Sam Trahan has begun HWRF (Hurricane-WRF) simulations to investigate the resolution and model configuration dependence of small-scale inner core dynamics and its impact on storm intensity. A collaboration with the UMBC Computer Sciences Department in hurricane visualization has led to innovative illustration-inspired representations of eyewall structure [Joshi et al. 2007].

Projects in Lagrangian transport modeling include a trajectory analysis showing long-range transport of CO from the July 2004 Canadian/Alaskan fires [McMillan et al. 2006]. Other trajectory simulations of the transport of volcanic SO_2 are being combined with a multi-sensor data analysis combining MLS, OMI, AIRS and CALIPSO measurements of SO_2, water vapor and aerosols in order to compare AURA measurements to those from other sensors. In addition, the characteristics of the horizontal transport at different vertical levels are being used to constrain the vertical distribution of the gas, about which little is known from column measurements such as AIRS CO and OMI SO_2

Objectives for FY 07-08

A major goal during the next year is to extend the hurricane modeling efforts and continue with analysis of AURA trace gas measurements. The work on non-coincident validation and increment statistics will be submitted for publication. Collaboration in research on visualization of atmospheric phenomena will continue and be extended to the development of visualization tools for model exploration.

NASA Grant: AURA Validation Support (NNG06GB04G)

NASA Grant: Atmospheric Composition (NNX07AM45G)

Internal: Hyperspectral Imager Data Collection and Lab Operation

Investigators: Juying Warner, Assistant Research Scientist

Abstract

The validation of Tropospheric Emission Spectrometer (TES) CO and ozone on Aura using AIRS products is a three-year project, of which this report covers the first year's activities. This comparison study, as well as its validation with the DC-8 in-situ measurements during INTEX-NA, was summarized in a publication [Warner et al., 2007]. The core of this project is to develop a set of research retrieval codes for AIRS CO products using Rodgers' Optimum Likely-hood method. Initial work involved establishing modules for this retrieval computational system.

A paper by Warner et al. [2006] was published to describe the capabilities of the UMBC VNIR sensor system and preliminary results and potential applications using this sensor. A thermal imaging capability was added to this lab by using the pyrometers and by renting a thermal imager. These sensors, as well as the UMBC VNIR sensor, were integrated onto a helicopter from RC&A Inc., a Frederick, MD based aerographic company, such that the sensors are ready for deployments of future field projects.

Description of Research

Atmospheric CO concentrations are simultaneously measured by EOS A-train satellite sensors, which include AIRS on Aqua, TES and MLS on Aura. Based on the heritage of the A-train system, the combined datasets from these sensors will provide the best available three-dimensional trace gas information that incorporates the uniqueness of AIRS large spatial coverage, TES high vertical resolutions, and MLS measurements at the upper troposphere and stratosphere. It is important to first establish a thorough evaluation of these sensors in terms of their data qualities and establish well-understood biases between them before they can be used conjointly. Warner has devoted her efforts towards this goal by carrying on three projects: (1) Intercomparing tropospheric CO products from the current satellite instruments: MOPITT, AIRS, and TES, and validating these products using in situ data. (2) Developing a new algorithm to retrieval tropospheric CO products using AIRS data, such that the CO products from all three sensors are based on one type of retrieval method. (3) Exploit numerical methods to establish data fusion among these sensors.

It is a challenge to isolate surface emissivities/reflectivities with the surface temperatures in satellite remote sensing applications. The UMBC VNIR sensor can sense geophysical properties of the earth surface in the visible and near IR spectral range at very high spectral and spatial resolutions. A new component has been added to measure the surface temperatures at very high spatial resolutions.

Accomplishments for FY 06-07

Research on satellite tropospheric CO inter-comparison has been summarized in a publication [Warner et al. 2007], as well as presented at the SPIE 2006 Annual meeting in San Diego, CA, the Aura validation workshop at Boulder, CO, and the AIRS science team meeting at Pasadena, CA. In summary, Warner and co-authors have assessed the quality of the satellite measurements of tropospheric CO by comparing two global products, AIRS and MOPITT, for the period from June 15 through August 14, 2004, during INTEX-A. Using the MOPITT a priori profile as AIRS' first guess provides global improvements to the agreements between CO retrievals from these two instruments. From the MOPITT, AIRS, and DACOM profiles comparisons during INTEX-A it is generally concluded that the three datasets agree within the range of data variability in the areas covered by the DC-8 spirals especially in the upper troposphere (250-550 hPa).

A large portion of Warner's efforts in all relevant research, collaboration, and delivery activities is to process AIRS global retrievals at UMBC. AIRS trace gas products have not been released through NASA DAAC and Warner has voluntarily delivered AIRS CO and O_3 products to the AURA validation teams via the AVE data center. Warner also co-authored papers as a result of these collaborations [Thompson et al. 2006; Morris et al. 2006].

AIRS and TES tropospheric CO concentrations are compared when the AIRS global datasets are collocated with TES global survey measurements during 2006. The comparison results from 2006 data were reported at the AIRS science team meeting in an oral presentation in March 2007. A paper summarizing these comparisons is under preparation. Another area of focus by Warner is to exploit the possibilities of combining AIRS and TES CO measurements as one product. Preliminary results are summarized in a paper submitted to GRL [Warner et al. 2007]. A proposal was also submitted to NASA ROSES-07 to seek support for the continuation of this work.

A new component of the surface imaging was added to the hyperspectral lab at JCET. As a result, a thermal infrared flyover was conducted in early March 2007 for the purpose of detecting spatially heterogeneous groundwater inputs to the stream. Warner was the coordinator for part of the flyover of Gwynns Falls, MD and her efforts were spent preparing equipment and data as well as mapping of a flight plan. This mission consisted of renting a helicopter and FLIR camera, as well as deploying two pyrometers owned by UMBC. Extensive communications were carried out with the FLIR company for camera rental to understand software and hardware options, as well as with Advanced Helicopter, Inc. at Frederick, MD for flight planning, scheduling, and sorting out technical details on the instruments' integrations.

Objectives for FY 07-08

Future work for the Aura validation will include the comparisons using more extended datasets, the inclusion of MLS data, and with higher spatial and temporal coverage, and more in-situ measurements. Next year's effort will also include the comparisons of AIRS O_3 to those from TES and OMI. Other investigations may include efforts to combine tropospheric CO and O_3 products from multiple sensors on A-train satellites to produce optimized global chemistry datasets that reflect the best spatial and vertical resolutions.

To develop a consistent tropospheric CO dataset from different sensors to study the earth climate, it is critical to minimize any biases that arise from the use of different algorithms. Warner will work to develop a new retrieval algorithm using a maximum a posteriori method for AIRS CO so that a better understanding of the instrument's sensitivities can be achieved when the same algorithm is used for both sensors. Now that the hyperspectral instrument is operational, Warner is actively seeking partnerships and sponsors for new research opportunities.

NASA Grant: Airs Trace Gas Retrievals for INTEX-A and INTEX-B (NNG-066-806G)

NASA Grant: Airs Trace Gas Retrievals Validation and Analysis (NNG-046-N42G)

NOAA Grant: Monitoring Tropospheric CO, CH_4 and CO_2 Profiles Using a Distributed Network of High Resolution Infrared Spectrometers (NA04 AOAR4310095)

Investigators: Leonid Yurganov, Senior Research Scientist; W. Wallace McMillan, JCET Fellow, Associate Professor, Physics

Abstract

The existing and archived spectra of ground-based, upward-looking Atmospheric Emitted Radiance Interferometers (AERIs) contain very useful information about members of the carbon family (CO_2, CH_4, and CO). A retrieval procedure developed at UMBC allows one to characterize pollution of the lowest 2 or 3 km of the troposphere with temporal resolution of a few minutes. During 2006-2007 all spectra for the Southern Great Plains (SGP) site of the Atmospheric Radiation Measurement Program (ARM) have been retrieved for carbon monoxide. To ensure a good quality of the data, collaboration with researchers from NOAA (Paul Novelli, PI) and from LBNL (Marc Fischer, PI) was established. They provided simultaneous in situ measurements, both for the surface layer and for aircraft. In view of the potential for using this site for validation of satellite-borne instruments, analysis of MOPITT and AIRS instruments was done and submitted for publication.

Description of Research

A goal of the project is to complete, validate, and implement an operational algorithm for tropospheric vertical profile retrievals of CO_2, CH_4 and CO with a minimum of two layers, planetary boundary layer and mid-troposphere trace-gas concentrations, from the existing distributed network of ARM sites. AERI's capability to simultaneously monitor temperature and water vapor enables some source discrimination such as CO_2 from combustion vs. biogenic processes. The demonstrated autonomous operation of the AERIs at the United States Department of Energy (DOE) ARM sites argues for their eventual deployment at numerous NACP and U.S. Interagency Carbon Cycle Science Program (CCSP) network stations. The proposed algorithm development builds on our ongoing research of compiling CO climatology for the ARM/SGP site. This site is panned to be used as ground truth for existing and pending space platforms.

Accomplishments for FY 06-07

Since July 2006 until May 2007, routine processing of AERI/SGP spectra for CO abundance was performed. By now all data between 1997 and 2007 have been processed. Weighted average CO concentrations that quantify a pollution of the lowest 2 or 3 km of the atmosphere available (the weighting function is now under calculation and the upper boundary of the AERI sensitivity will be determined). Collaboration with researchers from NOAA (Paul Novelli, PI) and from LBNL (Marc Fischer, PI) was established. They supplied independently measured CO surface (LNBL) and airborne (NOAA) data up to 5 km of altitude since the beginning of 2006. First comparisons reveal a good agreement. In addition to this research, for the same period of time the global CO variations were studied using AIRS and

MOPITT. The data of sun-viewing spectrometers in Russia and Australia were used as ground truth. A close link between these variations and emissions from wild biomass burning estimated independently was confirmed. According to MOPITT data, CO annual emission in 2006 was 184 ± 40 Tg higher than in 2000-2001. Available estimates of C/CO ratios enabled estimates of total carbon emissions from biomass burning in 2006: 0.6-1 Pg C per year larger than in 2000. This is comparable in magnitude with the modern estimates of the continental sink for carbon: 0.9 ±0.6 Pg C/ year. Therefore, wild fires can convert continents into net sources of carbon [Yurganov et al. 2007].

The JCET investigators plan to use these results in analysis of AERI data, in particular, in comparisons with satellite retrievals. Validation of MOPITT data [Yurganov et al. 2007] confirmed recently published conclusions of Deeter et al. [2007] that indicate a high sensitivity of MOPITT for the boundary layer over continents in summer time. If this is the case, then the AERI network may be used as a validation tool for satellites, at least in summer.

Another paper published in 2007 [Leung et al. 2007] used ground-based data supplied by the JCET investigators for comparison with three-dimensional models. It demonstrated that it is essential to use both surface and column observations of CO to constrain the magnitude of the fire emissions and their injection altitude. The paper also has shown that about half of the emissions were injected above the boundary layer.

Objectives for FY 07-08

The objectives depend to some extent on funding for new proposals. However, generally the researchers objectives include studying natural and/or anthropogenic pollution, cycles of tropospheric gases with respect to their influence on carbon cycle and global climate; integration of ground-based and space-borne measurements, ensuring long-term consistent data sets that can be used for quantitative assessments of perturbation of the carbon cycle; and intensification of collaboration with research teams involved in carbon cycle problems (J. Randerson, S. Wofsy, M. Fischer).

NASA Grant: Three Dimensional Air Quality System (3D-AQS) (NN-H-04-Z-YO-010-C)

Investigators: Hai Zhang, Research Associate; Raymond Hoff, JCET Director and Professor, Physics; Kevin McCann, Research Associate Professor, Physics

Abstract

The main accomplishments during this period include a product transfer of the Infusing satellite Data for Environment Application (IDEA) from University of Wisconsin to NOAA/NESDIS, integration of MODIS AOD/$PM_{2.5}$-sites matchup AOD data into AirQuest, investigation of the difference between MODIS AOD version v4 and v5 on their relation to $PM_{2.5}$, and investigation of GASP AOD sensitivity to water vapor and ozone.

Description of Research

Particulate matter with aerodynamic diameters less than 2.5 um ($PM_{2.5}$) can cause serious health problems. The $PM_{2.5}$ concentration is one of the air quality data monitored by the Air Quality System at the U.S. Environment Protection Agency (EPA). The limitation of the ground based $PM_{2.5}$ monitors is the gaps between stations. Satellite remote sensed aerosol optical depth (AOD) does not suffer this problem. The 3D Air Quality System is meant to integrate satellite aerosol data and ground $PM_{2.5}$ data into air quality decision support systems, which include the EPA's Air Quality System (AQS) and AirQuest database, the IDEA product, the U.S. Air Quality weblog, and the Regional East Atmospheric Lidar Mesonet. The focus of Zhang's research is on the IDEA product and the relationship between satellite remote sensed AOD and $PM_{2.5}$ measured at the surface in order to provide public satellite aerosol measurements as guidance for air quality monitoring and forecasting.

Accomplishments for FY 06-07

In an effort to provide more nearly continuous coverage of the continental United States, the JCET researchers are porting the present IDEA system, which overlays ground based particulate measurements with MODIS satellite measurements of AOD, to a computer that will ultimately be an operational system for NOAA. Two copies of the MODIS IDEA system have been set up: one operating at UMBC and another at NOAA/NESDIS. Zhang has been working on testing the two copies of the product against the University of Wisconsin/MODIS/IDEA product to ensure continuity in product and supervise the delivery of the new NESDIS IDEA product. On a day-to-day basis, this means acquiring the MODIS AM MOD04, the meteorological data, AIRNow data, satellite fire position data to produce superposition of AIRNow data, a forecast discussion and trajectory data.

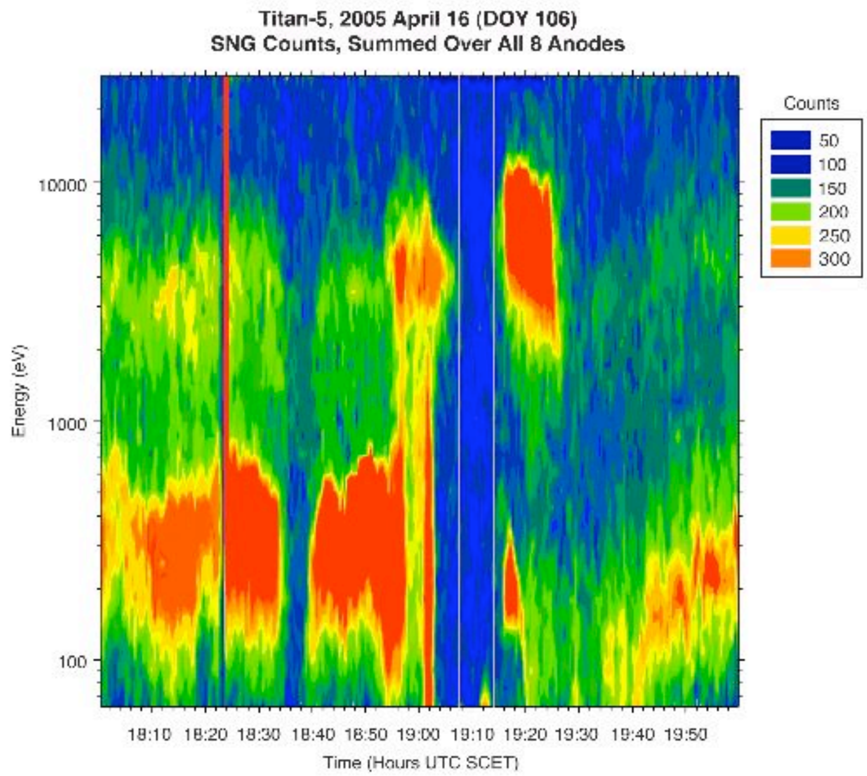
The MODIS aerosol product has changed a lot since the launch of Terra, and the latest version is v5.2.6. However, the IDEA product running at UW is still using version 4.0.1. In order to investigate the impact of the different versions of MODIS AOD product on the AOD and $PM_{2.5}$ relation, the researchers compared the different versions of MODIS AOD on their relations to $PM_{2.5}$ based on a two-year (2005-2006) matchup dataset of v4.0.1 and v5.2.6 of MODIS AOD from Terra and $PM_{2.5}$. The comparisons are performed in terms of their inversion methods and cloud screening algorithm in ten EPA regions over the United States. In terms of inversion methods, AODs from v4.0.1 have lower values than those from v5.2.6 over all EPA regions, and the correlation coefficients between AOD and $PM_{2.5}$ are higher for v5.2.6 than those for v4.0.1 over most of EPA regions. The cloud screening algorithms are found to have larger impacts in the AOD and PM2.5 relation: the AOD coverages of v4.0.1 retrievals are about 40% larger than those of v5.2.6 retrievals due to the different cloud screening algorithm. The correlation coefficients are much smaller for the whole dataset for v4.0.1 than those for the subset having one-to-one correspondence with v5.2.6, which indicates that the extra data in v4.0.1 are most likely contaminated by the cloud.

In other work, Zhang investigated the sensitivity of GOES Aerosol and Smoke Product (GASP) AOD retrievals to the variation of column water vapor and ozone. GASP is an AOD retrieval product from GOES imagery, and it provides near-real time AOD over the United States at 30-minute intervals. One potential source of error in its retrieval algorithm is that it assumes a constant total column water vapor and ozone when calculating gaseous absorption. The purpose of Zhang's research is to estimate the errors introduced by the water vapor and ozone content in the GASP retrieval. In order to do this, GASP retrieval algorithm runs were undertaken with new look-up tables (LUTs) created with different column water vapor and column ozone content, and the results are compared against the retrievals from the original LUT. Relatively small errors were found due to the gaseous absorption. The retrieved AODs are more sensitive to water vapor and ozone variations in the early morning and late afternoon cases due to larger air mass. For two extreme cases, i.e., lowest gaseous absorption and highest gaseous absorption, a mean difference was found of -0.016(0.011), an RMS difference 0.023(0.016) and a slope 0.94(1.04) between the AOD retrieved with low (high)-absorption LUT and that from original LUT for the retrieval in midday, while in the early morning and late afternoon when the sun zenith angle is large, the mean difference is -0.055 (0.044), the RMS is 0.10 (0.084), and the slope is 0.85(1.10) for the retrieval from low(high)-absorption LUT.

