NINETEENTH ANNUAL REPORT
THE JOINT CENTER FOR
EARTH SYSTEMS TECHNOLOGY

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

July 1, 2013 – June 30, 2014

The Joint Center for Earth Systems Technology

Nineteenth Annual Report
July 1, 2013 – June 30, 2014

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I. EXECUTIVE SUMMARY

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

There are 39 JCET faculty members and 16 JCET Fellows . This category of JCET membership includes civil servants from NASA, in addition to tenured/tenure track UMBC faculty. JCET research is also supported by three research analysts and an Instructional Designer. Brief biographies of each JCET faculty and associate staff members are included. The overall management and administration of JCET is governed by the executive board and carried out by an expert administrative staff. Dr. Susan Hoban is the Associate Director of Academics and coordinates the activities between the academic departments at UMBC and the JCET research faculty. . Dr. Hoban is a Senior Research Scientist and works with NASA Goddard's Education Department. The Board Chairman is a civil servant scientist at GSFC.

The body of this report is divided into sections which align with GSFC research areas. Within each section are presented brief accounts of group members' accomplishments, provided by the respective principal investigators supported through a JCET task and/or grant from NASA or other government agencies that was active during the reporting year July 1, 2013 to June 30, 2014. Each report includes a description of the research, Accomplishments and Objectives.

JCET scientists also contributed to education at UMBC by teaching in First Year Seminars, Honor College Courses and providing both graduate and undergraduate instruction in the Departments of Physics, Mathematics and Statistics, and Geography and Environmental Systemes. JCET Faculty mentoring graduate students in the Departments of Physics and Mathematics/Statistics. The JCET supported graduate students participated in a weekly seminar series with each student presenting once each semester. In the Fall semester, the graduate students presented on their own research. In the Spring semester, each student provided a seminar on a different aspect of wind energy research. More than twenty undergraduate students assisted JCET faculty and Fellow in their research.

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

June 2014

Danita Eichenlaub, Director
Susan Hoban, Associate Director, Academics

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II. TECHNICAL VOLUME

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Earth Sciences Division
(Code 610)

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CCNY Subcontract: **Cooperative Remote Sensing Science and Technology (NOAA-CRESST) Center (CCNY Subcontract)**

HU Subcontract: **Lidar Observations of Land-marine Boundary Layer (Hampton University Subcontract)**

HU Subcontract: **Planetary Boundary Layer Algorithm and Communication (Howard University Subcontract)**

MDE Grant: **UMBC Monitoring of Atmospheric Pollution: Vertical Profiling of Baltimore's Lower Troposphere and Chesapeake Bay Breeze Circulation Study at MDE Edgewood and Horn Point Monitoring Stations for Air Quality Applications (MDE Grant U00P3400325)**

MDE Grant: **UMBC Monitoring of Atmospheric Pollution: Vertical Profiling of Baltimore's Lower Troposphere for Air Quality Applications (MDE Grant U00P44000796)**

MEA Grant: **Measurements of Terrestrial and Offshore Wind Resource over Maryland for Strategic Planning and Development of Offshore Wind Energy Projects**

Investigators: Rubén Delgado, Assistant Research Scientist, JCET; Raymond Hoff, Science Advisor, JCET and Emeritus Professor, Physics; JCET; Alexandra St. Pé, JCET; Christopher Hennigan, Assistant Professor UMBC; Belay Demoz, Howard University; Barry Gross, City College of New York; Patrick McCormick, Hampton University; Fred Moshary, City College of New York; Scott Rabenhorst, Research Associate UMBC Physics; Ryan Stauffer, Penn. State University; Cristina Archer, University of Delaware; Michael Woodman and Laura Warren, Maryland Department of the Environment; Andrew Gohn, Maryland Energy Administration; Pius Lee, NOAA; Melvin Felton, Army Research Laboratory; Evan Osler, NRG Renewable Systems.

Students: Barry Baker, Graduate Student; Daniel Orozco, Graduate Student; John Sullivan, Graduate Student; Jingrui Wang, Graduate Student; Peter Luu, Undergraduate Student; Jared Johnson, Undergraduate Student; Daniel Wesloh, Undergraduate Student; Graham Antoszewski, Undergraduate Student; Farrah Daham, Undergraduate Student; Brian Carroll, Undergraduate Student; Steven Buchner, Undergraduate Student.

Description of Research

Elastic and wind lidar measurements are conducted to measure the vertical distribution of aerosols and wind over the Baltimore-Washington metro area to understand and aid in the assessment of whether exceedances of air pollutants and particulate smaller than 2.5 microns ($PM_{2.5}$) in the Mid-Atlantic United States, and to determine the impact of weather regimes in their seasonal variability. Active remote sensing lidar measurements support the NOAA CREST Lidar Network (CLN), which monitors air quality in the vertical from multiple locations on the eastern coast of the United States, the North American Global Atmospheric Watch: Aerosol Lidar Observation Network, Nocturnal Low Level Jet and Maryland offshore wind assessment studies, sponsored by the Maryland Department of the Environment (MDE) and Maryland Energy Administration (MEA).

Accomplishments in FY 13–14

UMBC's Atmospheric Lidar Group (ALG) continues to provide a set of atmospheric profiles of aerosols, by which analysts of state and federal agencies query their vertical distribution in near real time and compare to the inputs of three dimensional forecasts models. UMBC PBL algorithm was used to retrieve planetary boundary layer (PBL) heights for the National Weather Service Vaisala's CL31 ceilometers, as part of a Proof of Concept Test bed. The algorithm development allowed the evaluation of PBL heights retrieved from CL31 ceilometers, installed at nationwide ASOS sites, and to support the National Weather Service Sterling Field Support Center scientific efforts.

To establish background concentrations and local sources of particle pollution in the Mid-Atlantic United States, source apportionment of 24-hour integrated $PM_{2.5}$ chemical speciation data for the Baltimore metropolitan area for 2008-2012 was performed using the receptor model, Positive Matrix Factorization (PMF). Identification and apportionment of $PM_{2.5}$ to their sources is an important step in air quality management. Data from the Air Quality System (AQS) was used for the identification of 8 factors defined as: Sulfate-rich secondary aerosol (32.28%), Nitrate-rich secondary aerosol (13.1%), Gasoline (19.05%), Diesel (6.18%), Soil (4.43%), Biomass Burning (13.2%), and Marine Aerosol (4.43%) Industrial Processing (7.28%). A cluster analysis of column optical aerosol properties was carried out for aerosol classification, revealing that particle pollution in the Baltimore-Washington metropolitan area is made up from anthropogenic sources, in agreement with PMF results.

Our active remote sensing measurements were augmented with a scanning Doppler wind lidar (SDL) to characterize offshore winds in the state of Maryland. System was acquired in June 2013, as part of a Maryland Energy Administration (MEA) sole source grant, for offshore wind resource assessment in the Mid-Atlantic United States. The offshore wind resource measurements will provide wind energy stakeholders a validated database that will reduce uncertainty of winds over Maryland and along its shorelines for the development and integration of wind energy projects. These research activities will ensure Maryland's contribution to the nation's energy independence, environmental stewardship, and strengthened economy based on clean renewable energy sources. Lidar measurements (elastic and wind) within the marine boundary layer (20-40 km east of Ocean City, MD) were conducted during the month of July and August 2013 with a motion compensated Doppler wind lidar. These measurements are the first collection of offshore winds over Maryland's Wind Energy Area. Collectively, the unprecedented datasets from the summer 2013 campaign and offshore SDL data will serve as the foundation for understanding processes that drive the variability of Maryland's offshore wind energy resource on hours, days, and inter-annual timescales.

Objectives for FY 14-15

Land-marine boundary layer transition under different meteorological conditions will be examined. Three different stages of the land-sea/bay-breeze circulation: the offshore land-breeze flow, the near-calm period before the onset of a sea breeze and an onshore sea-breeze flow will be examined. The differences in backscatter between the moist, droplet-laden air over the water and the drier air over land with its smaller particles have allows to probe and identify these circulation features. The results will allow verify the vertical representativeness of atmospheric parameters in numerical weather prediction models. Seasonal variability of offshore winds will be carried out from Ocean City, MD to study the impact of weather regimes to PBL land-marine transitions for air quality and wind energy applications.

JPL Subaward: **AIRS Climate and Calibrations Algorithms**

NASA Grant: **Validation of the CrIS Sensor Products for Climate Research (NNX11AK78G)**

NASA Grant: **CLARREO: Development Guided by existing Hyperspectral Satellite Knowledge Base (NNX11AG61G)**

NASA Grant: (NNX12AG66G) **Hyperspectral Infrared Earth Radiance Time Series**

Task 381: **CrIS Flight Model 2 Thermal Vacuum Analysis (Sponsor: James Gleason)**

Investigators: Sergio DeSouza-Machado, Assistant Research Professor, Physics, JCET

Description of Research

NASA's Atmospheric Infrared Sounder (AIRS) has been operational since September 2002. Orbiting 16 times a day on the Aqua platform, this new generation instrument has proved to be very stable, and is now beginning to provide us with an opportunity to study a high quality 10 year dataset of atmospheric observations. Of particular interest to us, is how the cloud forcing has been changing over the years, which would be a measure of the cloud feedback. When pieced together with comparable new generation instruments that have recently come online, this should provide scientists with a comprehensive climate quality data record.

Accomplishments in FY 13–14

We continued to analyze 10+ years of AIRS data to provide estimates of atmospheric trace gas, temperature and humidity trends, and have started using cumulative distribution functions which are a more direct meaure of how the overall temperatures have changed. Work has been done under both clear and allsky conditions. The data was filtered by limiting the angles to close to nadir, which reduces the dataset to 5% of available data. Radiance trends were obtained from the filtered set, from which we chose specific channels (namely the 1231 cm-1 window channel) to look at cloud forcing. To this end, we developed a fast infrared scattering radiative transfer code which reduces the multilevel cloud profiles in Numerical Weather Prediction models, to two slab clouds; detailed comparisons with sophisticated models such as Maximum Random Overlap show this simplification yields a model which is very fast and almost as accurate. We used this code to test an Optimal Estimation retrieval scheme where atmospheric geophysical variables (temperature, humidity, ozone and column trace gas amounts) were retrieved in the presence of clouds. Diagnostics from the methodology are tied in to where we retrieve meaningful geophysical parameters from the AIRS data.