Objectives for FY 07-08

Zhang will continue working on IDEA product enhancement to include GASP AOD into the IDEA system with 30-minute update. He plans to develop algorithms to import the GASP into IDEA as a parallel source of AOD information as well as test continuity between MODIS and GASP AOD inputs on the stability of the IDEA analysis. The researchers will integrate GASP AOD/$PM_{2.5}$-derived from AOD into AirQuest, investigate the relation between GASP AOD and $PM_{2.5}$ over the Unite States and compare it against the MODIS AOD and $PM_{2.5}$ relation. Finally, Zhang plans to develop algorithms to map MODIS AOD and GASP AOD on CMAQ grid and integrate them into AirQuest.

Interdisciplinary Science Focus Group



Cassini Plasma Spectrometer (CAPS) measurements of ion counts at various energies (eV) and spacecraft event times (SCET) during the Titan 5 (T5) flyby of the moon. The vertical white lines indicate the depth of penetration of KeV magnetosphere ions into the upper atmosphere of Titan. The measurements were made on the 106th day of year (DOY) when the instrument was in its singles (SNG or non-coincidence) mode. The counts were enhanced by summing counts from all eight anodes (anode here refers to an ion detector with a collimator admitting ions from narrowly specified directions). (Figure provided by Dr. Richard Hartle.)

II.4 Interdisciplinary Science Focus Group: Vision

The Interdisciplinary Science Focus Group (ISFG) is comprised of researchers in various disciplines in the Earth and planetary sciences. The research has a broad focus. One area is the application modern technologies in space/ground observations and scientific computations to studies of dynamical processes in various components of the Earth system and interactions among them. A second is to understand possible sources of forces on the dynamical Earth, the responses of the Earth, and the consequences on global change and on our society. Group research, which uses an interdisciplinary approach where appropriate, includes the deep-interior structure of Earth, geodynamo/geomagnetism, tectonics, volcanic processes, reference frames, terrestrial gravity, boreal and carbon cycle biophysics, environmental science, surface change, planetary aeronomy, and meteorology. The third major area of research is in data assimilation, which touches on many of the earth sciences topics mentioned above. Data assimilation involves combining observation data with model forecasts to produce an improved state estimate. Within the ISFG, data assimilation is used in both atmospheric and solid earth science.

Deep-Earth research focuses on modeling the dynamical processes in the Earth's liquid outer core, geomagnetic field generation (the geodynamo), and interactions between the core and the solid Earth on time scales ranging from decades to over a century. Future research efforts shall focus on further improving the modular-based MOSST geodynamo model, and integrating the work with other ongoing Earth science modeling efforts; furthering studies on core-mantle interactions and their impact on Earth's rotation variation; and initiating multidisciplinary (e.g., geodynamo, geomagnetism, geodesy, and geodynamics) studies of the deep Earth. A data assimilation system is being developed to combine the MOSST model with the observation record of the Earth's magnetic field, in order to produce a more accurate picture of both the magnetic field and the core dynamics.

Volcanological research focuses on time-varying (interannual) volcanic eruptions, time series of eruption clouds, and their application to climate prediction. Future research activities include extending the eruption-produced sulfur and ash mass observations database for two more decades from the current 22-year-long records; inferring solid-Earth processes and improving eruption forecast accuracy via detection of pre-eruptive volcanic emissions and coordinated fieldwork; providing analytical tools to NOAA, FAA, and the USGS to mitigate aviation hazards; and developing new algorithms to increase the sensitivity for detecting sulfur dioxide with future satellite instruments. Space geodesy research focuses on the terrestrial reference frame, the Earth's gravity field model, and the observation of global sea level changes. This research subgroup intends to continue contributions to analysis, calibration, and exploitation of data from the CHAMP, GRACE, JASON and ENVISAT missions; to prepare for the GOCE missions; to provide more research results and data to NGS, USNO, and IERS; and to apply the results to gravity field modeling and other geophysical studies (e.g., earthquakes, large storms, surging/retreating of polar ice-caps, minute changes in sea level, eruption of volcanoes, etc).

Research efforts in data assimilation focus on statistical and computational methods to assimilate satellite-based observational data with numerical modeling. Near- and longer-term research plans include the development of the assimilation system for tropospheric carbon cycle species (CO, CO2), which can be used to improve the global carbon budget and to improve models of carbon species sources.

Planetary research in the ISFG focuses on planetary atmospheres and magnetic fields and their uniqueness and their similarities with terrestrial systems. Future research plans include further understanding the evolution of planetary atmospheres (part of NASA's goal to understand the origin and evolution of the Solar System) by developing analytical and numerical models for escape rates of the neutral and ionized components of planetary atmospheres. These rates are then used to estimate the loss of a particular constituent over geologic time scales (e.g., the amount of water Mars and Venus have lost over the last four billion years).

Group-wide, activities shall continue to expand research areas associated with NASA's Earth Science Enterprise through new projects and new initiatives, such as the carbon cycle initiative. Group participation will continue and expand in national and international research programs (e.g., the IERS' Global Geophysical Fluids Center; EarthScope); strengthen collaboration with scientists from other organizations (e.g., NIMA and USNO); to develop and implement cutting-edge research techniques, better access to various community research resources, and new research areas for group members and for UMBC faculty and graduate students, in general.

Collaborations with other JCET focus groups will continue and grow. Cooperation will continue with other university centers and departments on research proposals and projects, and on undergraduate/graduate curriculum development, with an eye to strengthening multidisciplinary research activities and improving scientific productivity by better exploiting research results and observational data from different disciplines of the Earth sciences. In so doing, these efforts will also expose students and faculty members to new research and technology developments. Members of the ISFG now teach courses and advise graduate students in the physics, mathematics and geography departments. Many of the courses are in geophysical or environmental science areas, which draw the academic departments further into these areas of research.

Such visions in research and in education will further the purpose of JCET as a University Research Center, not simply a research entity that presently interests GSFC. By helping expand the already wide spectrum of research interest areas at JCET, the ISFG makes the entire university organization stronger and more resilient with respect to fluctuations and redirection of funding themes of interest to NASA, NSF, and the other supporting agencies.

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

MIPS Grant: **Distributed Sensing of Hazardous Geophysical Flows (SENSEI) (MIPS Contract Agreement # 3619)**

NSF Grant: **Determining the Nature of Injuries Sustained in Landslide Disasters (VIP K-16 UMBC)**

NSF Grant: **Creating a Science Activity to Track Motion: Collaboration between UMBC Faculty, VIP and STEM Teachers (NSF VIP K-16)**

NSF Grant: **An Investigation of Progressive Failure in Landslides in the Area Affected by the 8th October 2005 Earthquake in Pakistan (NSF SGER)**

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

Abstract

The Landslide Observatory was renamed the Geophysical Flow Observatory (GFO) to better reflect the scope of the work undertaken. Both the GFO and the Landslide Mitigation Group (LMG), both run by Bulmer, have continued to build a reputation with Federal funding agencies, the NGO community and commercial enterprises. Duties are divided between pure and applied research as well as teaching and mentoring. Bulmer is supervising four Masters students at UMBC in the Department of Mechanical Engineering as well as having mentored two NASA Interns during Summer 2007. Funding for these was provided through the JCET Summer Intern Program and the NASA Summer Institute on Atmospheric, Biospheric, and Hydrospheric Sciences at GSFC. In addition, Bulmer filed three invention disclosures with UMBC for SENSEI, SENTINEL and WITNESS.

Description of Research

Current research interests include: remote sensing applications to the Earth, terrestrial planets and icy satellites; mechanics and landslide hazard and risk assessment; integrating spaceborne, airborne, surface and sub-surface data; configuring Unmanned Aerial Vehicles (fixed wing, rotor and lighter-than-air) and sensors (cameras), and designing data collection devices SENSEI, SENTINEL and WITNESS.

Accomplishments for FY 06-07

As part of ongoing research, a new image and topography data over Olympus Mons and the surrounding aureoles has been compiled into a GIS environment and assigned a common coordinate system. A digital elevation model has been created using a subset of the MOLA 128 degree/pixel data. Products derived from this topography data include a shaded relief, color coded elevation and slope gradient maps. Image data from THEMIS have been mosaiced and georeferenced to the MOLA DEM. This has provided the base for a geomorphologic map of the aureoles and volcanic edifice. As boundaries of aureoles have been identified it has been possible to calculate their dimensions and compare them with those derived from Viking data. The available evidence continues to support the aureoles as being derived from mass movements. In an effort to understand large rockslides a 1 m resolution DEMs has been created using data obtained over the Martinez Mountain rock avalanche using the NASA ATM IV LiDAR. Preliminary analyses of these data were presented at the 2007 Lunar and Planetary Conference and the AGU Spring Conference.

The goal of the SENSEI research is to demonstrate that a new emerging technology using radio frequency ranging can be used to measure surface motions associated with landsliding. Surface motion data on slopes can be obtained using a variety of technologies (e.g. GPS, inclinometers, and tiltmeters in bore holes) but costs per unit tend to prohibit many being deployed resulting is high-resolution data at only a few locations. SENSEI is designed around distributed sensor architecture where larger numbers of sensor units are distributed on any given slope. Bulmer supervised students research into: integrating the ranging board with the UMBC local sensing board from an accelerometer; rotation around cardinal points from a compass module and tilt from the vertical axis using a tiltmeter; optimal configurations of SENSEI arrays in variable terrain using analysis line-of-sight and range in a GIS environment; design of temperature sensors and analysis of data from a distributed temperature sensor arrays; and using an aerial platform to obtain transmitted data from a distributed array on variable terrain.

A collaboration between the GFO and the UMBC Department of Emergency Medicine has resulted in a search for historical medical records of landslide disasters worldwide. The expectation of the team physician was that deaths would be due to asphyxiation. However, an examination of these data has revealed that that cause of death was more varied and that the type of landslides (flow, slide and fall) and make up of the debris (wet, dry, percentage of rock and debris) can influence the kinds of injuries sustained (Table 1). This provides important guides to the kinds of resuscitation / first-aid equipment needed and that it is possible to tailor medical response for highest degree of effectiveness.

Type	**Injuries**
Debris flows with rock	Amputations. Almost no survivable spaces. Dirt in mouth and nares. Die rapidly or instantly from trauma
Wet slide	Amputations. Survivable space but drowning and asphyxiation Dirt in mouth and nares. Die rapidly or instantly from trauma
Dry slide	Survivable space but asphyxiation Lethal to non serious trauma injuries

Table 1. Relation between landslide type, injuries and survivability.

In January 2006, Bulmer was invited to examine the landslides associated with the 8th October 2005 Earthquake in Pakistan. Bulmer conducted a reconnaissance visit in January 2006, and submitted an SGER grant to NSF to conduct an examination of landslides processes before and after the 2006 monsoon season in Pakistan. In response to a request from the GSP for an assessment of data collection systems that could be deployed in Kashmir, a new low-cost, long duration, low maintenance, day and night operation slope movement data collection technique (SENTINEL) was designed at UMBC by Bulmer and Farquhar. This is based upon the comparison of time series digital photography of markers affixed to slopes. Results from a preliminary deployment of this system were published as the lead article in EOS. Bulmer and Farquhar have been asked by the World Bank to provide expert technical advice on appropriate data collection systems to determine landslide hazards in the Villcanota Valley, Peru.

Objectives for FY 07-08

Proposals will be submitted to NSF Earth Sciences, NASA Mars Data Analysis and Army Research Programs.

Task 71: NASA Terrestrial Ecosystems, Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency

NASA/ROSES: Remote Sensing for Carbon Science Research

NSF Grant: Applications of Solar Induced Fluorescence to the Assessment of Vegetation Photosynthetic Function and Physiological Condition

Investigators: Petya K. E. Campbell, Research Assistant Professor, Geography and Environmental Studies; Elizabeth Middleton, NASA GSFC, Code 614.1

Abstract

Current remote sensing methods do not provide accurate estimates of vegetation physiological status and C sequestration potential. Actively induced fluorescence measurements are commonly used in plant physiology to assess the condition and carbon allocation efficiency of leaves and whole plants, especially techniques based on actively induced chlorophyll fluorescence (ChlF). In the terrestrial biome, direct measurement of the solar-induced vegetation ChlF have not been possible due to the strong reflectance signal in the red and near-infrared spectral region. A new approach is to use an ultra-high spectral resolution instrument, a Fraunhofer Line Discriminator (FLD), to measure the solar induced ChlF signal as it fills in the atmospheric Fraunhofer lines in the solar spectrum. If scientifically proven, the FLD approach would allow the direct monitoring of vegetation photosynthetic function, physiological status and C sequestration potential, possibly on a global scale. This research will determine if solar-induced ChlF can provide results, regarding photosynthetic function, similar to those achieved using actively-induced ChlF methods at ground level. Both active and passive ChlF techniques are being tested in side-by-side measurements, conducting experiments using manipulated plants, and outdoors on forest and crop canopies.

Description of Research

Recent studies have demonstrated that superior results can be achieved with narrow band visible/near-infrared spectral reflectance analyses, as compared to results using traditional wide band (>20 nm) reflectance, for remote assessment of vegetation type and condition. To plan for future hyperspectral satellites, new studies are critical to define the optimal narrow band information required for monitoring ecosystem health from space. With this research high spectral resolution reflectance data obtained for vegetation over a range of functional types, species, phenology, and stress conditions is evaluated to establish which spectral algorithms perform rigorously with respect to correlation to photosynthetic function and efficiency. Reflectance data having contemporaneous photosynthetic data is being assembled from various field measurement projects conducted by the participants and through collaborations with other investigators. A second tier of evaluation is being performed on flux and environmental data provided by AmeriFlux collaborators, from tower sites representing a range of ecosystems. High performance of candidate spectral bio-indices, ascertained from an a priori list compiled from previous research, are being evaluated for remote sensing application at ecosystem scales at the AmeriFlux and intensive sites using several radiative transfer modeling tools and atmospheric correction modules. This project addresses NASA's program on plant functional types and physiology, and supports research to justify missions currently under development by NASA (Flora, from EO-1 Hyperion heritage) and the European Space Agency (FLEX, Fluorescence Explorer).

Improving our knowledge regarding 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. Current strategies for monitoring the status of vegetation from satellites rely on spectral reflectance, which provide estimates of vegetation vigor related to chlorophyll content. However, fluorescence from vegetation can relate inversely to photosynthetic efficiency and directly to chlorophyll concentration. Fluorescence offers a non-destructive, fast alternative to with diagnostic potential for early detection of changes in photosynthetic capacity, efficiency, rate, and to detect disturbances in the photosynthetic system. The goal is to evaluate existing and emerging fluorescence technologies for use in determining vegetation photosynthetic function and carbon/nitrogen cycling dynamics in plants exposed to environmental stresses linked to alterations in the global nitrogen cycle.

Accomplishments for FY 06-07

The contributions of fluorescence to reflectance on a range of C3 and C4 species under a full range of environmental stress regimes were assessed. The utility of spectral ratios computed from CF emission measurements and the reflectance ratios were compared for detecting vegetation at the leaf and canopy level. The research produced new algorithms and recommendations for cost-effective remote sensing techniques for assessing vegetation physiological condition, including: (a) processing and analysis of 2005 and 2006 reflectance (R) and fluorescence (F) data; (b) analyses of reflectance and fluorescence spectral data from both ad-axial and ab-axial foliar surfaces. Comparatively evaluated bio-physical measurements and the R and F trends in the datasets, including: corn under N treatments (0, 12, 25, 50, 75, 100, 125 and 150 % of optimal = 100% N level); soybean under elevated O_3 and CO_2, and maple under elevated UV radiation; and (c) collection of new 2006 spectral R, F and bio-physical data: DCMU experiment: To determine whether inhibition of photosynthesis can be detected through solar-exited fluorescence measurements, ChlF measurements were conducted on plants under a DCMU treatment. During the measurement efforts, extensive plant biophysical measurements (e.g., photosynthetic parameters, carbon allocation, pigment levels and biometrics) were collected for Soybean plants and Trees. The goals of this investigation is to determine if there are differences: 1) in the process of photosynthesis in plants from the same genotype due to the N treatments; 2) within N treatment due to the lower chlorophyll b content of the mutants; 3) determine the spectral responses associated with treatments and pigment levels.

Objectives for FY 07-08

The contribution of fluorescence to reflectance of crop and tree species will continue to be assessed, under stress factors such as DCMU, water stress and a full range of N treatment regimes. The utility of spectral ratios computed from CF emission measurements and the reflectance ratios will be compared for detecting vegetation stress at leaf and canopy level. The research will result in the development and validation of new algorithms and cost-effective remote sensing techniques for assessing vegetation physiological condition. Similarly, evaluation will be made of Solar induced Chlorophyll fluorescence to determine if it can provide scientifically meaningful results, as compared to steady state measurements. With this research the abilities of passive and active F measurement approaches for measuring vegetation photosynthetic rate and physiological conditions will be compared.

UMBC: **Remote Sensing of Volcanic and Anthropogenic SO2 Emissions**

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

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

NASA Grant: **Validation of OMI L2 Sulfur Dioxide Retrievals over Volcanic and Anthropogenic Sources (NNG06GJ02G)**

NSF Grant: **Virunga Volcanic SO_2 Emissions Research (VISOR) project (NSF EAR0510185)**

Investigators: Simon Carn, Assistant Research Scientist; Arlin Krueger, Research Professor, Physics; Nickolay Krotkov, GEST; Kai Yang, GEST; Keith Evans, Research Analyst; Gregg Bluth, Michigan Technological University; Fred Prata, NILU

Abstract

This research group leads the development and validation of sulfur dioxide (SO_2) algorithms for the Ozone Monitoring Instrument (OMI) on the Aura satellite. These data are being applied to detect volcanic eruption clouds in near real-time (NRT) for aviation hazard mitigation, and to quantify SO_2 emissions from volcanic and anthropogenic sources. In 2006-2007, a new OMI SO_2 algorithm was implemented, both for NRT operational use and production of the publicly released OMI total column SO_2 product on the NASA DAAC. The SO_2 group website was expanded to include OMI SO_2 maps for volcanic regions, updated daily. Validation of OMI SO_2 measurements using correlative satellite SO_2 retrievals, ground-based SO_2 data and in-situ aircraft measurements continued. A field campaign in eastern DR Congo involved collection of ground-based data on gas emissions from Nyiragongo volcano and sampling of a lava flow produced by a major eruption of Nymaulagira in November 2006.

Description of Research

The SO_2 emissions group in JCET is a leader in UV remote sensing of volcanic clouds, renowned for providing unique observations from the TOMS and OMI sensors to the scientific community. The goals of this research are to determine the effects of volcanic eruptions and passive volcanic emissions of SO_2 on the environment and climate and to ascertain the time-dependent properties of volcanic clouds containing SO_2, ash and sulfate aerosols. They also seek a fuller understanding of the solid earth processes that control the production and emission of SO_2 and ash in order to refine and develop methods of eruption prediction and airborne hazard mitigation using remotely sensed data. OMI measurements are being used to develop an accurate inventory of global SO_2 emissions, and will be exploited in operational environments such as volcanic eruption alarm and aviation hazard mitigation systems.

Accomplishments for FY 06-07

Development of the Linear Fit (LF) SO_2 algorithm, for retrieval of high SO_2 column amounts using OMI measurements, was completed [Yang et al., 2007]. This algorithm selects optimal wavelengths for SO_2 retrieval to avoid non-linear effects at high volcanic SO_2 loading that caused the provisional Band Residual Difference (BRD) algorithm to fail. The LF algorithm was implemented in the first public release of the Aura-OMI Level-2 Sulfur Dioxide Product (OMSO2), available from the NASA's GSFC Earth Sciences (GES) Data and Information Services Center (DISC). The SO_2 group website (http://so2.umbc.edu) was expanded to accommodate the new OMI SO_2 measurements. Scripts were developed to automatically generate SO_2 images for volcanically active regions using operational OMSO2 data. These images are being posted daily on the SO_2 group website to visualize volcanic degassing and eruption clouds. This approach serves as a testbed for a near real-time (NRT) system under development by collaborators at NOAA/NESDIS.

Long-range transport of SO_2 was observed by OMI following volcanic eruptions at Rabaul (Papua New Guinea), Piton de la Fournaise (Reunion) and Nyamulagira (DR Congo). OMI SO_2 measurements also played a key role in diagnosing the nature of activity at Fourpeaked volcano (Alaska), during its first historical eruption in September 2006, and permitted the dating of an unwitnessed submarine eruption of Home Reef (Tonga) in August 2006. Some highlights of OMI SO_2 observations since 2004 were showcased in an educational poster produced by NASA's Aura Outreach team.

Operational OMSO2 data were compared with in-situ aircraft SO_2 profiles measured in the lower troposphere over China during the East Aire campaign in April 2005. OMI tracked the SO_2 plume from China for 3 days over the Sea of Japan and the Pacific Ocean, with an estimated upper tropospheric SO_2 lifetime of ~2-4 days. This study identified the need for altitude and aerosol corrections to improve the accuracy of operational PBL SO_2 data from OMI. A provisional analysis of OMI measurements of SO_2 emissions from copper smelters in Peru was also completed [Carn et al., 2007]. These measurements have attracted the attention of the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) group that is working on the influence of anthropogenic and natural sulfate aerosol on the Southeast Pacific climate system. A collaboration with the VAMOS team is planned, focused on quantification of SO_2 emissions from sources on the west coast of South America.

Monitoring of gas emissions from Nyiragongo volcano (DR Congo), currently one of the strongest point sources of volatiles on Earth, continued using satellite and ground-based techniques. Measurements suggest that the composition of the volcanic plume has remained stable since monitoring began in 2005. A lava flow erupted from nearby Nyamulagira volcano (DR Congo) in November 2006 was also sampled for petrological analysis. This eruption produced the largest volcanic SO_2 loading measured from space during 2006.

Objectives for FY 07-08

OMSO2 algorithm development and evaluation will continue, focusing on spectral fit and iterative techniques that, unlike the LF and BRD methods, do not require ingest of operational ozone algorithm (OMTO3) data. The entire OMSO2 dataset will also be reprocessed for ECS collection 3. An AIRS SO_2 algorithm will be developed for implementation in the NOAA NRT SO_2 data delivery system, and the GOME-2 SO_2 data from the European MetOp platform will be evaluated. Validation of OMI SO_2 data will focus on analysis of aircraft data collected over Ecuador, Colombia and Mexico during the NASA Tropical Composition, Cloud and Climate Coupling (TC4) campaign in July-August 2007. The JCET researchers will also conduct ground-based SO_2 measurements at volcanoes and pollution sources using a new UV spectrometer system.

Task 31: **Carbon Cycle Research (NCC5-339)**

Task 77: **Data Blender Project**

Investigators: Forrest G. Hall, Senior Research Scientist; Fred Huemmrich, Research Assistant Professor, Geography and Environmental Systems; Derek Peddle University of Lethbridge; Qingyuan Zhang, GEST

Abstract

This research covers the Goddard carbon cycle team, the International Satellite Land Surface Climatology Project (ISLSCP), the MODIS BIOPHYS Project, MODIS Light Use Efficiency, and the Landsat Reanalysis Project

Description of Research

Hall continues to lead the GSFC Carbon Cycle Team. The group is composed of land, ocean and atmosphere discipline scientists, and discusses and develops strategic approaches to satellite mission formulation, proposal writing and execution. It also assists NASA HQ, providing technical and scientific planning information. The focus this year has been support of the Decadal Survey National Academy Panel to develop recommendations for Earth Science Missions for the next decade.

The successful submission of a major new effort to process the last 30 years of the GeoCover Landsat data set to surface reflectance was submitted and funded. The 30+ Landsat data record is an important one, for carbon cycling studies (e.g., disturbance history and statistics) but variability in Landsat calibration over the years and the lack of atmospheric correction algorithm rendered its use over large regions and over time very labor intensive, hence impractical.

Accomplishments for FY 06-07

Hall worked with NASA GSFC and HQ personnel to establish a planning response to the recommendations of the National Academy of Sciences Decadal Survey Report. The Carbon Cycle Team is actively involved in the planning for mission plans that anticipate the Decadal Survey Report schedules. Hall participated in a mission studies for monitoring vegetation structure and biomass using a combination of P-band Radar and lidar (BIOME). Subsequent to the selection of ICESat2 and the InSAR DESDynI mission by the Decadal Survey Panel, Hall has been participating in the development of those mission concepts.

The ISLSCP Initiative II data collection was completed and can be accessed at http://islscp2.sesda.com. The collection contains 52 global time series spanning the ten-year period 1986 to 1995 to support investigations of the global carbon water and energy cycle. The data were acquired from groups within a number of U.S. and international agencies, universities and institutions. The data were quality checked, some reprocessed to correct problems, then co-registered to equal-angle grids of one degree, 1/2 and 1/4 degree, a common land-water mask applied, gaps filled and reformatted into a common ASCII format. Each data set has been uniformly documented. Hall led the development of an ISLSCP Special Section in the *Journal of Geophysical Research Atmospheres* containing 14 research papers that have utilized the data collection. The JGR special issue was published in November 2006. Hall is lead author on two papers in that special issue. A follow-on project called LANDFLUX will focus on the production of land data series to support climate data records for surface-atmosphere fluxes of carbon, heat and water.

The JCET research team has continuing the development of the BIOPHYS algorithm to process Landsat data, primarily for the purpose of validating BIOPHYS. The effort was aimed at developing physically-based approaches to the retrieval of biophysical parameter data using multi-spectral, angle & date MODIS data. A number of Landsat frames have been processed for validation, with more to be done in the future, as well as extending the algorithm to process MODIS multi-angle data. Publications documenting this work are in preparation.

Research into MODIS Light Use Efficiency is progressing nicely and has resulted in a collaboration with Hank Margolis, PI of the major Canadian effort to study terrestrial ecosystems—a project similar in structure to BOREAS and in some sense, a BOREAS follow-on. The team have published a paper in *Remote Sensing of Environment* showing that MODIS 531 nm band is sensitivity to variations in the photosynthetic uptake of carbon dioxide, thus demonstrating that MODIS can be used to measure plant light use efficiency, a major missing variable in satellite monitoring of the carbon water and energy cycle. Demonstrating this capability from space is an important break through, scaling results obtained previously only at the leaf and canopy level from aircraft.

It is now possible to automatically process Landsat 5 and 7 GeoGover Landsat images to surface reflectance for the decade of the 80s, 90s and 00's for North America in just a few hours. A web site to provide the data for download by anyone at no cost has been established. The technology is being transferred to USGS for operational products. The team is beginning to apply Landsat Biophys to the reprocessed data sets to produce disturbance images.

Objectives for FY 07-08

The Carbon Group will continue to develop the ICESat2 and DESDynI mission studies for NASA HQ, as well as coordinating responses to various announcements of opportunity. The team plans to complete the first version of BIOPHYS, test it using data from MODIS, develop an evaluation plan, produce a provisional biophysical parameter data set to be released to modelers, and place these provisional data sets online. Also, the team plans to develop techniques to produce disturbance maps using physically-based MODIS approach modified for Landsat.

The focus to date on gapfilling ETM+ has involved the use of multiple ETM+ scenes (gap locations are random from one acquisition date to the next), MODIS images to track phenologically induced spectral changes over time and ratioing of MODIS and similar ETM+bands for acquisitions where ETM+ data exists. The ratios are then applied to MODIS data acquired simultaneously with the missing data gaps to estimate ETM+ values. Other methods being explored consist of neural nets to model gap radiances from ETM+ and MODIS acquisitions. A paper has been published in IEEE [Gao et al. 2005] detailing the algorithm and a proposal written to the TERRA/AQUA/ACRIM Announcement of Opportunity to continue this work in tracking ecological changes in globally important ecosystems.

Task: **Planetary Atmospheres, Ionospheres and Magnetospheres**

Investigators: Richard E. Hartle, JCET Fellow and Associate Director

Abstract

Titan and Venus, bodies without internal intrinsic fields, are studied in this task. The Cassini orbiter mission and the numerous flybys of Saturn's moons are the central focus of this reporting period. In particular, Cassini Plasma Spectrometer (CAPS) studies involved analysis and interpretation of plasma measurements made during Titan flybys. Water group ions from Enceladus and in Saturn's rotating magnetosphere were observed to penetrate Titan's upper atmosphere (see figure at the start of this focus group section).

Description of Research

A general objective is to further understanding of the evolution of planetary atmospheres as part of NASA's goal to understand the origin and evolution of the solar system. In this regard, analytical and numerical modeling and data analysis are carried out to describe escape processes to determine escape rates of the neutral and ionized components of planetary atmospheres. External sources of atmospheric gases are also included, especially in those instances where there is a net gain as the case of oxygen supplied to Titan. These studies contribute to estimates of such things as the amount of water Venus and Mars may have lost over their history. Currently, a more focused objective is to analyze and interpret measurements being made by the Cassini Plasma Spectrometer (CAPS) on the Cassini orbiter mission.

Accomplishments for FY 06-07

The evolution of atomic and molecular constituents in planetary atmospheres is dependent on their escape and accretion rates. Atmosphere escape rates are generally enhanced on those bodies lacking intrinsic magnetic fields, in which case the solar wind or flowing plasma interacts directly with their atmospheres and ionospheres. Venus and Titan are two bodies without intrinsic fields that have been studied during this reporting period, with most attention paid to Titan.

An invited paper on "Pickup Ion Phase Space Distributions at Titan: Effects of Atmospheric Spatial Gradients" by R. E. Hartle and E. C. Sittler, Jr. was given at the IUGG/IAGA meeting in Perugia, Italy. A principle stimulating this work is that the composition and structure of neutral exospheres imbedded in moving plasmas can be determined by measurements of the velocity distributions of their pickup ion progeny. Hartle and Killen [2006] and Hartle et al. [2006a] had discussed this earlier for the lunar and Titan exospheres, respectively. The concept was then explicitly described in a detailed closed-form expression showing how the pickup ion velocity distributions are dependent on the spatial structure of the neutral source gases [Hartle and Sittler 2007]. Since Titan's neutral exosphere extends into the Saturn's magnetosphere (or solar wind) and well above its ionopause, it serves as a good place to analyze such characteristics. They were analyzed using pickup ion measurements made by the Cassini Plasma Spectrometer (CAPS) at Titan [e.g., Hartle et al. 2006b] and an ion kinetic model. The model [Hartle and Sittler 2007] is an expression describing the phase space density of pickup ions, which is derived from the Vlasov equation with an ion source that explicitly accounts for the velocity and spatial variation of the exosphere source gases. A fundamental parameter in the phase space density expression is the ratio of the gyroradius to the neutral scale height, $\alpha = r_g/H$. Titan's exosphere includes H, H_2, CH_4 and N_2, with scale heights near the exobase of ~ 2400, 1200, 149 and 85 km, and α's of ~ 0.1, 0.4, 27, and 82, respectively. This structured exosphere yields pickup ions whose phase space distributions are beam-like when $\alpha >> 1$ and fluid-like when $\alpha << 1$. Downstream from the source peak, the light pickup ions, with $\alpha << 1$, are easily observed because the phase space density is almost uniform over the orbit phases. On the other hand, the phase space distribution of the heavier ions, with $\alpha >> 1$, peaks over a narrow velocity and spatial range. This beam-like nature makes it more difficult to observe the heavy ions because the downstream positions and viewing directions are narrowly constrained.

The flux of energetic ions entering Titan's upper atmosphere from Saturn's rotating magnetosphere is a source of oxygen for the oxygen poor atmosphere A recent analysis of ion measurements made by CAPS during the TA flyby showed that magnetosphere O^+ was absorbed by the atmosphere [Hartle et al. 2006a,b]. The viewing directions of the spectrometer anodes during the T5 flyby were ideal for studying the precipitation of such heavy ions in Titan's thermosphere. An analysis of the CAPS ion data resulted in the identification of 5-10 keV water group ions (O^+, OH^+ and H_2O) penetrating more than 300 km below the exobase [Hartle et al. 2006c] as identified by the vertical white lines in the color figure. It was suggested that the water plumes of Enceladus were the likely source of these precipitating ions.

Two separate but complimentary studies were made by Coates et al. [2007] and Szego et al. [2007] to describe the plasma structure of the magnetic tail of Titan. The CAPS electron data showed an unusual split tail signature with two principal intervals of interest outside the nominal wake produced by Saturn's rotating magnetosphere. Interval 1 shows direct evidence for ionospheric plasma escape at several Titan radii down the moon's tail. Interval 2 shows a complex plasma structure, a mix between plasma of ionospheric and magnetospheric origin. Interval 1 is thought to be on magnetic field lines that thread through the dayside ionosphere while those threading through the nightside connect with interval 2. A mechanism for plasma escape down the tail was suggested, which is based on ambipolar electric fields set up by the hot ionospheric photoelectrons.

Using the first three years of plasma and field measurements made from the Pioneer Venus Orbiter (PVO), a study of Venus ionospheric flow was made to determine where ion dynamics uncoupled from the neutral atmosphere. In the region of strong-ion neutral coupling, neutral composition measurements showed evidence of ion neutral drag [Grebowsky et al. 2007].

Objectives for FY 07-08

Atmosphere escape processes will continue to be studied with particular attention to studies of Saturn's magnetosphere interaction with Titan's atmosphere. This will be accomplished by analysis and interpretation of measurements made by the CAPS instrument on the Cassini orbiter and other Cassini instruments. The techniques developed to study Titan will be applied to observations made at some of the other moons of Saturn. In keeping with the new Moon/Mars initiative, a proposal (with Hartle as Co-I) is planned for the development of a pickup ion mass spectrometer that can be used to obtain the composition and structure of the lunar exosphere and map the composition of the surface.

Task 86: **Physically-Based Continuous Fields and Land Cover Mapping Algorithm Using MODIS and Multisource Data**

Investigators: Forrest Hall, Senior Research Scientist; D. Peddle, University of Leithbridge; K. F. Huemmrich, Research Assistant Professor, Geography and Environmental Systems

Task 95: **Direct Satellite Inference of Ecosystem Light Use Efficiency for Carbon Exchange using MODIS on Terra and Aqua and Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency**

Investigators: E. Middleton, NASA GSFC, Code 614.1; K. F. Huemmrich, Research Assistant Professor, Geography and Environmental Systems; Forrest Hall, Senior Research Scientist; R. Knox, NASA GSFC, Code 614.4; H. Margolis, Univ. Laval

Task 72: **Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency**

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

Task 96: **North American Forest Disturbance and Regrowth Since 1972**

Investigators: J. Masek, NASA GSFC, Code 614.1; K. F. Huemmrich, Research Assistant Professor, Geography and Environmental Systems

Abstract

The investigation of the use of optical remote sensing to determine structural characteristics and processes in terrestrial ecosystems is the goal of this collection of research tasks. Work concentrated on the development of models of ecosystem carbon exchange using spectral reflectance as inputs, focusing on the detection of transient changes in vegetation spectral reflectance as an indicator of plant stress. Further, canopy reflectance models were used to determine vegetation structural characteristics from satellite reflectance data and use time-series of vegetation structure to study changes in landscapes.

Description of Research

This research aims to develope 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 through the use of models. Canopy reflectance models take vegetation structural information (e.g., leaf area index and tree crown shape) and optical properties (e.g., leaf spectral reflectance and transmittance) and calculate the observed reflectance for a given viewing direction and solar illumination conditions. These types of models generally cannot be mathematically inverted to directly determine vegetation characteristics from reflectance data. To determine landscape characteristics in the Physically-Based Continuous Fields study, canopy reflectance models are run in the forward mode multiple times varying the inputs over the range of possible values. The reflectance values output by the model along with all of the input values are stored in a database or look up tables (LUT). Given observed reflectance values, the database or LUT is searched to find modeled reflectances that match. These retrieved values provide estimates of the observed vegetation characteristics along with a measure of uncertainty. Presently, this multiple forward mode approach is being used with multiple spectral bands and multiple viewing angles to evaluate the best approaches to use. The canopy reflectance models were also used to study how different types of disturbance and regrowth scenarios would affect landscape reflectance.

Hyperspectral and narrow-band multispectral data can detect changes in apparent leaf spectral reflectance associated with plant stress. Combining canopy level reflectance data with measurements of ecosystem carbon flux from flux towers at a similar spatial scale provides the opportunity to see if these stress effects can be observed at an ecosystem level. Studies using ground-, aircraft-, and satellite observations for a number of different ecosystem types are being performed. The satellite approach uses narrow MODIS spectral bands intended for ocean studies over land, which required the development of a new processing stream for these data, as the ocean bands have not been processed over land. The researchers found that the detection of a signal indicating vegetation stress is hampered by different viewing geometries of each observation from the satellite that result in the instrument observing different amounts of shadow and illuminated canopy.