An ongoing collaboration with NASA-JPL involves using the Fast Radiative Transfer Model with Scattering (SARTA-Cloudy) developed at UMBC, to analyze AIRS radiances in the presence of dust. The aim is to improve AIRS L2 products in the presence of dust.

A new optical depth database has been generated for use with our monochromatic line-by-line code, kCARTA. The database uses the recently released HITRAN 2012 lineshape parameters. This code will be used to generate new Fast Models for use with AIRS and CrIS.

Two invited talks were given last year. One was at NASA-Jet Propulsion Laboratory (JPL) in Pasadena, CA, where the focus was how to use our scattering model to retrieve aerosol and cloud properties, and to improve AIRS L2 products. The second was at the National Institute of Standards and Technology (NIST) in Gaithersburg, MD, where the talk was an overview of using 10+ years of AIRS data for climate studies.

Objectives for FY 14-15

Intercomparing MERRA and ERA cloud products, and geophysical parameters (Dr. Larrabee Strow and Dr. Andrew Tangborn, UMBC)

Continue to use 10+ years of AIRS spectral data to look for climate trends under cloudy conditions (Dr. Larrabee Strow and Dr. Andrew Tangborn, UMBC)

Use 10+ years of AIRS data to study changes in probability distribution functions (Dr. Andrew Tangborn)

Use 10+ years of AIRS data to look for changes in extremes (Dr. Andrew Tangborn, UMBC)

Develop AIRS L2 retrievals using cloudy sky RTA (Dr. Larrabee Strow)

Implement aerosol retrieval algorithm into JPL/NOAA AIRS L2 code

NOAA Grant: GOES-R Air Quality Proving Ground (AQPG) (NA10NES4280016, NA11NES4400009)

NASA Grant: UMBC Participation in Discover AQ (NNX10AR38G)

Investigators: Raymond Hoff, Research Professor JCET and Emeritus Professor, Physics, Rubén Delgado, Faculty Research Assistant, JCET; Amy Huff, Battelle Memorial Institute, Shobha Kondragunta, NOAA NESDIS/STAR and Fran Fitzpatrick, Fibertek.

Students: Daniel Orozco, Graduate Student; Interns: Hasnain Tasaddaq, Mechanical Engineering

Description of Research

The correlation of column measurements of aerosols as seen from NASA and NOAA satellites with ground based measurements of aerosol light scattering and aerosol mass is a challenging problem, but one which must be assessed in order to advance the utility of those satellite observations. DISCOVER-AQ is a five-year "mission" in the Earth Venture series designed to address this issue. UMBC co-investigates on this project.

A second project is to prepare State, local and tribal air quality forecasters for the next generation satellite measurements which will be available from the Advanced Baseline Imager on the GOES-R series of satellites which will launch in 2015. GOES-R is in a geostationary orbit so it views the western hemisphere at least once every 5 minutes so it will add aerosol and cloud motion to the suite of measurements that we have become used to from polar orbiters. GOES-R ABI aerosol optical depth adds visible and infrared channels that are similar to those on MODIS and VIIRS.

The third project is a development subaward to build a novel high-spectral resolution lidar for NASA using a fiber laser transmitter.

Accomplishments in FY 13–14

Hoff participated in the third Discover-AQ deployment in Houston, Texas. The UMBC Leosphere lidar was used to derive mixed layer heights and aerosol profiles from downtown Houston. Overall, the project did not see significant aerosol events. On one case in late September, significant haze occurred in Houston but unfortunately the NASA aircraft was unable to fly on that day.

Orozco continues to analyse data from the Baltimore-Washington and California deployments of DISCOVER-AQ. Two journal articles are in preparation by him. One paper has been submitted by Patricia Sawamura on the Baltimore-Washington study and Hoff is completing a paper comparing High Spectral Resolution Lidar, UMBC ground based lidars and the WRF-Chem model run by GSFC from the Baltimore-Washington Deployment.

The GOES-R Air Quality Proving Ground (AQPG, http://alg.umbc.edu/aqpg/) is designed to show state and local forecasters what they will have available after GOES-R launches. An Observing Systems Simulation Experiment (OSSE) was completed and a journal article has been submitted. A user group of 39 state and local forecasters have volunteered to advise the project on the utility of such data. In the 2011 demonstration project that ran during the DISCOVER-AQ period, forecasters were generally pleased with what they saw. This training has given rise to two tutorial videos

https://www.youtube.com/watch?v=vuoDpVafZAA and

https://www.youtube.com/watch?v=k17IYMCcHvY, which were presented at the NOAA booth at the American Geophysical Union meeting.

The Fibertek STTR development of a fiber laser based high spectral resolution lidar is nearing completion. UMBC's portion of this work is to design and construct the receiver assembly and to couple the laser through the receiver telescope as a transmitter. UMBC will test the new unit at UMBC against the Elastic Lidar Facility which has a long heritage here. This project is on schedule to complete in December 2014.

Objectives for FY 14-15

In July-August 2014, DISCOVER-AQ will carry out a four week project in the Denver, Colorado, front range region. UMBC will participate with MPL lidars, a wind lidar, and a 355nm Leospere lidar at a site near Golden, Colorado. The hydration system for the PI-Nephelometer has been constructed and will allow the measurement of the aerosol phase function under controlled degrees of relative humidity. This is Orozco's Ph.D. thesis topic. In addition, Professor Chis Hennigan of the Chemical and Environmental Engineering Department will participate in the experiment and have two UMBC students, Jessica Izumi and Jared Johnson also in Colorado.

The GOES-R AQPG will conduct the second demonstration project in during the DISCOVER-AQ mission. The results of this experiment will be analyzed on a new grant to Dr. Amy Huff at Pennsylvania State University. The UMBC portion of the Air Quality Proving Ground terminates in August 2014.

The Fibertek STTR will complete in December 2014 after a testing period for the new instrument.

Task 359: **Trace Gas Retrievals using AIRS (Sponsor: Steven Pawson)**

Task 381: **CrIS Flight Model 2: Thermal Vacuum Analysis (Sponsor: James Gleason)**

NASA Grant: CLARREO Development Guided by Existing Hyperspectral Satellite Knowledge Base (NNX11AG61G)

Investigators: Larrabee Strow, Research Professor, Physics; Sergio DeSouza-Machado, Research Asst Professor, JCET; Chris Hepplewhite, Associate Research Scientist, JCET; Howard Motteler, Associate Research Scientist, JCET; Andrew Tangborn , Research Associate. Professor; Breno Imbiriba, Research Assc, JCET; Tilak Hewagama, Associate Research Scientistt, JCET; and Paul Schou, Research Analyst, JCET

Description of Research

The hyperspectral infrared radiance measurements from the NASA EOS-AQUA Atmospheric Infrared Sounder (AIRS), the NASA/NASA SNPP Cross-Track Infrared Sounder (CrIS), and the Infrared Atmospheric Sounding Interferometer (IASI) provide a wealth of information about the Earth’s atmosphere and surface. AIRS and CrIS fly in a 1:30 am/pm equator crossing sun-synchronous orbit, while IASI is in the 9:30 am/pm orbit. AIRS began operation in Sept. 2002, and has now provided a nearly continuous record of infrared (IR) radiances for 11+ years. Together AIRS/CrIS plus IASI provide four snapshots of the diurnal cycle, and we have the possibility of producing a long-term 20+ year radiance record from the instrument trio, from which we can measure climate change over a time scale of decades. For this, we have developed methodologies to retrieve accurate, well-characterized trends in many of the atmospheric variables (such as temperature, water vapor, trace gas column amounts) measured by hyperspectral infrared satellite sounders, by first determining the linear trend of the measured radiances. Of particular interest to us will be how the cloud forcing has been changing over the years, a measure of the cloud feedback. We will also be looking at the time evolution of the probability distribution functions of AIRS radiances, and tie them to the changes in geophysical parameters and cloud distributions. This work is ultimately dependent on how well the satellite records from different instruments can be combined to form a long time series, and on how stable each instrument is over its lifetime. We have continued our involvement in the validation and pre-launch testing of the CrIS series of satellites, as well as working with AIRS and IASI in order to have a detailed understanding of their calibration.

Accomplishments in FY 13-14

We continued to monitor and analyze 10+ years of AIRS data, to determine long term trends of geophysical parameters. We are in the process of finalizing the determination clear sky radiance trends, which will be tied into the long term stability of the AIRS instruments (DeSouz-Machado/Tangborn/Strow) and have begun analyzing allsky radiance trends, which include the effects of clouds. For inclusion of cloud effects in our studies, we have developed a fast infrared scattering radiative transfer code which reduces the multilevel cloud profiles in Numerical Weather Prediction models, to two slab clouds; detailed comparisons with sophisticated models such as Maximum Random Overlap show this simplification yields a model which is very fast and almost as accurate. We used this code to test an Optimal

Estimation retrieval scheme where atmospheric geophysical variables (temperature, humidity, ozone and column trace gas amounts) were retrieved in the presence of clouds. (DeSouza-Machado/Strow).