Accomplishments for FY 06-07

Huemmrich collected hyperspectral reflectance data at multiple times diurnally in a corn field, comparing these observations with carbon fluxes measured in the same field to determine if short-term changed in apparent spectral reflectance can be associated with photosynthetic down-regulation and the reduction of carbon uptake by the corn. For the study of vegetation structures, he merged the SAIL and GOMS canopy reflectance models to produce a model that describes radiative transfer through tree crowns as well as produces shadows from the crowns. This new model is being used to estimate leaf area index, branch area index, fraction of canopy cover, and crown shape from MODIS data combining observations collected on nearby days with different viewing geometry. He also used the GeoSail canopy reflectance model on Landsat data to estimate vegetation structural changes over a 25-year time series.

The JCET investigator is a member of the Science Advisory Group for the Barrow Arctic Science Consortium in Barrow, AK. He proposed and chaired a session at the AGU Fall Meeting in December on remote sensing of terrestrial carbon fluxes. In addition, Huemmrich developed and taught an upper level undergraduate class in Arctic Geography.

Objectives for FY 07-08

Huemmrich plans to continue the work on remote sensing of plant stress, including developing techniques for adjusting MODIS data to minimize the effects of view geometry on the detection of vegetation stress, and applying these results to multiple ecosystems. He will create models of vegetation canopy radiative transfer dynamically linked to leaf level photosynthesis and stress response, providing a physical link between the leaf- and canopy-level observations. The researcher will expand the use of multiple forward mode modeling of canopies to ecosystems beyond boreal forests for the retrieval of ecosystem biophysical characteristics. These new techniques will be used for the detection of vegetation disturbance over all of North America. Finally, he will continue to work on the development of research activities on monitoring high latitude ecosystem change, as well as begin working on the use of remote sensing for biodiversity, linking biodiversity with ecosystem processes.

Task 84: Numerical Modeling Historical Martian Dynamo

Investigators: Weiyuan Jiang, Research Assistant Professor, Mechanical Engineering; Weijia Kuang, JCET Fellow, NASA GSFC, Code 698

Abstract

One of the most important findings of the Mars Global Surveyor (MGS) mission was strong crustal magnetization in the highland crust of the Martian southern hemisphere (e.g., Acuña et al. 1998, 2001). On the other hand, little crustal magnetization was found in other areas of Mars, in particular the Hellas and Argyre impact basins. These observational evidences suggest that Mars once had an active dynamo in its early evolution stages.

While geophysical exploration of Mars interior structures (e.g., seismic/geodetic information on the core) can help differentiate these scenarios, critical information should also include (1) the amount of gravitational energy that could be released in the core in the secular cooling of the Mars and (2) the minimum gravitational energy for an active core dynamo. Currently the latter can best (perhaps only) be obtained via extensive numerical modeling efforts using self-consistent numerical dynamo models to systematically investigate the convection and the generation of the magnetic field in the Mars core. In particular, numerical models help specify the energy budget necessary to produce a dynamo with various scenarios of the Martian core (e.g., the Martian core with various possible parameters). This research uses the Modular Scalable and Self Consistent (MoSST) core dynamics model to demonstrate the process of annihilation of the Mars dynamo and explore the properties of the magnetic field and the convective flow in the core.

Description of Research

The dynamical properties of Martian dynamo were studied, focusing on magnetic field strength, spatial and temporal variation of the field respect to specified buoyancy force (that drives core convection), core geometry (e.g., with or without a finite solid inner core), and other non-dimensional parameters (e.g., Ekman Prandtl numbers that describe core fluid properties). Based on this, the conditions in which the dynamo operates were examined. In particular, research focused on the minimum Rayleigh numbers (the non-dimensional parameter in the numerical model describing the buoyancy force strength) necessary for the existence of the dynamo with the core geometries and the parameter domain.

Following this, the dynamo existence conditions for various parameter domains were studied, determining possible scaling rules that enable scaling the numerical dynamo solutions to the parameter domain of the Martian core, aiming directly at the fundamental question of why the Martian dynamo ceased to exist.

Accomplishments for FY 06-07

The first accomplishment is the discovery of subcritical dynamos in a Mars-like core (within computationally achievable parameters). This subcritical dynamo state discovered from our numerical simulation suggests that Mars dynamo could terminate very rapidly, in a time period less than 1% of its entire history (e.g., assuming Mars dynamo exists in the first 500 million years of the Mars, it could stop in less than 5 million year period), and with a much less than 1% perturbation to its thermodynamic state in the core.

The second is the discovery of frequent magnetic polarity reversals. The magnetic fields of the dynamo solutions for low Rayleigh numbers (in particular those near the subcritical point) are very different from those for large Rayleigh numbers: the field polarity reverses frequently for subcritical dynamo solutions.

The third discovery is the concentration of magnetic flux in the southern hemisphere. This numerical result suggests that the internal dynamo process may also contribute to the observed northern-southern hemisphere biased Mars crustal magnetization, such as the strongest magnetization in the Noachian-aged southern highland (Whaler and Purucker 2005).

Objectives for FY 07-08

The JCET investigators intend to use numerical simulation to understand whether the subcritical dynamo state could exist for a variety of core properties. In particular, they intend to identify whether such subcritical dynamo is achievable for a negligibly small inner core.

An investigation is planned into how the dynamo state evolves from one that generates and maintains a stable, nearly axial-dipole magnetic field (at the Mars surface) to one with a low-latitude dipolar, frequently reversing magnetic field. In particular, examining the energy budget required for such transition is a focus of research.

Based on the results of the activities above, they intend to investigate potential measurable magnetic properties from numerical models that can be used to interpret current and future Mars observations, thus furthering our understandings of the dynamical processes in the Mars interior and its evolution history from combined model simulation and observation analysis.

NASA Grant: Dynamics of eastern Mediterranean, Sea Level and altimetry Calibration-validation (DynMSLaC) (NNG05GO31G)

NURI Grant: Current and Future Satellite Mission Data Analysis for Global Gravity Field Modeling and Reference Frame Implementation (NMA201-01-2008)

NASA Grant: Understanding Sea Level Variations: Reference Frame, Data Analysis, and Modeling (NRA-03-OES-03 funding Tasks 85 & 90)

NASA Grant: Current and Future Satellite Mission Data Analysis for Global Gravity Field Modeling and Reference Frame Implementation (SENH-0126-0180)

Task 33: Space Geodesy Applications to Earth Sciences

Task 68: Altimeter Calibration and Mean Sea-level Monitoring: Project GAVDOS

Task 105: Design and Optimization of NASA's Future Space Geodetic Networks in Support of GGOS

Investigators: Erricos C. Pavlis, Research Associate Professor, Physics; Magdalena Kuzmicz-Cieslak, Research Associate; Glynn Hulley, Research Assistant, UMBC, Physics; Keith Evans, Research Analyst, Peter Hinkey, undergraduate student assistant, UMBC

Abstract

Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), Global Positioning System (GPS), altimetry, and in situ data are used for the definition and evolution of the origin, scale and orientation of the reference frame, observation of the static and temporally varying gravitational field, tests of fundamental physics theories, and to plan future dedicated missions and the optimal networks to track them. Global change studies rely on the precise definition and evolution of the reference frame. The change itself can be observed in minute changes in the gravitational field determined from dedicated space missions (CHAMP, GRACE, GOCE). Combination of altimetry, tide gauge data and in situ measurements are used to calibrate current and future oceanographic missions' data used in studies of global sea level changes.

Description of Research

The JCET research team is a leader in the analysis of SLR and GPS data sets for the development and maintenance of global terrestrial reference frames. Pavlis chairs the Int. Laser Ranging Service's (ILRS) Analysis Working Group, the Refraction Study Group, and, along with Hulley, worked on improved atmospheric delay corrections in SLR [Hulley and Pavlis 2007]. The two co-authored a chapter in the IERS' Conventions 2003 living document (http://tai.bipm.org/iers/conv2003/ conv2003.html), describing the state-of-the-art and newly adopted procedures for atmospheric corrections in laser ranging. The team maintains a time series of long-wavelength temporal variations of the terrestrial gravity field and improves the longer wavelength portion of current models for the static part. JCET's research team is a leading member of an international effort to define the optimal design of NASA's future space geodetic tracking networks. The team established and operates an international facility for sea level monitoring, altimeter calibration and environmental observation for weather forecasting.

Accomplishments for FY 06-07

The NIMA NURI grant is in its last year, and the work accomplished this year includes the validation of the first NGA-contributed SINEX files for the ITRF process. A project to reinstate routine absolute gravity surveys of key observatories at reasonable time intervals was begun. As a first step, a database was generated with the sites that have been surveyed so far, along with diagrams, pictures, and gravity values and error estimates. An additional database was also created with the temporal variations (secular, annual, semi-annual and seasonal) for all harmonics up to degree and order (60,60) from the latest release (R04).

The reanalysis of the entire 1976-2007 SLR data set was submitted to ILRS. The new Int. Terrestrial Reference Frame solution was evaluated and validated with reports to ILRS and IERS, outlining the objections of ILRS on the adoption of this solution. These were highlighted in invited presentations [Pavlis 2006; Pavlis and Ries 2006]. JCET researchers participated in the 2007 Science Working Team meeting of the OSTM-JASON project [Pavlis et al. 2007]. GAVDOS research activities continue under the OSTM program, and at a second facility, KASTELI, on the north coast of mainland Crete, now under construction.

A collaboration with a large international group of scientists on improved measurement of the relativistic “frame-dragging” effect has begun, as well as on a proposal for dedicated geodetic-quality SLR target satellites. The data analysis is now repeated by an independent group at Geoforschungs Zentrum Potsdam in Germany, with their own software package (EPOS). New results are forthcoming based on more recent gravity models from GRACE.

Work on the Mean Sea Level (MSL) project focused on accuracy assessment of the knowledge of the geocenter and quantified the implications in terms of MSL variability. First results were presented in several presentations during the 2007 European Geosciences Union general assembly. Work now focuses on the development of simulation techniques for further validation and study of the error budget associated with MSL determination and its long- and short-term variations. A whole year of SLR and VLBI data has been successfully simulated for four different size networks and combinations.

Objectives for FY 07-08

Expanding the analysis of GRACE data is planned. The temporal variations will be tested in the reanalysis of SLR data for an iteration of ITRF2005 and the generation of a SLR-only reference frame. As an ILRS Analysis Center, the JCET research team will continue to provide automated weekly data analysis and annual contributions. Operations are being extended to include more SLR targets as well as the completion of re-processing (backwards) historical data, extending the record to the early years of SLR tracking (ca. mid-1970s). The precise orbits determined during these analyses will be made public through the ILRS and the team web site.

Installation of meteorological and communications/data relay equipment for project GAVDOS in collaboration with our European partners will be completed, and the team will continue the routine operation of the JCET facilities on Gavdos and Crete. Both sites will be instrumented so that they will be eligible for participation in the Int. GNSS Service (IGS) and METEOSAT transmission packages as well as wireless connections. All activities and products are documented and disseminated via a web site that is continuously expanded and upgraded according to the needs of the various projects it supports.

NSF Grant: **CMG: Geomagnetic Data Assimilation**

NASA Grant: **Assimilation of MOPITT Carbon Monoxide Observations**

Task 49: **Carbon Cycle Data Assimilation**

Investigators: Andrew Tangborn, Research Associate Professor, Mathematics and Statistics; Zhibin Sun, Research Associate; Weijia Kuang, JCET Fellow, NASA GSFC, Code 698; Jeremy Bloxham, Harvard University; Steven Pawson, NASA GSFC; Ivanka Stajner, SAIC; Daniel Jacob, Harvard University

Abstract

Research is carried out in the general area of geophysical data assimilation. Specific projects are in solid earth and atmospheric data assimilation. Solid earth research is concerned with assimilating geomagnetic observations at the Earth's surface into a geodynamo model, with the purpose of improving estimates of the unobserved state variables inside the core and improving forecasts of future changes to the surface magnetic field.

Atmospheric research has been focused primarily on carbon cycle data assimilation. This work has involved assimilating satellite measurements of carbon monoxide from the SCIAMACHY and MOPITT instruments. Chemical constituent data assimilation serves the dual purposes of determining the amount of useful information in satellite retrievals, and to produce the best possible estimate of the spatial distribution of a particular chemical species. Assimilation also encompasses parameter estimation, which allows for improved estimation of carbon fluxes.

Description of Research

The geomagnetic data assimilation research group, funded by both NSF and NASA, is a collaborative project involving scientists and graduate students from UMBC, Goddard Space Flight Center and Harvard University. The JCET investigators have been employing techniques traditionally used in Numerical Weather Prediction (NWP) with the goals of predicting future changes to the Earth's magnetic field, and gaining better estimates of the fluid motion inside the Earth's core. One of the major obstacles to geomagnetic data assimilation is the fact that observations can only be for part of the magnetic field, and only at the Earth's surface. This means that the vast majority of the state of the system unobserved, and that obtaining estimates of forecast errors for these states cannot be obtained directly. The researchers are developing ensemble methods to estimate forecast error covariance in order to overcome this difficulty. It is also difficult to determine whether assimilation of the magnetic field observation has improved the core state estimate. To this end, Observing System Simulation Experiments (OSSE's) are developed using synthetic observations from a single model run.

Carbon cycle data assimilation, funded by two grants from NASA, is concerned with developing the means to assimilate measurements of carbon species into the constituent assimilation system in the Global Modeling and Assimilation Office at GSFC. The purpose of this work is to improve estimates of global distributions of carbon species in the atmosphere, and to improve estimates of production at the Earth's surface. Current work is focused on assimilating measurements of carbon monoxide from the SCIAMACHY and MOPITT instruments.

Accomplishments for FY 06-07

During the past year, two geomagnetic data assimilation algorithms have been developed and tested. These use different approaches to estimating forecast errors needed for the assimilation algorithm. In particular, a multivariate forecast error covariance was developed in which the correlation between the errors in the observed component of the magnetic field and those in the unobserved component are estimated using an ensemble method. This approach has shown to improve the estimation of the unobserved component [Sun et al. 2007]. In addition, JCET investigators have completed the development of the framework for Observing System Simulation Experiments (OSSE's), which enable them to determine how the estimates of unobserved variables are improved by the assimilation [Liu et al. 2007].

Assimilation of SCIAMACHY total column CO retrievals has also been completed during the past year. The researchers have been able to show that these near infrared measurements can be used to substantially improve the estimate of CO concentrations throughout the troposphere and even into the boundary layer.

Objectives for FY 07-08

Geomagnetic data assimilation will continue with further development of OSSE's to test new assimilation algorithms. Further testing of ensemble methods, and the gradual implementation of more sophisticated and computationally expensive algorithms are planned, including an Ensemble Kalman filter and a 4-dimensional variational method.

Plans for the carbon cycle assimilation include the combined assimilation of MOPITT and Scanning Imaging Absorption SpectroMeter for Atmospheric Chartography (SCIAMACHY) CO observations. Development of carbon cycle assimilation within the GEOS-5 assimilation system in the Global Modeling and Assimilation Office is also planned.

NASA Grant: NNG05GC-79-A

Task 88: Geomagnetic Data Assimilation (NSF); Core Dynamics and The Application to Surface Geodynamics Observables (NASA)

Investigators: Zigang Wei, Visiting Assistant Research Scientist; Weijia Kuang, JCET Fellow, NASA GSFC, Code 698

Abstract

The geomagnetic field that originates from the Earth's interior has been long known to vary with time. A series of historical observations can be assimilated into a geodynamo model in order to help forecast the future changes of the geomagnetic field. The JCET investigators have carried out this data analysis focused on 7000 years of geomagnetic data assimilation.

Description of Research

Three sources of geomagnetic observation models are employed in this work: paleo- or archeo- models, historical models and modern models, with a combined duration of 7000 years. The models have different temporal and spatial resolution, and they cover different times but with overlapping spans. However, the models don't match well in the overlap regions, and therefore cannot be used together to carry out data assimilation. To make the models usable, the investigators have adopted a variable weight function to assign the contributions of the models before performing analysis. After this treatment, a single joint observation model is generated with a continuous first derivative that covers the entire 7000 years. Based on this time series of observations, the data assimilation model will predict the geomagnetic status for the next 20 years or more.

Accomplishments for FY 06-07

The researchers combined the comprehensive (geomagnetic) models, GUFM1 historical geomagnetic models and CALS7k paleo-magnetic models. By requiring the combination to be continuous, along with other desired characteristics of the models, a module was built to join them together, allowing them to be fed into the assimilation system. The data assimilation runs were carried out using 20, 40, 100, 400, 5000 and 7000 years of observations, respectively. The JCET investigators compared the differences and correlations between forecasts and observation, as well as forecast and free model runs. A suite of Matlab codes was built to perform this analysis.

Objectives for FY 07-08

Dr. Wei will be involved in AIRS CO retrieval processing and analysis with Dr. Juying Warner. At the same time, he and Dr Kuang will continue to analyze, plot and explain the assimilation results in the geodynamo research group at JCET.

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III. Supporting Information

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Xiong X, K. Chinag, J. Sun, W. Barnes, B. Guenther, and V. Salomonson (2007), NASA EOS Terra and Aqua MODIS On-orbit Performance, *J. of Advances in Space Research*, submitted.

Xiong X, R. Wolfe, W. Barnes, B. Guenther, E. Vermote, N. Saleous, and V. Salomonson (2007), Terra and Aqua MODIS Sensor Design, Radiometry and Geometry for Land Remote Sensing, in *Land Remote Sensing and Global Environmental Changes: NASA's Earth Observing System and the Sciences of ASTER and MODIS*, Spinger-Verlag, submitted.

Yurganov, L. N., W. W. McMillan, A. V. Dzhola, E. I. Grechko , N. B. Jones, and G. R. van der Werf (2007), Global AIRS and MOPITT CO Measurements: Validation, Comparison, and Links to Biomass Burning Variations and Carbon Cycle, *JGR*, MS #2007JD009229, submitted.

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

Barnes W., X. Xiong, X. Xie, A. Wu, K. Chiang, J. Sun, V. Salomonson, and B. Guenther (2006), Four Years of Aqua MODIS On-orbit Radiometric Calibration, Proceedings Sensors, Systems, and Next Generation of Satellites X, SPIE 6361, pp.63610R, Stockholm, Sweden, 11-13 September.

Bell, T. L., D. B. Wolff, A. Hou, and P. K. Kundu (2007), Validating and Comparing Remote-Sensing Observations of Precipitation using Scatterplots: Statistical Issues, Poster presentation at the PMM Science Team Meeting, Atlanta, GA, 7-10 May.

Beller, D., A. Griswold, M. H. Bulmer, and P. J. McGovern (2007), An examination of slope streak emplacement using new HiRise Data, NASA Intern Poster Session, Goddard Space Flight Center, Greenbelt, MD, July.

Beller, D., A. Griswold, M. H. Bulmer, and P. J. McGovern (2007), Examination of Martian slope streak emplacement, Oral presentation #1, Tenth Annual Summer Undergraduate Research Fest, College of Natural and Mathematical Science, University of Maryland, Baltimore County, Baltimore, MD, 8 August.

Bulmer, M. H. (2006), Creating Hazard Maps to cover the area affected by the 8th October, 2005 earthquake, Kashmir: Recommendations to the Rural Housing Project, World Bank, June 2006, Landslide Observatory/ Landslide Mitigation Group Open File Report 06-06.4, p2.

Bulmer, M. H. (2007), Annual progress report on NSF Grant entitled An investigation of progressive failure in landslides in the area affected by the 8th October 2005 Earthquake in Pakistan, p4.

Bulmer, M. H. (2007), Examination of Olympus Mons Aureole deposits, Annual report to Lunar and Planetary Institute, USRA Subcontract to UMBC of NASA MDAP Grant NNG05GQ71G, Studies of volcanic growth, spreading and collapse on Mars, pp 4.

Bulmer, M. H. (2007), Olympus Mons Aureoles, NASA Summer Institute on Atmospheric, Biospheric, and Hydrospheric Sciences, Goddard Space Flight Center, 13 June.

Bulmer, M. H., and M. Roshan (2006), Brief report to MercyCorps: Rubble dump site in Muzaffarabad, Kashmir, June 2006, Landslide Observatory/ Landslide Mitigation Group Open File Report 06-06.1b, p4.

Bulmer, M. H., and M. Roshan (2006), Brief report to UNHCR: School site in Botha, Kashmir, June 2006. Landslide Observatory/ Landslide Mitigation Group Open File Report 06-06.3, p4.

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Bulmer, M. H., B. A. Campbell, and T. Gregg (2006), Topographic and compositional studies of andesite lava flows at Sabancaya volcano, Southern Peru, NSF- INT-0105865 Final Report p.8.

Bulmer, M. H., B. Zimmerman, D. Finnegan, and L. Glaze (2006), An examination of the rheology of debris aprons, 4th International Conference on Debris-Flow Hazards and Mitigation: Mechanics, Prediction, and Assessment, China.

Bulmer, M. H., B. Zimmerman, D. Finnegan, and L. Glaze (2006), An examination of the rheology of Martian debris aprons, *Lunar and Planet Sci.*, 37th. 2275.

Bulmer, M. H., D. Finnegan, and S. W. Anderson (2007), Defining the Optimal Topographic Resolution for Process-driven Studies, 38th Lunar and Planetary Science Conference, Abstract #1116.

Bulmer, M. H., D. Finnegan, J. Smith, J. Morgan, and P. McGovern (2007), Topographic Constraints and Resolution Necessary to Understand the Emplacement of the Olypmus Mons Aureoles, 38th Lunar and Planetary Science Conference, Abstract #1793.

Bulmer, M. H., D. N. Petley, and A. Kausar (2006), An Examination of Landslide Hazards Posed by the 8th October 2005 Earthquake in Pakistan, Invited presentation at USAID, Washington, DC, 11 March.

Bulmer, M. H., D. N. Petley, and A. Kausar (2006), An Examination of Landslide Hazards Posed by the 8th October 2005 Earthquake in Pakistan, Invited presentation at InterAction, Washington, DC, 11 March.

Bulmer, M. H., D. N. Petley, M. Bond, and R. Bissell (2006), Determining the nature of injuries sustained in landslide disasters. 4th International Conference on Debris-Flow Hazards and Mitigation: Mechanics, Prediction, and Assessment, China.

Bulmer, M. H., D. N. Petley, M. Bond, and R. Bissell (2006), Determining the nature of injuries sustained in landslide disasters, International Conference on 8th October 2005 Earthquake in Pakistan Its Implication and Hazard Mitigation, Islamabad, Pakistan, 18-19 January.

Bulmer, M. H., M. C. Bond, R. Bissel, and D. Alves (2006), Determining the nature of injuries sustained in landslide disasters: Natural and Anthropogenic Disasters: Earth and Health Scientists Working Together to Identify Potential Health Issues and Improve Outcomes (GSA Geology and Health Division), invited presentation to 2006 Philadelphia Annual Meeting, Paper No. 4-8, 22-25 October.

Bulmer, M. H., M. Roshan, S. S. Akhtar, and S. K. Wahla (2006), Field report: Landslide investigation in the Neelum and Jhelum Valleys, Kashmir. Landslide Observatory/ Landslide Mitigation Group Open File Report 06-06.2, p 18.

Bulmer, M. H., T. Farquhar, and M. Roshan (2007), Report to Baltimore County Department of Public Works. Tracking surface motion. Ingate Road, Halethorpe, Baltimore County, Geophysical Flow Observatory, Open File Report 07-07.1, p 21.

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Bulmer, M. H., T. Farquhar, and M. Roshan (2007), Slope stability after the 8th October 2005 Earthquake in Kashmir, invited presentation to 2007 GSA Denver Annual Meeting, Paper No. 64-7, 28-31 October.

Cahalan, R. F., A. Marshak, G. Wen, and T. Várnai (2007), How can 3D radiative transfer help correctly interpret satellite data on aerosol-cloud interactions?, 32nd International Symposium on Remote Sensing of Environment, San Jose, Costa Rica, 25-29 June.

Cahalan, R. F., and L. Oreopoulos (2006), Global perspective on cloud horizontal inhomogeneity from MODIS, presented at the SPIE Asia-Pacific Remote Sensing Fifth International Symposium, Goa, India, 13-17 November.

Campbell, P. K. E., E. M. Middleton, L. A. Corp, M. S. Kim and E. W. Chappelle (2007), Chlorophyll fluorescence contribution to the apparent red/near-infrared reflectance of vegetation, *Science of the Total Environment, special issue of BIOGEOMON 2006*, in press.

Carn, S. A., A. J. Krueger, S. Arellano, M. Segovia, N. A. Krotkov, and K. Yang (2007), Daily monitoring of Ecuadorian volcanic degassing from space, AGU Joint Assembly, Acapulco, Mexico, 22-25 May (invited paper).

Carn, S. A., N. A. Krotkov, A. J. Krueger, and K. Yang (2006), The first daily measurements of passive volcanic degassing from space, AGU Fall Meeting, San Francisco, CA, 11-15 December (invited paper).

Carn, S. A., N. A. Krotkov, A. J. Krueger, and K. Yang (2007), A survey of volcanic degassing in the Americas since 2004, AGU Joint Assembly, Acapulco, Mexico, 22-25 May.

Carn, S. A., N. A. Krotkov, A. J. Krueger, R. M. Hoff, K. Yang, and A. J. Prata (2007), New Insights into Volcanic Degassing from OMI and the A-Train, ENVISAT Symposium, Montreux, Switzerland, 23-27 April.

Carn, S. A., N. A. Krotkov, K. Yang, A. J. Krueger, A. J. Prata, and R. M. Hoff (2007), Advances in the detection and tracking of volcanic clouds from space, 4th International Workshop on Volcanic Ash, Rotorua, New Zealand, 22-25 March (invited paper).

Carn, S. A., N. A. Krotkov, K. Yang, and A. J. Krueger (2007), The state of the art of measuring volcanic degassing from space, International Conference on Evolution, Transfer and Release of Magmas and Volcanic Gases, Academia Sinica, Taipei, Taiwan, 22-27 April (keynote).

Chiu, J. C., A. Marshak, and W. Wiscombe (2006), Extending our knowledge of two-channel zenith radiance observations from Pt. Reyes to the Black Forest, presented at the 2006 ARM IRF/CLOWD working group meeting, Washington, D.C., 3–5 October.

Chiu, J. C., A. Marshak, and W. Wiscombe (2006), How can one retrieve cloud properties using ARM zenith radiance measurements?, presented at the 2006 ARM Cloud Properties working group meeting, Annapolis, MD, 8–10 November.

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Ciufolini, I., and E. C. Pavlis (2006), GRACE-enabled Space Geodetic Experiments for Fundamental Physics, Eos Trans. AGU, 87(52), Fall Meet. Suppl., Abstract G13A-0022, San Francisco, CA, 8-9 December.

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Delgado R., R. M. Hoff, R. R. Rogers, and K. McCann (2006), Comparison of the ELF/CALIPSO during the Initial Summer Validation Period over the Baltimore Region, 4th National Oceanic and Atmospheric Administration-Educational Partnership Program Meeting, Tallahassee, FL, 29-31 October.

Delgado, R., R. M. Hoff, R. R. Rogers, K. McCann, C. A. Hostetler, and J. W. Hair (2006), Comparison of the ELF/AHSRL/CALIPSO during the Initial Summer Validation Period over the Baltimore Region. Proceedings of the American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, 11-15 December.

Delgado, R., R. R. Rogers, Z. Li, N. S. Jordan, K. Mubenga, K. McCann and R. M. Hoff (2007), Active and Passive Remote Sensing of Atmospheric Aerosols: UMBC Atmospheric Lidar Group, 4th Lidar Workshop in Latin America, Ilhabela, Brazil, June.

Engel-Cox, J., A. Prados, K. McCann, H. Zhang, and R. Hoff (2007), Remote Sensing Data and the 3D Air Quality System (3D-AQS), Paper # 422, Air and Waste Management Annual Conference and Exhibition, Pittsburgh, PA, 26-29 June.

Engel-Cox, J., E. Zell, R. Hoff, K. McCann, A. Prados, H. Zhang, and A. Wimmers (2007), Remote Sensing Data and the 3D Air Quality System (3D-AQS). Extended Abstract # 2007-A-422-AWMA, Air and Waste Manage. Annual Meeting, Pittsburgh, PA.

Engel-Cox, J., R. Hoff, J. Al-Saadi, F. Dimmick, B. Johns, C. Kittaka, S. Kondragunta, K. McCann, A. Prados, J. Szykman, A. Wimmers, and E. Zell (2007), Integration of satellite-derived data into EPA's air quality decision support systems, 2007 EPA National Air Quality Conference: Air Quality Forecasting, Mapping, and Monitoring, Orlando, FL 11-14 February.

Farquhar, T., and M. H. Bulmer (2007), Distributed Sensing of Hazardous Geophysical Flows (SENSEI), MIPS Project Final Report, Contract Agreement #3619, p. 9.

Farquhar, T., and M. H. Bulmer (2006), SENTINEL: a method of detecting a landslide using a distributed array of solar powered light emitting diodes, Invention disclosure filed with UMBC, p4.

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Gendreau, K., J. V. Martins, and Z. Arzoumanian (2006), Instrument and Method for X-ray Diffraction, Fluorescence, and Crystal Texture Analysis without Sample Preparation, Patent Application.

Grecu, M., W. S. Olson, D. E. Waliser, C.-L. Shie, and W.-K. Tao (2006), Estimating Global Latent Heating Distributions Using a PR/TMI-Trained Radiometer Algorithm, 2nd NASA Energy and Water cycle Study NEWS PI Meeting, Adelphi, MD, 26-28 September.

Grecu, M., W. S. Olson, D. E. Waliser, C.-L. Shie, and W.-K. Tao (2007), Estimating Global Latent Heating Distributions Using a PR/TMI-Trained Radiometer Algorithm Workshop on Satellite Observations of the Global Water Cycle, Irvine, CA, 7-9 March.

Griswold, A., M. H. Bulmer, D. Beller, and P. J. McGovern (2007), An examination of the Olympus Mons Aureoles. NASA Intern Poster Session, Goddard Space Flight Center, Greenbelt, MD, 12 August.

Hartmann, P., A. Tokay, A. Bataliga, B. Sheppard, K. Wu, and P. Joe (2006), Comparison of two ground based disdrometers and two vertically pointed radar reflectivity measurements, 4th Eurpoean Conference on Radar Meteorology and Hydrology, Barcelona, Spain, September.

Hilsenrath, E., and J. Langen (2006), Constellation Study: Atmospheric Composition, CEOS Strategic Implementation Team-19, La Jolla, CA, 19 September.

Hilsenrath, E., J. Langen, and C. Zehner (2007), The Atmospheric Composition Constellation: A proposed example of Integrated Earth Observing System for GEOSS, IGARSS 2007 Barcelona, Spain, 23 July.

Hoff, R. M. (2007), "When faculty say 'x', they mean 'y'", Panelist, PROMISE Seminar, UMBC, Baltimore, MD.

Hoff, R. M., and J. B. Halverson (2007), Global Warming – the 2007 Edition, Physics Department Seminar, University of Maryland, Baltimore County, Baltimore, MD, 28 February.

Hoff, R. M., J. A. Engel-Cox, F. Dimmick, J. J. Szykman, B. Johns, S. Kondragunta, R. Rogers, K. McCann, D. A. Chu, O. Torres, A. Prados, J.Al-Saadi, C.Kittaka, V.Boothe, S. Ackerman, and A. Wimmers (2006), 3D-AQS, a Three-Dimensional Air Quality System, 22nd International Laser Radar Conference, Nara, Japan, 24-28 July.

Hoff, R. M., O. Torres, R. Delgado and R. Rogers (2007), Lidar Validation of Calipso and OMI Using Ground-Based Sensors From REALM. AMS Annual Meeting, San Antonio, TX, January.

Hoff, R., H. Zhang, S. Kondragunta, I. Laszlo, and A. Wimmers (2007), An IDEA for GOES-R, NOAA GOES-R Algorithm Working Group Annual Meeting, Lansdowne, VA, 14-18 May.

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Huemmrich, K. F. (2006), A Users Guide to NDVI and EVI, presented at The Validation of Global Vegetation Indices and Their Time Series, Missoula, MT, 7 August.

Huemmrich, K. F., E. M. Middleton, G. Drolet, F. G. Hall, H. Margolis, and R. G. Knox (2006), Determining Ecosystem Light Use Efficiency Using MODIS, American Geophysical Union (AGU) 2006 Fall Meeting, San Francisco, CA, December.

Hulley, G. and E. C. Pavlis (2007), Refraction modeling in SLR by ray tracing through meteorological data, EGU2007-A-04957, EGU 2007, Vienna, Austria, 15-20 April.

Hulley, G., and E. C. Pavlis (2006), Improvement of Current Refraction Modeling in Satellite Laser Ranging (SLR) by Ray Tracing through Meteorological Data, 15th Int. Laser Workshop, John Luck (ed.), Geosciences Australia, Canberra.

Hulley, G., and E. C. Pavlis (2006), Improvement of Current Refraction Modeling in Satellite Laser Ranging (SLR) by Ray Tracing through Meteorological Data, 15th Int. Laser Workshop, Canberra, Australia, 16-20 October.

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Jiang, W., and W. Kuang (2006), Dynamo action with different Rayleigh numbers: towards understanding the annihilation of Martian dynamo, American Geophysics Union Assembly, San Francisco, CA.

Jiang, W., W. Kuang, and A. Tangborn (2006), MoSST: a modular, scalable numerical core dynamics model, Western Pacific Geophysics Meeting, Beijing, China.

Johnson, B. T., G. Skofronick-Jackson, J. Wang, and G.W. Petty (2006), Passive and Active Microwave Remote Sensing of Cold-Cloud Precipitation: Wakasa Bay Field Campaign 2003, 3rd International Precipitation Working Group and Coordination Group for Meteorological Satellites (IPWG-CGMS) Workshop, Melbourne, Australia, 23-27 October.

Johnson, B.T., G. Skofronick-Jackson, J. Wang, G.W. Petty (2006), Parameterization of Mid-to-High Latitude Cold-Cloud Precipitation Microphysics, IEEE International Geoscience and Remote Sensing Symposium (IGARSS06), Denver CO, 31 July – 4 August.

Jordan, N. S., C. Ichoku, and R. Hoff (2007), Estimating Smoke Emissions Over the U.S Southern Great Plains Using MODIS Fire Radiative Power (FRP) Measurements. AEROCENTER Seminar, NASA Goddard Space Flight Center, Greenbelt, MD, 30 January.

Jordan, N. S., C. Ichoku, and R. M. Hoff (2006), Smoke Emissions Over the U.S. Southern Great Plains Using Satellite Fire Radiative Energy (FRE), Proceedings of the American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, 11-15 December.

Jordan, N. S., C. Ichoku, and R. M. Hoff (2007), Smoke Emission Estimations for the U.S. Southern Great Plains (SGP), 4th Annual CoRP Science Symposium, College Park, MD, 19-20 June.

Kearney, C., I. M. Watson, G. J. S. Bluth, S. A. Carn, and V. J. Realmuto (2007), A comparison of ultraviolet and thermal infrared SO2 retrievals of a near-pure SO2 plume, AGU Joint Assembly, Acapulco, Mexico, 22-25 May.

Keyser, J., T. Farquhar, and M. H. Bulmer (2006), SENSEI Project: Microcontroller based distributed sensing of hazardous geophysical flows. Graduate student awards, Department of Mechanical Engineering, UMBC.

Knyazikhin, Y., A. Marshak, J. C. Chiu, D. Huang, W. Wiscombe, and P. Pilewskie (2007), A new approach to interpret measurements of spectral surface reflectance around ACRF central facility, presented at the 17th ARM Science Team Meeting, Monterey, CA, 26–30 March.

Kondragunta, S., P. Lee, J. McQueen, C. Kittaka, A. Prados, P. Ciren, I. Laszlo, R. B. Pierce, R. M. Hoff, and J. J. Szykman (2006), Air Quality Forecast Verification using satellite data, Paper #6299-22, SPIE Optics and Photonics 2006, San Diego, CA, August.

Koren, I. (2006), Pushing the Envelope of Aerosol Research, Global Warming and the Next Ice Age, invited talk to Aerosol Workshop Santa Fe, NM, July.

Koren, I. (2007), Clouds twilight zone - a smooth transition from clouds to aerosols, invited talk to ESF - INTROP conference, Crete, 22-24 April.

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Krotkov, N. A., A. J. Krueger, K. Yang, S. A. Carn, P. K. Bhartia, and K. Evans (2007), OMI SO2 product status and outlook, OMI Science Team Meeting #12, Baltimore, MD, 5-8 June.

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Krueger, A. J., N. A. Krotkov, and S. A. Carn (2007), The 1982 El Chichon eruption: the birth of volcanic sulfur dioxide monitoring from space, AGU Joint Assembly, Acapulco, Mexico, 22-25 May.