We are directly involved in the ongoing validation of the CrIS radiances (Motteler/ Hepplewhite/Imbiriba/Strow) together with collborators from NOAA, JPL and University of Wisconsin. In order to be able to use the datasets of these two instruments for a long term climate record, we are involved in detailed comparisons of the Simultaneous Nadir Observations (SNOs) of these two instruments at all latitudes (Hepplewhite/Strow). Detailed monitoring has shown the instruments to be very stable and accurate, whose measured radiances inter-compare extremely well with each other. We have also developed algorithms to turns the AIRS (diffraction grating single detector) radiances into a CriS-like interferogram, which will allow us to tie the two instrument records together for long-term climate monitoring. We are presently working with the JPSS Project Office at NASA/Goddard to ensure proper pre-launch testing of the next CrIS instrument scheduled to fly on JPSS_1.

Key to all the above is our fast infrared radiative transfer model SARTA. The existing spectroscopy uses the HITRAN 2008 molecular lineshape parameters. We have already generated a compressed lookup-up table using the most recent HITRAN 2012 lineshape parameters for our line-by-line model kCARTA to use, and are finalizing algorithms for comparing the optical depths from kCARTA against those computed using LBLRTM (DeSouza-Machado/Hewagama/Strow). These codes are available to user via github.

Personnel changes:

Dr. Tilak Hewagama, a Planetary Atmosphericist worked with us for one year to help calibrate the CrIS instrument, using his expertise in instrument calibration and line-by-line codes.

Dr. Christopher Hepplewhite, a Science Team Member on HIRDLS, joined the group, and will help inter-compare the AIRS and CriS instruments, as well as use his extensive background knowledge and experience in Atmospheric Physics, to help analyze changes in the observational data record.

Dr. Breno Imbiriba secured a faculty position at a university in his native Brazil, and left after working with our group for 5-7 years.

Mr. Paul Schou has reduced his involvement with our group, but is still actively helping us with system administration and online data maintenance.

Objectives for FY 14-15

The thermal vacuum testing of the next CrIS instrument flying on JPSS-1 should start in the near future. Unlike the NPP CrIS instrument, flight model 2 will be tested in full-resolution mode for both the mid-wave and short-wave bands. We will analyze gas cell data taken during testing to ensure that CrIS is operating properly, and to test a number of new approaches for processing interferograms to calibrated spectra. This work will improve the CrIS spectral calibration. CrIS operation at high-resolution in the short-wave will allow the global, long-term carbon monoxide measure record of MOPITT and AIRS to be continued with CrIS on JPSS-1. We are working with both NOAA and NASA on improved CrIS calibration approaches (numerical conversion of interferograms to calibrated spectra) and will implement the best approach in collaboration with the University of Wisconsin Space Science and Engineering Center (SSEC) to produce a stable and accurate record of CrIS L1b radiances data under NASA HQ direction. These will be preliminary candidates for hyperspectral climate data records.

AIRS will soon have a 12-year record of hyperspectral radiances. We plan to use new analysis approaches to (radiance derivatives) to make robust measurements of changes in atmospheric parameters. These include minor gas trends, such as methane, that are difficult to characterize with standard retrieval approaches. Work will continue on fully characterizing calibration differences between AIRS, CrIS, and IASI and exploring the best way to produce a consistent radiance record from these three sensors. We also hope to continue to explore the use of radiance PDFs (Probability Distribution Functions) as an approach for high-accuracy characterization of atmospheric trends with these sensors.

Task Number 357: Making Earth System Data Records for Use in Research Environments (MEASURES) (Sponsor Nick Krotkov)

Investigators: Leonid Yurganov, Senior Research Scientist, UMBC, JCET; Nickolay Krotkov, GSFC, Principle Investigator; Simon Carn , Co-I, Assistant Professor, Department of Geological and Mining Engineering and Sciences, Michigan Technological University;; Keith Evans, Analyst, UMBC, JCET.

Description of Research:

The research of Dr. Yurganov is connected with application of satellite gaseous composition data for problems of air pollution and climatic change. Sulfur dioxide (SO2) is erupted by volcanoes into the middle and upper atmosphere (Carne et al., 2005). It is further converted into aerosol particles. In some cases these particles may reside in the atmosphere for several years. The volcanic aerosol is an important component in the global climate models. A part of the entire MEASURES project that is lead by Dr. Yurganov is development and quantification of the infrared retrieval techniques for SO2 using radiation data gathered by NASA satellites (Atmospheric infrared sounder/Aqua, Cross-track Infrared Sounder (CrIS)/Suomi).

Accomplishments for FY 13 – 14

A Matlab-based code developed at the UMBC by Scott Hannon and Larrabee Strow that allows for the retrieval of SO2 from volcanoes during day and night using AIRS data with equal accuracy has been modified for a better taking clouds into account. New data sets for atmospheric conditions from NASA archives have been made possible to be used by this code. A priori information on the height of the volcano plume has been studied and assessed. Several volcanic events have been investigated. A significant set of data for evaluation of accuracy of these retrievals has been analyzed during the reporting period and compared with retrievals using other instruments and codes (Fred Prata's codes, AIRS, OMI, IASI instruments). A new, alternative retrieval technique has been developed. It was found that this new and more simple technique performs equally well compared to existing technique. Moreover, it works two time faster. Ozone Monitoring Instrument (OMI) retrievals correlate well with the AIRS data in tropical areas. Near Real Time (NRT) GSFC SO2 retrievals has been evaluated as well. Accuracy of these retrievals is lower than the UMBC retrievals, but tracking of SO2 plumes from volcanoes may be performed very well. The UMBC codes are now modified to be compatible with FORTRAN codes. Writing of Fortran codes is in progress. Also a preparatory work for the Arctic methane and ice cover project that starts in October 2014 has been done. Measurements of methane along the route of a Russian icebreaker Akademik Fedorov from Norway to Eastern Arctic and back has been collected. Increased methane was measured far away from shores in the Arctic Ocean and preliminary identified as emissions from the sea bed.