Krueger, A. J., S. A. Carn, N. A. Krotkov, K. Yang, P. F. Levelt, G. Serafino, G. Stephens, M. Guffanti, D. Schneider, G. Hufford, and C. Kessinger (2006), NASA research satellite data for volcanic aviation hazards, Support to Aviation Control Service (SACS) workshop, BIRA-IASB, Brussels, Belgium, 3 October.

Kuang, W., and A. Tangborn (2006), Development of Geomagnetic Data Assimilation, Integration of 400 years of surface geomagnetic observations into geodynamo modeling, 11-15 December.

Kummerow, C., and W. S. Olson (2006), GPROF 2004, 2007, and the Global Precipitation Climatology Project, 2006 Meeting of GRP Working Group on Data Management and Analysis, Adelphi, MD, 13-15 November.

Kundu, P. K. (2007), Understanding Irregular Variability of Atmospheric Processes in Probabilistic Terms, Dept. of Mathematics and Statistics, UMBC, UMBC Probability/Statistics Day, Baltimore, MD, 28 April.

Kundu, P. K., and R. K. Siddani (2006), A New Class of Probability Distributions for Describing the Spatial Statistics of Area-averaged Rainfall, Poster presentation at the JCET Retreat, Baltimore, MD, 23-24 October.

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Lyu, C., J. Sun, X. Xiong, and W.Barnes (2006), Multi-Year Lunar Observations from TRMM/VIRS, Terra/MODIS and Aqua/MODIS, Proceedings Remote and Modeling of Ecosystems for Sustainability III. SPIE 6298, pp.629811, Diego, CA, 14-16 August.

Marshak, A., T. Várnai, G. Wen, B. Vant-Hull, F. Evans, and R. F. Cahalan (2006), How 3D science can help to correctly interpret MODIS data for better understanding of aerosol-cloud interactions, MODIS Science Team Meeting, College Park, MD, 2 November.

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Martins, J. V. (2006), GEST / JCET Earth Sciences Seminar, NASA Goddard Space Flight Center, Greenbelt, MD, 12-14 July.

Martins, J. V. (2006), Invited Lecture at the Code 610 NASA GSFC project Scientist Forum, 7 December.

Martins, J. V. (2006), Invited Lecture at the Institure of Physics, University of Sao Paulo, Brazil, 10 August.

Martins, J. V. (2006), Invited Lecture at the NASA GSFC aerosol strategy workshop, Greenbelt, MD, 26-27 October.

Martins, J. V. (2006), Invited lecture presented at The 2nd International Conference on Global Warming and the Next Ice Age, and Aerosol Workshop on Climate Prediction Uncertainties, Santa Fe, NM, 17-21 July.

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Sawyer, G. M., S. A. Carn, C. Oppenheimer, and V. Tsanev (2007), Gas emissions from Nyiragongo volcano, D.R. Congo, International Conference on Evolution, Transfer and Release of Magmas and Volcanic Gases, Academia Sinica, Taipei, Taiwan, 22-27 April.

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Wicks, D. E., W. W. McMillan, J. Warner, C. Barnet, G. Sachse, M. Avery, and L, Sparling (2006), Correlations of Tropospheric CO and O_3 as Observed by AIRS during INTEX-B/MILAGRO and TEXAQS/GoMACCS, *Eos. Trans. AGU*, Fall Meet. Suppl., Abstract A31B-0894.

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Wimmers, A., T. Rink, S. Ackerman, S. Bachmeier, R. Hoff, and J. Engel-Cox (2007), Visualizing a new generation of remotely-sensed aerosol observations in three dimensions, 2007 EPA National Air Quality Conference: Air Quality Forecasting, Mapping, and Monitoring, Orlando, FL, 11-14 February.

Wu, A. C. Lyu, X. Xiong, and W. Barnes (2006), Tracking VIRS/TRMM On-Orbit Calibration with MODIS, Proceedings Remote Sensing and Modeling of Ecosystems for Sustainability III. SPIE 6298, pp.62980Y, San Diego, CA, 14-16 August.

Xiong X., N. Che, W Barnes, Y. Xie, L. Wang, and J. Qu (2006), Status of Aqua MODIS Spatial Characterization and Performance, Proceedings Sensors, Systems, and Next Generation of Satellites X, SPIE 6361, pp.63610T, Stockholm, Sweden, 11-13 September.

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Yurganov, L., and W. McMillan (2007), Ground- and space-based spectrometers for monitoring biomass burning emissions. Poster presentation at the Canada-Mexico-United States Joint Meeting on the North American Carbon Program, Colorado Springs, CO, 25-26 January.

Yurganov, L., W. McMillan, A. Dzhola, and E. Grechko (2006), 2006 Boreal Forest Fires: Tropospheric CO Perturbations Detected from Ground and Space, oral presentation at the 2006 Fall AGU Meeting, San Francisco, CA, 13 December.

Yurganov, L., W. McMillan, A. Dzhola, and E. Grechko (2007), Tropospheric CO interannual variations as a proxy for emissions from boreal forest fires. Poster presentation at the U.S. North American Carbon Program (NACP) Investigators Meeting, Colorado Springs, CO, 22-24 January.

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Zhang, S., A. Hou, and W. Olson (2006), Assimilation of Rain-Affected Microwave Radiances Versus Rain Retrievals in GEOS-5, 2006 American Geophysical Union Fall Meeting, San Francisco, CA.

III.5 Courses Taught

CHEM 100: *The Chemical World* — This is an introductory chemistry course for non-majors. I designed this course with an emphasis on environmental chemistry including current topics such as U.S air quality and global warming. (Taught by Ana Prados, Spring 2007)

GES 110: *Physical Geography* — An introduction to Earth systems science, examining the major systems on the planet including atmosphere, cryosphere, hydrosphere and geosphere. The course also provides an introduction to the remote sensing of Earth using satellite technology. (Taught by Jeffrey Halverson, Spring 2007)

GES 311: *Weather and Climate* — Introductory survey course for majors that presents the fundamental dynamics and thermodynamics of mid-latitude weather systems, including extratropical lows, fronts and the jet stream. (Taught by Jeffrey Halverson, Fall 2006)

GES 400A: *Arctic Geography* — This course was designed to acquaint students with the physical, biological, and cultural characteristics of high latitude regions. The class examined past, present and potential future climate conditions; climate interactions with the physical environment such as snow cover, permafrost, and sea ice; effects of climate on terrestrial and marine ecosystems; and how humans interact with this environment. (Taught by K. F. Huemmrich, Spring 2007)

HCST 100: *Human Context of Science and Technology* —The Science and Politics behind Global Warming (2 lectures). This team-taught course focuses on various aspects of the interface between science and culture. (Lectures given by Lynn Sparling, Fall 2006)

MATH 710B: *Special Topics in Applied Mathematics: Data Assimilation* — This graduate course presented the theoretical development of data assimilation, including Kalman filtering, variational techniques and ensemble methods. The students were assigned a number of projects in which they applied these techniques to simple models. (Taught by Andrew Tangborn, Spring 2007)

PHYS 220: *Introduction to Computational Physics* — An introduction to the basic methods of computational physics, as well as an overview of recent progress in several areas of scientific computing. Deals with basic computational tools and routines, covering differential equations, spectral analysis and matrix operations. Advanced topics covered include Monte Carlo simulations, lattice gas methods, molecular dynamics and symbolic computing. (Taught by Kevin McCann, Spring 2007)

PHYS 340L: *Electronics for Scientists* — This is a basic lecture and laboratory course in electronics. Properties of semiconductor devices and their combinations in amplifiers, oscillators, timers, switching circuits, digital circuits, and electronic instruments in common use in the scientific laboratory. (Taught by W. Wallace McMillan, Spring 2007)

PHYS 407: *Electromagnetic Theory* — Review of vector calculus, electrostatics, dielectric media, electric currents, magnetic fields, electromagnetic induction and magnetic properties of matter, Maxwell’s equations. (Taught by Lynn Sparling, Fall 2006)

PHYS 450: *Special Topics in Physics* — Undergraduate research in wind energy. (Taught by Lynn Sparling, Fall 2006, Spring 2007)

PHYS 602: *Statistical Mechanics* — Statistical Mechanics is a probabilistic approach to equilibrium properties of large numbers of degrees of freedom. In this course, basic principles are examined. Topics include: thermodynamics, probability theory, kinetic theory, classical statistical mechanics, interacting systems, quantum statistical mechanics, and identical particles. (Taught by Kevin McCann, Spring 2007)

PHYS 621: *Atmospheric Physics I* — Composition and structure of the Earth's atmosphere, atmospheric thermodynamics, development of the fundamental equations of motion for a rotating, stratified fluid, balanced flow, waves, vorticity, overview of planetary boundary layer, the global circulation, and other selected topics. (Taught by Lynn Sparling and William Olsen, Fall 2006)

PHYS 622: *Atmospheric Physics II* — Second semester general atmospheric physics course. Topics include an introduction to atmospheric radiation transfer, cloud physics, and aerosol physics. (Taught by W. Wallace McMillan, Spring 2007)

PHYS 622: *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 lectures by Ali Tokay, Spring 2007)

PHYS 721: *Atmospheric Radiation* — This course introduces the student to formal radiative transfer theory, which is quickly simplified for application to the Earth's atmosphere. The physical processes that contribute to absorption and scattering in the Earth's atmosphere are examined. Topics include molecular absorption via vibration-rotation transitions and spectral line formation in inhomogeneous atmospheres. Rayleigh and Mie scattering theory are covered, as well as their application to radiative transfer in clouds and aerosol-laden atmospheres. The importance of radiative transfer to the heat balance of the Earth and implications for weather and climate are examined. (Taught by Lazaros Oreopoulos and Tamás Várnai, Fall 2006)

PHYS 731: *Atmospheric Dynamics* — Overview of conservation laws, principles of rotating fluids, basic fluid flows, and approximations to the primitive equations; quasigeostrophic dynamics of mid-latitude synoptic systems , baroclinic waves, frontogenesis, dispersion, propagation, and energetics of atmospheric waves on different temporal and spatial scales of motion; survey of nonhydrostatic cloud and mesoscale convective systems. (Taught by Lynn Sparling, Spring 2007)

III.6 Colloquia and Seminars

Carn, S.A. (2006), New insights into volcanic degassing from NASA satellites, invited seminar given at the NASA Graduate Student Summer Program (GSSP) seminar series, NASA GSFC, Greenbelt, MD, 14 November.

Chiu, J. C. (2007), Progress in measuring optical properties of broken clouds, seminar given at the Physics Department, University of Maryland, Baltimore County, Baltimore, MD, 25 April.

Chiu, J. C. (2007), Retrieving cloud optical properties from zenith radiance measurements: Examples from ARM, MPLnet, and AeroNet, seminar given at the NASA Goddard Space Flight Center, Greenbelt, MD, 18 April.

Chiu, J. C. (2007), What can we learn about cloud properties from ground-based zenith radiance measurements?, seminar given at the Physics Department, University of Maryland, College Park, MD, 12 March.

Johnson, B. T., G. Skofronick-Jackson, J. Wang, and G.W. Petty (2006), Parameterization of Mid-to-High Latitude Cold-Cloud Precipitation Microphysics, NASA Goddard Space Flight Center, Code 614.6 Seminar, Greenbelt MD, 15 August.

Koren, I. (2007), Clouds twilight zone, invited talk to Kaufman Symposium, NASA-GSCF, Greenbelt, MD, 30-31 May - 1 June 1.

McMillan, W. W. (2006), AIRS Minor Constituents Focus Group: turning small residuals into science, Invited talk at the AIRS Science Team Meeting, Greenbelt, MD, 26 September.

McMillan, W. W. (2006), AIRS Near-Realtime Retrievals in support of the TEXas Air Quality Study (TEXAQS) II Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS) Texas Commission on Environmental Quality (TCEQ), NOAA, NASA, Invited talk at the AIRS Science Team Meeting, Greenbelt, MD, September 28, 2006.

McMillan, W. W. (2006), AIRS Views of Anthropogenic and Biomass Burning CO: INTEX-B/MILAGRO and TEXAQS/GoMACCS, AGU Fall Meet, San Francisco, CA, 11-15 December.

McMillan, W. W. (2006), Atmospheric InfraRed Sounder (AIRS) Views of Mexico City and the Southeastern United States during MILAGRO, contributed poster, First MILAGRO Science Data Workshop, Boulder, CO, October.

McMillan, W. W. (2007), 4.5 Years of v4.0.9.0 AIRS CO, Invited talk at the AIRS Science Team Meeting, Pasadena, CA, 28 March.

McMillan, W. W. (2007), AIRS CO: Impact of v5 improvements Over v4: working smarter…, Invited talk at the AIRS Science Team Meeting, Pasadena, CA, 28 March.

McMillan, W. W. (2007), AIRS satellite products for TexAQS2006: August 30 case study, invited talk at the TexAQS2006 Data Workshop, Austin, TX, 31 May.

McMillan, W. W. (2007), Infrared Remote Sensing of CO from Space and Ground, invited seminar, Penn State University Department of Meteorology, 18 January.

Oreopoulos, L. (2007), How MODIS observations can be used to detect the most heterogeneous and susceptible warm clouds, invited talk at Rutgers University, 28 February.

Tangborn, A. (2006), Assimilation of MOPITT total column Carbon Monoxide Observations – JCET faculty meeting, UMBC, Baltimore, MD, 13 December.

Tangborn, A. (2007), Assimilation of SCIAMACHY total column CO, Earth and Planetary Sciences, Harvard University, Cambridge, MA, 18 June.

Tangborn, A. (2007), Wavelets in timeseries analysis, Lectures in METEO 630 class, Department of Meteorology, University of Maryland, College Park, 1 May and 3 May.

Torres, O. (2007), A New Challenge in Aerosol Remote Sensing: Measuring Aerosol Absorption from Space, NASA GSFC Laboratory for Atmospheres, Special Seminar, Greenbelt, MD, 19 March.

Torres, O. (2007), The Global Distribution of Dust and Smoke: Measuring Aerosol Absorption with TOMS and OMI observations, CIMAS Seminar, Invited Presentation, University of Miami, 27 March.