Objectives for FY 14 -15

Dr. Yurganov will be responsible for finalizing of the development of a FORTRAN-based code for retrievals of SO_2 from AIRS radiation data and implementation of this code on the NASA computers. Also modification of this code for the CrIS data is planned for the period between January and June 2015. Volcanic eruptions since 2002 (AIRS) will be investigated and estimates of total SO_2 mass emitted by these volcanoes will be supplied to NASA as an independent assessments that should validate OMI data. The proposal “Long-term Satellite Data Fusion Observations of Arctic Ice Cover and Methane as a Climate Change Feedback” has been approved by NASA and the start of the work is assigned for October 1, 2014. Validity of the satellite methane data for the Arctic will be thoroughly investigated. Main atmospheric and oceanic processes responsible for the methane cycle there will be assessed.

Meoscale Atmospheric Processes Laboratory (Code 612)

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Task 304: Passive And Active Microwave Retrievals Of Frozen And Melting Precipitation Hydrometeors (Sponsor: Gail Skoronick-Jackson)

NASA Grant: Improvements Of Passive And Active Microwave Precipitation Retrieval Algorithms For Mixed-Phase Precipitating Clouds (NNX11AR55G)

Investigator(s): Benjamin T. Johnson, Assistant Research Professor, JCET and UMBC Physics Department; Gail Skofronick-Jackson, NASA GSFC Code 612; William Olson, Associate Research Professor, JCET.

Description of Research:

Johnson's research has focused primarily on improving multi-sensor microwave (passive and active) retrievals of cold-cloud and mixed phase precipitation. The primary goal is to obtain a higher quality retrieval of precipitation properties such as particle size distribution, particle density, precipitation rate, and particle shape. These improvements can then be implemented in remote sensing algorithms to obtain a more realistic and accurate precipitation retrieval. He has also recently provided calibration assistance for the CoSSIR aircraft instrument (http://cossir.gsfc.nasa.gov/), and participated in a Global Precipitation Measurement mission ground validation campaign called IPHEx (integrated precipitation and hydrology experiment)

Accomplishments for FY13-14:

The primary accomplishments during this reporting period are focused toward precipitation retrieval algorithm development and improvement for the Global Precipitation Measurement Mission, which launched in February, 2014. The primary focus has been testing and modifying the Goddard Profiling Algorithm (GPROF) to improve snowfall retrieval accuracy. In support of the development of the retrieval algorithm, Johnson has focused on computing the microwave properties of realistically shaped ice and snow hydrometeors, and incorporating this into a database for use in the retrieval algorithm.

Johnson is also the principal investigator on a proposal to study the microwave scattering properties of melting ice particles, such as snowflakes and aggregates of snowflakes. The primary goal is to be able to accurately simulate satellite-based observations of snowfall and light rain events. The research on this topic was completed during the reporting period, and a publication is currently under revision.

In addition to his research, Johnson is also a member of the Global Precipitation Mission (GPM) combined radar/radiometer precipitation algorithm development team, and radiometer-only algorithm team. As members of these teams, Johnson is tasked with developing and testing the standard GPM algorithms for passive and combined precipitation retrievals. Johnson is also an active member of the particle size distribution working group, and the land surface working group; both of which operate in support of GPM/PMM.

Johnson was mission scientist for the first three weeks of the recent PMM/GPM ground validation campaign, IPHEx. During this time he coordinated research flight planning, aircraft operations, ground operations, and mission operations on a daily basis with dozens of supporting scientists and engineers working at various locations in North Carolina and surrounding regions.

Johnson has also been an active reviewer for the Journal of Applied Meteorology and Climatology (JAMC), Journal of the Atmospheric Sciences (JAS), Journal of Geophysical Research Atmospheres (JGR-A), and Atmospheric Measurement Techniques (AMT).

Objectives for FY14 -15 :

Primary objective is to develop, test, and validate GPM-era combined passive microwave / radar (GMI/DPR) retrieval algorithm(s) for light rain and snow over both land and ocean using a variety of existing satellite and ground based observations, new retrieval methods, and field experiment results. Work will continue to update and evaluate the GPM algorithms to reflect new data sources and any issues with the satellite.

The research direction is toward developing a working "real-time" post-launch algorithm for GPM which will combine all aspects of the aforementioned research: realistically shaped melting particles, improved retrieval capability, improved forward modeling capability, retrieval over land and ocean of both rain and snowfall, with validation and an estimation of the uncertainties in the retrieved quantities.