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
Roughness parameters of desert surfaces	Army Research Office	Bulmer		Not Awarded
Aerosol processing by deep convection and the radiative effect of its anvil cirrus and outflow	DOE		Koren, Várnai	Pending
Evaluation of GCM Column Radiation Models under cloudy conditions with the ARM BBHRP Value Added Product	DOE	Oreopoulos		Awarded
Parameterization and analysis of 3-D solar radiative transfer in clouds	DOE	Várnai		Pending
Photosynthetic light use efficiency: Quantifying diurnal and seasonal carbon dynamics in cornfields	DoE	Middleton	Huemmrich	Not Awarded
Terrestrial Carbon Processes Research, Photosynthetic light use efficiency: Quantifying diurnal and seasonal carbon dynamics in cornfields	DoE	Middleton	Campbell	Pending
Distributed sensing of hazardous geophysical flows (SENSEI)	MIPS	Farquhar	Bulmer	Awarded
A Climate Record of Tropospheric Carbon Monoxide Measurements From EOS and Past Satellite Instruments: Using a Uniform Retrieval Algorithm	NASA	Warner		Not Awarded
A Common Web-Based AOP Data Processor	NASA	D'Alimonte		Not Awarded
A Common Web-Based IOP Data Processor	NASA	D'Alimonte		Pending
A Long-Term Precipitation Dataset with Uncertainty Information	NASA	Kummerow	Berg, L'Ecuyer, Olson, Grecu	Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
A multi-decadal sulfur dioxide climatology from UV satellite instruments	NASA	Krotkov	Krueger, Carn, Yang, Tilmes	Pending
Addressing the Challenge of the Madden-Julian Oscillation with TRMM-era Science: Hydrologic and Thermodynamic Structure in the Retrievals, Reanalysis, and Simulations	NASA		Olson	Not Awarded
Aerosol-cloud interactions: How 3D science can help to correctly interpret satellite data	NASA	Cahalan	Marshak, Várnai	Awarded
An Intercomparison of Tropospheric Carbon Monoxide Measurements from the Past and Current Satellite Instruments: Using a Uniform Retrieval Algorithm	NASA	Warner	McMillan	Awarded
Analysis of the Accuracy of Radiometric and Bio-geochemical Ocean Color Data Products	NASA	D'Alimonte		Not Awarded
Application of the Critical Albedo as a Shortcut to Direct Radiative Forcing Measurements by Remote Sensing	NASA	Martins		Pending
A-Train and IASI CO and O_3 Observations and Near-Real-Time Assimilation Tests for ARCTAS Flight Planning and Post-Mission Analysis	NASA	McMillan	Sparling	Pending
Building an integrated view of Terra, Aqua, and Aura trace gas products: global modeling and detailed case study investigations	NASA	McMillan	Yurganov	Pending
Characterizing the Saharan air layer and its impact on tropical cyclone development using OMI and other A-Train data	NASA	Torres		Pending
Characterizing Volcanic Clouds from Top to Bottom with the A-Train	NASA	Carn	Krueger	Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Climate Effect of Black Carbon Aerosol on Tropical Convective Clouds and Precipitation	NASA	Martins		Awarded
Cloud susceptibility derived from MODIS observations as a tool for assessing the indirect aerosol effect on global and regional scales	NASA	Oreopoulos	Platnick	Pending
Combined Radar/Radiometer Estimates of Precipitation and Latent Heating Profiles for Training Spaceborne Passive Microwave Radiometer Algorithms	NASA	Olson		Awarded
Consulting in support of Glory-APS Measurements of aerosol single scattering albedo	NASA	Torres		Pending
Continuation of I3RC with applications to THOR cloud data analysis	NASA	Cahalan	Marshak, Várnai	Pending
Development of a Consistent Global Long-term Aerosol Database by Combining Data from Multiple Satellite Sensors	NASA	Torres		Pending
Development of a Hyperspectral Smart Sensing System (HS3) for Earth Science Sensor Web Applications	NASA	Powell	Campbell	Pending
Differences and Similarities of Tropical Cyclone Rainfall Over Land and Sea Using Multisatellite Analyses: Implications for Inland Flooding Prediction	NASA	Jiang, Halverson, Zipser	Amitaii	Awarded
Enhanced OMI aerosol product: Use of information from A-train sensors and extension of retrieval to aerosol-cloud mixtures	NASA	Torres		Pending
Environmentally-Induced Structural and Functional Changes in Key Global Ecosystems	NASA	Hall	Huemmirch	Not Awarded
EOS and NPP satellite data fusion to develop a long-term record on Aerosol absorption	NASA	Torres		Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Forecast and Analysis of the Transport of Aerosol and Carbon Monoxide Using GEOS-5/GOCART Model Simulations and MODIS/AIRS Satellite Measurements During ARCTAS	NASA	Chu	Warner, Bian, Remer, Chin, Colarco	Pending
Going Global, Operational with BIOPHYS: A physically-based algorithm for inferring continuous fields of vegetation biophysical parameters	NASA	Hall	Huemmrich	Not Awarded
Ground-based measurements of ozone and carbon monoxide tropospheric column amounts: local pollution, global climate change, and satellite validation	NASA	Yurganov	McMillan	Not Awarded
High Latitude Terrestrial Ecosystem Spectral Network	NASA	Huemmrich		Not Awarded
Improved clouds and radiation in GEOS-5 from global analysis, parameterization and assimilation of A-Train cloud retrievals	NASA	Oreopoulos	Platnick	Not Awarded
Inversion of combined OMI and MODIS data for detailed aerosol characterization	NASA		Torres	Awarded
Investigating the 3-Dimensional Structure of Stratospheric-Tropospheric Exchange Events Through an Integrated Analysis of MLS, TES, OMI, and AIRS Retrievals	NASA	McMillan		Pending
Investigation of Aerosol Spectral Absorption Properties from UV to NIR	NASA	Martins		Awarded
Mapping ecosystem light-use efficiency using satellite data	NASA	Huemmrich		Pending
Measurements of the hydrometeor size distribution for the NASA precipitation measurement mission	NASA	Tokay		Awarded
Mesoscale Chemical Tracer Forecasts for TC^4	NASA		Prados	Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Multi-frequency Polarimetric Radar, Profiler, and Space-borne Studies of Particle Size Distributions and Mixed Phase Processes in Cold and Warm Season Precipitation	NASA		Olson	Awarded
Multiplatform Aircraft Package for Cloud Aerosol Interaction Studies	NASA	Martins	Fernandez-Borda	Pending
New CO and O_3 Products for Climate and Air Quality Studies Using Multiple Sensors on A-train Satellites	NASA	Warner	Strow	Pending
North American high latitude land cover and carbon exchange	NASA	Huemmrich		Pending
Particle Absorption Characterization for the Retrieval of Aerosol Optical Depth from CALIPSO Observations	NASA	Torres	DeSouza-Machado	Awarded
Polar Studies Using a Hyperspectral Imager on UAV	NASA	Warner	Huemmrich	Not Awarded
Rainbow and Cloud Side Remote Sensing for Cloud Microphysical Retrievals	NASA	Martins		Pending
Remote sensing assessment of vegetation function using spectral (solar fluorescence and reflectance) measurements	NASA	Campbell		Awarded
Remote Sensing Measurements of Aerosol Absorption and its Effects on Climate Forcing	NASA	Martins		Pending
Remote Sensing of Avian Species Richness and Community Composition	NASA	Huemmrich		Not Awarded
Role of Hurricanes on Water and Latent Heat Budgets within Gulf of Mexico and Caribbean Sea Basins	NASA	Smith	Mehta	Not Awarded
Snow and sea ice thickness from offbeam lidar returns	NASA	Cahalan	Várnai	Not Awarded
Studies of Snow and Mixed Phase Precipitation from TRMM and GPM	NASA	Heymsfield	Heymsfield, Halverson, Tian	Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
The Use of Remote Sensing Data and Seasonal Climate Predictions to Identify and Predict Hydro-meteorological and Global Climate Signals in Malaria Disturbances	NASA		Mehta	Not Awarded
Validation of Non-Coincident Trace Species Measured by AURA Using Trajectory Mapping and Statistical Analysis	NASA		Sparling	Awarded
Exploring How Mediterranean Sea Could Transform From Concentration to Dilution Basin: Use of AQUA, SCATTEROMETER, TOVS, & TRMM Measurements plus Additional Satellite Datasets to Examine Governing Controls on E - P over Mediterranean	NASA EOS	Mehta, Smith		Pending
A portable and Novel X-ray Diffractometer for Earth and Solar-system Exploration	NASA GSFC	Martins		Not Awarded
RAIMPol: A Near Infrared Rainbow and Aerosol Imaging Polarimeter for Earth & Solar-system Exploration	NASA GSFC	Martins		Awarded
Retrieval Algorithm Development for Precipitating Snow Detection and Estimation using High Frequency Observations	NASA GSFC	Skofronick-Jackson	Johnson, Olson, Wang, Grecu, Kim	Awarded
Retrievals of Precipitating Snow and Light Rain Using Synergistic Multi-Sensor Active and Passive Observations	NASA GSFC	Skofronick-Jackson	Johnson, Olson	Awarded
Field-based evaluation of the feasibility of a new low cost extended duration night-day slope monitoring system, deployed either by astronauts or by robots	NASA Langley	Bulmer		Pending
Optimizing the collection and application of topography data on Mars	NASA MRF	Bulmer		Not Awarded
Topography data on Mars: Optimizing its collection and application using laser scanning	NASA MRF	Bulmer		Pending

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
A study of the mechanisms of rock deformation on Mars: Slope Failures and Landslides	NASA PG&G	Bulmer		Not Awarded
Explaining Role of Tropical Storms & Hurricanes on Water Balance within Gulf of Mexico-Caribbean Sea Basin as Determined by Unified Water Budget Satellite Retrieval System	NASA PMM	Smith	Mehta	Awarded
A study to determine slope stability on the Moon and reduce landslide risk	NASA RFI	Bulmer		Pending
Global Sea Level in a Changing Climate: Reference Frames, Data Analysis, and Interpretation	NASA ROSES	Ray	Pavlis	Awarded
Improved ground validation rain estimates at Kwajalein, RMI and Melbourne, Florida for comparison and validation to TRMM and Other Satellite Estimates	NASA ROSES		Tokay	Awarded
Measurements of column amounts of carbonaceous gases in interior Alaska from the ground and from space: impact from biomass burning	NASA ROSES	Yurganov	McMillan	Not Awarded
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	Bell	Kundu	Awarded
Validation efforts for the NASA's precipitation measurement mission in mid-latitude coastal site – Wallops Island	NASA ROSES	Tokay		Not Awarded
Validation of TRMM Radar-derived rain Rates using rain-gauge Data from TRMM Ground Validation Sites and a Statistical Model	NASA ROSES	Kundu		Not Awarded
Interannual to Decadal Climate Variability Information for Urban Water Policy and Decision-Making Support: A Case Study of the Orlando and Tampa Urban Areas	NOAA		Mehta	Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
Creating a science activity to track motion: collaboration between UMBC faculty, VIP and STEM teachers	NSF	Bulmer		Awarded
Determining the Nature of Injuries Sustained in Landslide Disasters. Creating a Classroom Activity for Earth Science Teachers	NSF	Bulmer		Awarded
IPY: Lagrangian assimilation of long lived Polar balloons	NSF	Tangborn	Kalnav, Szunyogh, Ide	Not Awarded
MRI: Acquisition of an Institutional High-Performance Computing Resource	NSF	Sparling		Not Awarded
Multiple Time-scale Interactions in Water Cycling, Precipitation, and Hydrology between Tropical Pacific-Atlantic Oceans and Continental United States	NSF		Mehta	Not Awarded
Progressive Movement of Natural Versus Engineered Slopes, Pursuant to the Kashmir Earthquake	NSF	Bulmer		Not Awarded
Using enhanced visualization to increase understanding of coupled processes and nonlinear interactions in the atmospheric sciences	NSF	Sparling		Pending from Last Report
Vertical Heating Structure in Large-Scale Convectively-Coupled Waves	NSF	Waliser	Olson	Not Awarded
An investigation of progressive failure in landslides in the area affected by the 8th October 2005 Earthquake in Pakistan	NSF SGER	Bulmer		Awarded
An investigation of progressive failure in landslides in the area affected by the 8th October 2005 Earthquake in Pakistan	NSF SGER	Bulmer		Awarded
Collaborative research on dust emissions and feedbacks to the hydrologic cycle in the West-African Sahel	NSF-Hydrology	Tokay		Not Awarded

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
MRI Development of a Continuum X-Ray Diffraction and Fluorescence (CXRDF) System for Atmospheric Aerosols and Cloud Ice Particles: Laboratory and Field Units	NSF-MRI	Martins		Not Awarded
Investigations of Tropical Cyclone inner core dynamics and its impact on storm intensity	UMBC DRIF	Sparling		Awarded
Cloud detection and avoidance for the Landsat Data Continuity Mission	USGS	Oreopoulos		Awarded
Landslide Risk Assessment and Mitigation Study in the Villcanota Valley, Peru	World Bank	Bulmer		Awarded

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III.8 Biographies

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

Dr. Mark Bulmer is Research Associate Professor in Joint Center for Earth Systems Technology, and affiliated with the UMBC Department of Geography and Environmental Sciences. He is an Adjunct Associate Professor of Geology at University of Buffalo, SUNY, a Visiting Scientist at the Smithsonian Institute and a visiting scholar the the Royal United Services Institute. He has 13 years of experience in earth and planetary research. His research interests are in the area of mass movement dynamics both on Earth and the terrestrial planets combining field measurements with remotely sensed data. He has led or participated in over 20 major field tests and campaigns. He is the author of journal articles, technical reports, conference proceedings papers, education videos for Middle School age, and has given numerous public presentations of his work. Dr. Bulmer obtained a Bachelor of Science degree in Geography at University of London, King's College in 1990 and a Ph.D. in Astronomy & Physics (Planetary Volcanology) at University College London in 1994. He has conducted research at the NASA Jet Propulsion Laboratory and Goddard Space Flight Center, and the Smithsonian National Air and Space Museum. Dr. Bulmer serves on the American Geophysical Union Tellers Committee and the Landslide Working Group of the Committee for Earth Observing Satellites. He has received grants from NASA, ESA, CSA, ISA, NSF, National Geographic, Royal Geographical Society, Smithsonian Institution and Radarsat International. He has peer review roles at NASA and NSF and has held memberships in four scientific societies.

Dr. Petya K. Entcheva Campbell received a BS in Forestry from the Academy of Forest Engineering, Sofia, Bulgaria in 1988, MS in Forest Sylviculture and Ecology from the University of Massachusetts at Amherst, MA and a Ph.D. in Forest Analysis/Remote Sensing in 2000 from the University of New Hampshire, Durham, NH, where her research focus was on the development of remote sensing techniques for forest health assessment. Her research interests and directions include: (1) vegetation stress detection using fluorescence and optical remote sensing techniques (2) investigation of relationships among vegetation biophysical parameters and their spectral responses, (3) in situ ground spectroscopy for measuring spectral signatures of the vegetation, (4) spectral and spatial characterization of vegetation responses to a variety of natural and anthropogenic stress agents (e.g., air-pollution, pest/pathogen impacts), and (5) development of methods for ecosystem monitoring, early damage detection, and change detection at both landscape and regional scales. In 2000, Dr. Entcheva Campbell joined NASA as a NRC associate and worked at Goddard Space Research Center for two years before joining JCET/UMBC where she is currently employed. Currently, she is a member of the GSFC fluorescence and FLORA teams as an investigator on NASA, NSF and USDA grants.

Dr. Simon A. Carn received a BA in Earth Science from Oxford University, UK, in 1993, and a DEA (the French equivalent of an MS) in Volcanology from Université Blaise Pascal, Clermont-Ferrand, France, in 1994. He received a PhD in Volcanology in 1999 from the Department of Earth Sciences, Cambridge University (UK), for research on volcanism in Indonesia. From 2000-2001 he worked as a volcanologist on the active volcanic island of Montserrat (West Indies). In 2001 he joined the Joint Center for Earth Systems Technology (JCET) at the University of Maryland Baltimore County (UMBC), to work on remote sensing of volcanic sulfur dioxide (SO_2) emissions using UV satellite data from the NASA Total Ozone Mapping Spectrometer (TOMS) missions and since 2004 from the Ozone Monitoring Instrument (OMI) on the EOS/Aura spacecraft. His main research interests are satellite and ground-based UV/IR data analysis applied to studies of volcanic degassing, eruption monitoring, and air pollution monitoring. Dr. Carn has lead or participated in field campaigns at active volcanoes in Indonesia, Guatemala, Democratic Republic of Congo, Chile, Papua New Guinea and Italy. He is an Assistant Research Scientist in JCET and currently serves as PI for validation of OMI SO_2 data from the Aura satellite.

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

Dr. Davide D'Alimonte received the Laurea degree in physics from the University of Physics, Turin, Italy, in 1997 and the PhD degree in oceanography from the University of Southampton, Southampton, UK, in 2003. From 1999 to 2002 he was at the Joint Research Centre of the European Commission, Ispra, Italy, involved in ocean color activities for the determination of optically significant seawater constituents in complex coastal waters using neural network methods. From 2003 to 2005, he has been a member of the Neural Computing Research Group, University of Aston, Birmingham, U.K., where his research work focuses on the mathematical modeling and statistical analysis of DNA microarray data, and ocean color applications. Since May 2006, he has been a member of the Joint Centre for Earth System Technology, University of Maryland, Baltimore County.

Mr. Ruben Delgado is a Research Associate 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 2007, 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. He has published 4 refereed journal articles about LIDAR measurements and chemical models of the mesospheric potassium layer. During his career, he has also carried out computational and experimental research involving laser photolysis of gas phase polyatomic species followed by probing of the nascent radicals and ions with Laser Induced Fluorescence and Time-of Flight Mass Spectroscopy.

Dr. Jeffrey B. Halverson has traveled the world's tropical latitudes to better understand how intense storms of rain and wind develop and intensify. He has conducted research in Brazil, Australia, the South China Sea, Costa Rica, the Marshall Islands, West Africa and various locations in the Caribbean studying tropical weather systems. Dr. Halverson's research examines the atmospheric factors that cause hurricanes to rapidly change intensity. In 2001, he helped pioneer a new aircraft-based, upper atmospheric measuring system to take direct measurements in the eye of a mature hurricane from an altitude of 70,000 feet. 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. Forrest Hall has been active in the field of remote sensing since 1972 and has been at NASA's GSFC since 1985. He is Senior Research Scientist at JCET UMBC. Dr. Hall has an undergraduate degree in Mechanical Engineering from the University of Texas, and the MS and PhD degrees in Physics from the University of Houston.

Dr. Richard Hartle received a B.S. from the University of Michigan in 1959, and a Ph.D. in physics in 1964 from the Pennsylvania State University, where his major research interest was theoretical plasma physics. In 1964, he joined NASA, and worked at the Ames Research Center for three years before transferring to GSFC, where he is still employed. During his career, he has carried out theoretical and experimental research on the solar wind, planetary atmospheres and ionospheres, plasma physics, and gas dynamics using measurements made from the instruments on satellites such as the Atmosphere Explorers, Dynamics Explorer, Mariner 10, Voyager, Pioneer Venus, Galileo and Cassini. He has published over 100 refereed papers; the most recent concentrate on various gas escape mechanisms and how they affect the evolution of planetary atmospheres, and especially the evolution of water (oceans) on Venus and Mars. He is also active in plasma studies of Saturn's moons, especially Titan, using measurements made from the Cassini orbiter. At GSFC, he has been the head of the Planetary Atmospheres Branch (1975 – 1985, 1991 – 1995), project scientist for the Earth Observing System (1983 – 1987), and assistant chief of the Laboratory for Atmospheres (1985 – 1991).

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

Dr. R. M. Hoff is a Professor of Physics at the University of Maryland, Baltimore County. He is also Director of the Joint Center for Earth Systems Technology and the Goddard Earth Sciences and Technology Center. Dr. Hoff has 32 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 85 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 is a member of the Science Advisory Group on Aerosols to the Commission of the Atmospheric Sciences of the World Meteorological Organization. He serves on a National Academy of Sciences/National Research Council Panel on Mesoscale Meteorological Observations for Multiple National Needs. 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 becomes 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 field work in a variety of habitats including arctic and sub-arctic tundra, temperate rain forests, and deserts.

Dr. Weiyuan Jiang received a B.S. degree in applied mechanics and a M.S. degree in fluid mechanics from Fudan University, Shanghai in 1993 and 1996, respectively. He worked at Shanghai Institute of Applied Mathematics and Mechanics, Shanghai University for two years. He received his Ph.D in 2004 from Clarkson University, where he worked on instability of multi-layer fluid motion at the Department of Mechanical and Aeronautical Engineering. He subsequently joined JCET of UMBC as a research associate. His research interests range from instabilities of fluid motion, film coating, computational fluid dynamics, parallel computation and geodynamo. His research is currently focused on the time-variable gravity caused by large-scale mass redistribution of the mantle and the parallel computation on the MoSST(Modular, Scalable, Self-consistent, Three-dimensional) core dynamics model and the Martian historical dynamo. He currently is a research assistant professor affiliated with the Department of Mechanical Engineering of UMBC.

Mr. Benjamin Johnson received the 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 is expected to complete his Ph.D. degree in Fall 2007 from the University of Wisconsin–Madison. He is currently a Research Associate in JCET in the precipitation focus group. His research interests cover a broad spectrum of precipitation cloud modeling, radiative transfer, and remote sensing. Mr. Johnson is focusing on combined dual-frequency radar and multi-channel radiometer retrievals of frozen and mixed-phase precipitation at microwave frequencies in the 10 to 340 GHz range, with a focus on the upcoming Global Precipitation Mission (GPM) science objectives. He is also actively involved in CloudSat/Calipso/GPM ground validation experiment (CARE- C3VP), which occurred during November 2006 through February 2007 near Toronto, Canada.

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

Dr. Ilan Koren received his degrees from the department of Geophysics and Planetary Sciences in Tel Aviv University, Israel. He received his Ph.D with distinction in 2002 where his major research interest was on spatial and temporal patterns in clouds and aerosols. He joined NASA's MODIS aerosol team as a National Research Council (NRC) fellow and received two awards for Best Senior Author Publication for his work on cloud-aerosol interaction. In summer

2004 he joined JCET as an Assistant Research Scientist. His research interests include remote sensing and modeling of clouds and aerosols, the role of aerosols on climate, and the impact of aerosols on the lifecycle and optical properties of clouds.