Additionally, work will continue in the investigation of the relationship between the complex physical properties of ice-phase precipitation particles (including melting particles) and their interaction with active and passive microwave radiation at wavelengths typically employed by remote sensing platforms.

Finally, efforts will continue to improve calibration methods for the CoSSIR instrument and begin a new role as lead scientist for the CoSMIR instrument.

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

Task: 347 UV integration under MPLNET Lidar Network (Sponsor: Judd Welton)

Investigator: Simone Lolli, Research Associate, JCET

Description of Research:

MPLNET (Micro Pulse Lidar NETwork) is in the process of incorporating a new UV elastic lidar into the network. However, the wavelength and signal noise characteristics are different. Specifically, the current standard algorithms for layer height detection and aerosol and cloud retrievals should be tested on new data retrieved at different wavelength and develop methods to incorporate the data successfully. Taking advantage of the two wavelengths, when available, it is possible to retrieve microphysical properties of the precipitation, cloud and aerosols. New algorithms will be developed and new products will be available for MPLNET Lidar Network

Accomplishments in FY 13-14

A manuscript has been published (Dec, 9th, 2013) in the Journal of Atmospheric and Oceanic Technology (Lolli et al., 2013). The manuscript describes a new technique to retrieve the median average drop size of light rain precipitation using the two different wavelengths (UV and VIS) in MPLNET. This technique allows measuring average raindrop size, of fundamental importance for planetary radiation budget calculations.

A manuscript has been published (Dec, 13th, 2013) in the Atmospheric Measurement Techniques (AMT) Journal (Lolli et al., 2013). The manuscript describes the development of a UV Doppler Wind lidar to measure the atmospheric wind profile. The UV lidar has been tested in the frame of European Space Agency (ESA) measurement campaign to be deployed on a satellite, in the frame of the Atmospheric Dynamic Mission (ADM)

A standalone version of MPLNET algorithm under MATLAB has been released. The investigator was installing the program at Universiti Sains Malayisa (USM) of Penang, which is our partner in 7-SEAS Mission. During his trip in Penang as visiting professor, the investigator held a short course on lidar data analysis applied to atmospheric science. The PhD students are now completely independent in data analysis and submitted for the first time an abstract to SPIE conference (Amsterdam, Sept. 2014). The paper was accepted as oral.

Collaboration with the European Centre for Medium-Range Weather Forecast (ECMWF) has started. A paper has been submitted to SPIE conference and accepted for oral presentation to show the first results of an intercomparison between the aerosol extinction profiles measured by the lidar and the model output.

Objectives for FY 14-15

The algorithm to retrieve average median raindrop size will undergo under further testing in two different double wavelength MPLNET new permanent measurement sites in Wallops and in Penang, Malaysia. The investigator will test then the method and its limitations both at mid-latitudes and in tropical regions. For the end of the year is supposed to be released a final version of the algorithm that will be implemented in MPLNET Version 3.

The investigator, together with ECMWF, will work to assimilate lidar data measurement into MACC-II aerosol forecast model. A scientific paper will be published together with ECMWF.

The investigator will study the radiative forcing of cirrus clouds analyzing MPLNET measurement database (14 years of data for some locations). The main goal is to find any seasonal or geographical pattern in cirrus clouds radiative forcing. A scientific paper will be submitted to a very prestigious journal (as Nature or Science) if the results found something exceptional. An algorithm for near real time cirrus clouds radiative forcing retrieval will be implemented to be part of MPLNET products.

The investigator will setup a lidar measurement campaign together with USM University in Penang, Malaysia, to publish a scientific paper on aerosol characterization over the Malaysian peninsula.

Task 348: **Improvement of feature detection algorithms within the Micropulse Lidar Network (MPLNET), NASA Grant: NNX10AT36A (Sponsor: Judd Welton)**

Investigators: Jasper Lewis, Post-Doctoral Research Associate, JCET

Description of Research

This research is focused on the development of cloud and boundary layer detection algorithms for the Micropulse Lidar Network (MPLNET). The improved algorithms will be used to develop multiyear climatologies at multiple sites around the globe within the network. Results from this research will improve studies of air quality and climate.

Accomplishments in FY 13–14

Development of the version 3 cloud detection algorithm has reached near completion and preliminary tests were conducted using the Goddard (mid-latitude) and Singapore (tropical) sites. A climatology of daytime cirrus cloud properties was developed for multiple collocated Aerosol Robotic Network (AERONET) sites which is currently being used to validate their new cloud screening process. Retrievals of cloud optical depth in Phimai (Thailand) were used to validate a method of partitioning the relative contributions of aerosols and clouds from ground-based solar spectroradiometric measurements.

Lewis is also a co-investigator on a proposal to study mixing layer heights in the DC-Baltimore, MD urban region. The proposed research will use ground-based, airborne, and satellite measurements of the mixing layer height to advance our understanding and predictive capabilities of urban air quality and climate and optimize the NASA Unified variant of the Weather Research and Forecasting model (NU-WRF).