Dr. Weijia Kuang received his B.Sc. degree in space engineering sciences from Changsha Institute of Technology, Peoples Republic of China (PRC) in 1982, the M.Sc. degree in theoretical physics from Wuhan University, PRC in 1985, and the 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 more than 20 peer-reviewed papers published, with the most recent on 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 an 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 has received a Bachelor's degree in physics in 1991, a Master's degree in physics/nuclear applied physics in 1994, and a Ph.D. in physics/applied physics in 1999 from the University of Sao Paulo (USP), Brazil. He joined the Group of Studies of Air Pollution of the Institute of Physics of 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 the 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 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 24 refereed papers and has given over 60 presentations in international conferences, the most recent being on the radiative effect of biomass burning and biogenic aerosols, MODIS cloud masking, and interaction between aerosols and clouds. In 2001 he was elected as a representative member of the IRC (International Radiation Commission) for the period 2000-2004, now extended to the period 2004-2006. In 2004, he proposed cloud side vertical profile measurements of cloud microphysical properties and thermodynamic phase from aircraft and space. In 2006 he was hired as Associate Professor in the Department of Physics of the University of Maryland Baltimore County, while keeping his affiliation with the Joint Center for Earth Systems Technology.

Dr. Kevin J. McCann is an Research Associate Professor in JCET and is affiliated with the Physics Department at UMBC. Dr. McCann is engaged in research to use LIDAR to measure atmospheric aerosols to help estimate pollution levels. Dr. McCann has worked for over 20 years in the field of theoretical and experimental underwater acoustics at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). Prior to this overlong stint at APL Kevin had been working on theoretical atomic and molecular collisions and atom/molecule surface interactions at Georgia Tech and the University of Virginia. This work was directed at an understanding of the collision cross sections that are relevant in the interstellar medium and, to some extent, planetary atmospheres. Dr. McCann received all three of his college degrees from Georgia Tech and did his Ph.D.disser¬tation work (1974) with Dr. Ray Flannery there on atomic collision processes. Dr. McCann has published over 50 refereed journal articles in the areas of atomic and molecular collisions and acoustic propagation.

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

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

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

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

Dr. Erricos C. Pavlis received his Dipl. Ing. from the Nat. Tech. Univ. of Athens, Greece in 1975, and his PhD in Geodetic Science from The Ohio State Univ., Columbus, Ohio. Dr. Pavlis is currently a Research Associate Professor, Physics, at the Univ. of Maryland, Baltimore County, doing research for NASA, EU and the NGA. He participated in the LAGEOS, LAGEOS 2, the Crustal Dynamics and WEGENER Projects, the TOPEX/POSEIDON and JASON Missions, and the development of EGM96. Currently science team member of GRACE and OST missions, and a co-PI of the LARES mission, vice-chairman of COSPAR's Panel on Satellite Dynamics, member of GGOS Steering Committee, IERS Directing Board, ILRS's Governing Board, Central Bureau and Coordinator for Analysis and Modeling, chairman of the ILRS Refraction Study group, IAG's Subcommission 1.4 Working Group 1.4.4, and associate editor for the journal of Celestial Mechanics and Dynamical Astronomy.

Dr. Ana I. Prados received the B.A in Physics and Chemistry from the University of Florida in 1992, and a Ph.D in Chemistry from the University of Maryland, College Park in 2000 where her major research was in-situ measurements and modeling of U.S air pollutants. In January 2001 she received a National Research Council post-doctoral fellowship at the Naval Research Laboratory, Washington D.C., where she worked on upper tropospheric/lower stratospheric ozone transport from remote sensing instrumentation until October 2003. She then began work in the area of satellite aerosol retrievals at NOAA/NESDIS, initially with CIRA, then joined JCET in October 2005. She currently works on the integration of in-situ and remote sensing data for air quality applications at UMBC and NASA GSFC.

Dr. Lynn C. Sparling is an associate professor of Physics at UMBC and is a UMBC affiliate member of JCET. She received a BS in Chemistry from the University of New Mexico in 1976, a MS 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 the University of Maryland Baltimore County in 1974 and the M.S. and Ph.D. degrees in physics from the University of Maryland, College Park in 1977 and 1981, respectively. He is currently a Research Professor in the Department of Physics at the University of Maryland Baltimore County. His research interests include molecular spectroscopy, especially spectral line shapes, and radiative transfer, and atmospheric remote sensing. He is a Member of the NASA AIRS and NPP (CrIS Sensor) science teams, and a Co-Investigator on EUMETSAT's IASI sounder on the new METOP platform.

Dr. Andrew Tangborn received undergraduate degrees from the University of Washington in Mathematics and Mechanical Engineering and 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. These include atmospheric constituent data assimilation for the carbon cycle (SCIAMACHY and MOPITT), polar wind observations using data from the VORCORE balloon experiments and solid earth data assimilation in which geomagnetic field observations are assimilated into a geodynamo model. He is currently a research associate professor and is affiliated with the department of mathematics at UMBC where he teaches graduate courses in data assimilation; computational fluid dynamics and wavelet transform methods.

Dr. Ali Tokay received his B.S. from Istanbul Technical University in 1984, M.S. from Saint Louis University in 1988, and Ph.D. from University of Illinois at Urbana-Champaign in 1993. Dr. Tokay was a research associate through a National Research Council Fellowship between 1993 and 1995. He then joined Saint Louis University as a assistant professor in 1995 and University of Maryland, Baltimore County (UMBC) as a research assistant scientist in 1997. Dr. Tokay was a principal investigator during a series of field campaigns under the NASA Tropical Rainfall Measuring Mission. He has taught a number of undergraduate and graduate courses at both Saint Louis University and UMBC, including advising and mentoring a number of successful ungraduate and graduate students. Dr. Tokay is an affiliated assistant professor of Department of Geography and Environmental Sciences and research assistant professor of Joint Center for Earth Systems Technology at UMBC. Dr. Tokay is a member of the NASA precipitation science team.

Dr. Omar Torres received a BS in Geodetic Engineering from Bogota District FJC University (Colombia), in 1978, a MS in Meteorology from the University of The Philippines in 1982 and a Ph.D. in Atmospheric Sciences in 1989 from the Georgia Institute of Technology. His main research area at Georgia Tech was climate applications of radiative transfer modeling. Since the culmination of his doctoral studies, Dr Torres has been a member of TOMS ozone processing team at GSFC. From 1989 to 1998 he was affiliated with Raytheon STX Corporation as Senior and Principal Scientist. In September 1998, he joined JCET as Associate Research Professor. His current research activities involve ultraviolet radiative transfer modeling with applications to the retrieval of aerosol properties and evaluation of effects of aerosols in the retrieval of atmospheric ozone content. Dr. Torres has authored or co-authored over 50 peer reviewed scientific publications in these areas. He is a currently a member of the OMI (Ozone Monitoring Instrument), the NPP (NPOESS Preparatory Project), and the CALIPSO Science Teams.

Dr. Tamas Várnai received his M.Sc. equivalent degree in Meteorology from the Eötvös Loránd University, Budapest, Hungary in 1989. He then joined the Hungarian Meteorological Service for two years, after which he enrolled to McGill University in Montreal, Canada. His research activities focused on how cloud heterogeneities influence the way clouds reflect solar radiation. After receiving his Ph.D. in Atmospheric and Oceanic Sciences in 1996, he continued his research as a post-doctoral fellow first at McGill University, then at the University of Arizona. In addition to examining the theory of three-dimensional radiative effects, his work also included the development of operational algorithms for the MISR (Multi-angle Imaging SpectroRadiometer) instrument on board the Terra satellite, calculating the amount of solar radiation clouds reflect. Dr. Várnai joined JCET in 1999, where he works on estimating the influence of cloud heterogeneities on operational Moderate Resolution Imaging Spectroradiometer (MODIS) cloud property retrievals and develops cloud property retrieval algorithms for the Thickness from Offbeam Returns (THOR) lidar system.

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 the 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.

Dr. Juying Warner is currently a research scientist at the Joint Center for Earth Systems Technology (JCET) located at the University of Maryland Baltimore County (UMBC). Her research interests include the global transport of trace gases and aerosols emitted from biomass burnings and/or other anthropogenic sources using satellite products from NASA/EOS programs. Her research interests also include remote sensing techniques, retrieval algorithms for satellite and airborne instruments, and radiative transfer computations. While working at the National Center for Atmospheric Research (NCAR) from 1997-2004, Dr. Warner led the effort to develop a satellite operational cloud detection algorithm for MOPITT (Measurement Of Pollution In The Troposphere) instrument that measures atmospheric carbon monoxide and methane and that is currently on board NASA EOS Terra satellite. In this algorithm, a multi-satellite-instrument collocation technique is used so that MODIS cloud mask products can be applied to the operational MOPITT cloud algorithm. As a graduate student at the University of Maryland at College Park, Dr. Warner inter-compared eight research and operational atmospheric radiative transfer models by studying the physical processes and the mathematical approximations in each model and carried on sensitivity studies of atmospheric constituents and trace gases. She also developed a new radiative transfer model to calculate the radiative energy and heating by the atmospheric gases. The model was then validated against radiance and flux observations from field experiments. Dr. Warner received her Ph.D. degree from the University of Maryland at College Park in 1997.

Dr. Leonid Yurganov is a Senior Research Scientist at UMBC, Physics Dept. and JCET. His current research expertise is connected with remote sensing of tropospheric composition, mostly CO and other members of carbon family, as well as ozone. He graduated from Leningrad State University in 1969 (MS) and Institute of Atmospheric Physics in 1979 (Ph.D.) (both in Russia). He was 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 39 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 Mechanisms in China. He received M.S. in computer science in 2002 from Towson University. In May 2006, he received his Ph.D. in atmospheric physics from UMBC. He is now working as a visiting research associate in JCET. His current research interest is in remote sensing of aerosol to help air quality estimation and forecasting.

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III.9 Table 1: JCET Faculty (as of September 30, 2007)

NAME	TITLE	AFFILIATION
Dr. William Barnes	Senior 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. Simon Carn	Assistant Research Scientist	Research Faculty
Dr. Christine Chiu	Research Assistant Professor	Physics
Dr. Davide D'Alimonte	Assistant Research Scientist	Research Faculty
Mr. Ruben Delgado	Research Associate	Research Faculty
Dr. Sergio deSouza-Machado	Research Assistant Professor	Physics
Dr. Forrest Hall	Senior Research Scientist	Research Faculty
Dr. Jeffrey Halverson	Associate Professor	Geography and Environmental Systems
Mr. Scott Hannon	Research Assistant	Research Faculty
Mr. Ernest Hilsenrath	Professor of Practice	Research Faculty
Dr. Raymond Hoff	Professor	Physics
Dr. K. Fred Huemmrich	Research Assistant Professor	Geography and Environmental Systems
Dr. Weiyuan Jiang	Research Assistant Professor	Mechanical Engineering
Mr. Ben Johnson	Research Associate	Research Faculty
Dr. Ilan Koren	Assistant Research Scientist	Research Faculty
Dr. Arlin Krueger	Research Professor	Physics
Dr. Prasun Kundu	Research Associate Professor	Physics
Dr. Magdalena Kuzmicz-Cieslak	Research Associate	Research Faculty
Dr. Kevin McCann	Research Associate Professor	Physics
Dr. Amita Mehta	Research Assistant Professor	Physics
Dr. Howard Motteler	Research Associate Professor	Computer Science and Electrical Engineering
Dr. William Olson	Research Associate Professor	Physics

NAME	TITLE	AFFILIATION
Dr. Lazaros Oreopoulos	Research Associate Professor	Physics
Dr. Erricos Pavlis	Research Associate Professor	Physics
Dr. Derek R. Peddle	Associate Research Scientist	Research Faculty
Dr. Ana Prados	Assistant Research Scientist	Research Faculty
Dr. Andrew Tangborn	Research Associate Professor	Mathematics and Statistics
Dr. Marco Tedesco	Assistant Research Scientist	Research Faculty
Dr. Ali Tokay	Research Associate Professor	Geography and Environmental Systems
Dr. Omar Torres	Research Associate Professor	Physics
Dr. Tamás Várnai	Research Assistant Professor	Physics
Dr. Juying Warner	Assistant Research Scientist	Research Faculty
Dr. Zigang Wei	Visiting Asst. Research Scientist	Research Faculty
Dr. Leonid Yurganov	Senior Research Scientist	Research Faculty
Dr. Hai Zhang	Research Associate	Research Faculty

III.10 Table 2: JCET Fellows (as of September 30, 2007)

NAME	AFFILIATION
Dr. Robert Cahalan	NASA GSFC
Dr. Belay Demoz	NASA GSFC
Dr. Jill Engel-Cox	Battelle Memorial Institute
Dr. Richard Hartle	NASA GSFC
Dr. Weijia Kuang	NASA GSFC
Dr. Thorsten Markus	NASA GSFC
Dr. Alexander Marshak	NASA GSFC
Dr. Vanderlei Martins	UMBC Physics
Dr. W. Wallace McMillan	UMBC Physics
Dr. Harvey Melfi	Emeritus
Dr. Chintan Patel	UMBC CSEE
Dr. Steven Platnick	NASA GSFC
Dr. James Plusqellic	UMBC CSEE
Dr. Marcos Sirota	Sigma Space Corporation
Dr. Lynn Sparling	UMBC Physics
Dr. David Starr	NASA GSFC
Dr. Larrabee Strow	UMBC Physics
Dr. David Whiteman	NASA GSFC

III.11 Table 3: JCET Associate Staff (as of September 30, 2007)

NAME	TITLE
Mr. Dominic Cieslak	Engineer
Mr. Keith Evans	Research Analyst

III.12 Table 4: JCET Administrative Staff (as of September 30, 2007)

NAME	TITLE
Ms. Valerie Casasanto	Program Coordinator
Ms. Danita Eichenlaub	Associate Director
Mr. Glen Engel-Cox	Communications Manager
Dr. Jeffrey Halverson	Associate Director
Dr. Richard Hartle	Associate Director
Dr. Raymond Hoff	Director
Ms. Camilla Hyman	Accountant I
Dr. William Lau	Chair, Executive Board
Dr. Tom Low	Associate Director
Ms. Cathy Manalansan	Administrative Assistant II
Ms. Grace Roscoe	Executive Administrative Assistant
Mr. Derek Stivers	Business Specialist
Ms. Nina von Gunten	Administrative Assistant I

III.13 Table 5: JCET Focus Group Leaders (as of September 30, 2007)

FOCUS GROUP	GROUP LEADER
Atmospheric Radiation	Dr. Omar Torres
Clouds and Precipitation	Dr. Jeffrey Halverson
Interdisciplinary Science	Dr. Andrew Tangborn
Observation Science	Dr. Kevin McCann

Acronyms and Abbreviations

ABOVE	AIRS BBAERI Ocean Validation Experiment
ADRO	Application Development and Research Opportunity
AERI	Atmospheric Emitted Radiance Interferometer
AERONET	Aerosol Robotic Network
AFL	Atmospheric Fourier Transform Infrared (FTIR) Laboratory
AGU	American Geophysical Union
AIRS	Advanced Infrared Sounder
ALEX	Atmospheric Lidar Experiment
AMSR-E	Advanced Microwave Scanning Radiometer – EOS
AMSU	Advanced Microwave Sounding Unit
ARM	Atmospheric Radiation Measurement
BBAERI	Baltimore Bomem Atmospheric Emitted Radiance Interferometer
BOREAS	Boreal Ecosystem Atmosphere Study
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAMEX	Convection and Moisture Experiment
CHAMP	Challenging Minisatellite Payload
CLAMS	Chesapeake Lighthouse and Aircraft Measurements for Satellites
CMB	Core-Mantle Boundary
CNR	Italian National Research Council
CREST	Cooperative Center for Remote Sensing Science and Technology
CrIS	Cross-Track Infrared Sounder
CRM	Cloud Resolving Model
CRYSTAL-FACE	Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment
DOE	U.S. Department of Energy
DRU	Data for Research Use
DSD	Drop Size Distribution
ELF	Elastic Lidar Facility
EOS	Earth Observation System

EP	Earth Probe
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
EUMETSAT	European Organization for the Exploration of Metrological Satellite
FPAR	Fraction of Photosynthetically Active Radiation
GCM	General Circulation Model or Global Climate Model
GEST	Goddard Earth Sciences and Technology Center
GETA	Global Eta
GOCE	Gravity Field and Steady-State Ocean Circulation Mission
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
GPM	Global Precipitation Measurement Mission
GPS	Global Positioning System
GRACE	Gravity and Climate Recovery Experiment
GRSP	Geologically Rough Surfaces Project
GSFC	Goddard Space Flight Center
GV	Ground Validation
HSB	Humidity Sounder Brazil
I3RC	Intercomparison of 3-D Radiation Codes
IAG	International Association of Geodesy
IEEE	Institute of Electrical and Electronics Engineers
IERS	International Earth Rotation Service
IGAC	International Global Atmospheric Chemistry Project
IGARSS	IEEE International Geoscience and Remote Sensing Symposium
IHOP	International H_2O Project
ILRS	International Laser Ranging Service
ISCCP	International Satellite Cloud Climatology Program
ISLSCP	International Satellite Land Surface Climatology Project
LAGEOS	Laser Geodynamics Satellites
LANDMOD	Landslide Modeling and Forecasting Utilizing Remotely Sensed Data
LaRC	Langley Research Center
LBA	Large Scale Biosphere Atmosphere Experiment

LIDAR	Light Detection and Ranging
LITE	Lidar In-Space Technology Experiment
MASSMOVE	Mass Movement (model)
MGS	Mars Global Surveyor
ML	Maximum Likelihood
MODIS	Moderate Resolution Imaging Spectroradiometer
MOSST	Modular, Scalable, Self-consistent, Three-dimensional
NACP	North American Carbon Program
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NGS	National Geodetic Survey
NIMA	National Imagery Mapping Agency
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRA	NASA Research Announcement
NSF	National Science Foundation
NWP	Numerical Weather Prediction
OMI	Ozone Monitoring Instrument
PDF	Probability Distribution Function
PI	Precipitation Index or Principal Investigator
PR	Precipitation Radar
R	Rain Rate
RAMMMP	Regional Air Monitoring, Measurement, and Modeling Program
REALM	Regional East Atmospheric Lidar Mesonet
SAFARI	Southern African Regional Science Initiative
SCS	South China Sea
SLR	Satellite Laser Ranging
SSM/I	Special Sensor Microwave/Imager
TMI	TRMM Microwave Imager
TOGA	Tropical Ocean Global Atmospheres Experiment

TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
TRF	Terrestrial Reference Frame
TIROS	Television Infrared Observation Satellite
TRMM	Tropical Rainfall Measuring Mission
UMBC	University of Maryland, Baltimore County
USDA	U.S. Department of Agriculture
USNO	U.S. Naval Observatory
UV	Ultraviolet
WMO	World Meteorological Organization
WVIOP	Water Vapor Intensive Operations Period
Z	Radar Reflectivity Factor