Objectives for FY 14-15

Testing of the version 3 cloud detection algorithm will be completed and the results published during the upcoming fiscal year. A study is planned to assess the efficacy and limitations of cloud optical depth and extinction retrievals from MPLNET using a collocated high spectral resolution lidar (HSRL) in Singapore.

Task 301: **Extreme Precipitation Analysis over the US Great Plains (Sponsor: Scott Braun)**

Task 330: **Capacity Building Training for Water Resource Management (Sponsor: Scott Braun)**

USDA/NIFA Grant: Predictability and Prediction of Decadal Climate and its Societal Impacts in the Missouri River Basin with Climate, Hydrology, Crop Yield, Earth System, and Economic Land Use Models (Grant 2011-67003-30213)

Investigators: Amita V. Mehta (Co. I., Research Assistant Professor, JCET); Vikram M. Mehta (PI, Center for Research on the Changing Earth System); Cody L. Knutson (National Drought Mitigation Center, University of Nebraska); Bruce McCarl (Dept. of Agricultural Economics, Texas A & M University); Norman J. Rosenberg (Center for Research on the Changing Earth System); Raghavan Srinivasan (Dept. of Biological and Agricultural Engineering, Texas A & M University)

Description of Research

Mehta's research during 2013-14 focused on 1) NASA Applied Remote Sensing Training to develop presentation modules for conducting trainings about NASA products from satellites and earth system models useful for water resource and disaster management, 2) National Institute for Food and Agriculture (NIFA) - US Department of Agriculture (USDA) project, to develop statistical technique to downscale surface temperature and rainfall from climate prediction model simulations over the central United States Great Plains (USGP) region and participate in analysis of climate data and their impacts on water and agricultural production 3) NASA Energy and Water Cycle Studies (NEWS) project to analyze the atmospheric water cycle over the USGP from satellite measurements and atmospheric model analysis.

Accomplishments for FY 13-14

Mehta, as a part of the Applied Remote Sensing Training (ARSET) program team, conducted two webinar series and a one-day, in-person training course focused on introducing NASA remote sensing and earth system modeling data and tools for environmental applications. The webinars included a 5-week series focused on introducing freshwater quantities for water resources management and a 4-week series on flood monitoring. The webinar sessions were conducted once a week for an hour. The water resources management webinar was offered twice a day to accommodate US and international participants. Over 197 individuals from 120 organizations and 25 countries participated in the water resources webinar while more than 65 individuals from 15 countries participated in the flood monitoring course. The in-person training was conducted at the United States Agency for International development (USAID) – geospatial Learning Center on April 16, 2014. These training courses also introduced and provided web-based demonstration of NASA data access tools and analysis with GIS applications. The trainings introduced data and access of rainfall from TRMM, soil moisture, evapotranspiration, and runoff from GLDAS/NLDAS, snow cover from

MODIS, and ground water from GRACE. The webinars and training material are available from (arset.gsfc.nasa.gov).

Mehta attended NASA Applied Sciences – Water Resources Science Team meeting in September 2013 to explore potential to include some of their research results and tools in to ARSET. Mehta presented an overview of the ARSET activities at the annual meeting of the American Meteorological Society in February 2014.

As a part of NASA Energy and Water Cycle Studies program, Mehta has been working on detecting extreme rainfall events over the USGP. Mehta used TRMM multi-satellite Precipitation Analysis (TMPA) version-7 to update the extreme event analysis over the USGP. Results of this study will be published during 2014-15. A proposal to extend the scope of this project to other geographical regions was submitted.

As a co-investigator of a USDA-NIFA multi-disciplinary project, with multi-institute team members, Mehta, with the assistance from a graduate student from University of Maryland, Baltimore County, Mr. Sai Popuri, produced downscaled T and Pr based on a statistical regression technique (Tobin, 1958) from two Coupled Model Inter-comparison Project phase-5 (CMIP-5) climate models (HadCAM3 and MIROC5). Furthermore, the downscaled data were used to force Soil and Water Assessment Tool (SWAT) to simulate decadal climate variability of water and crop yields over the Missouri Riven Basin (MRB). Mehta attended a workshop on using SWAT in July 2013. Mehta also attended the MRB stakeholders' meeting in November 2013 and attended Science Team meeting of this project hosted by the National Science Foundation (NSF) in January 2014 and contributed to the project poster presentation.

Objectives for FY 14-15

Mehta will continue to work on the ARSET capacity building project on water resources and disaster management. Mehta will be involved in planning and developing three webinar series and two hands-on training courses during this period. In addition to water resources quantitate, water quality trainings will be offered starting from Fall 2014. Moreover, GIS-based trainings on disaster monitoring and mapping along with socioeconomic data access and applications will be introduced.

For the USDA-NIFA project, Mehta will help conclude the project by participating in writing publications and reports, For the NEWS project, Mehta will extend the extreme rain event analysis to global tropical and mid-latitude regions and create a data-base of these events accompanied by meteorological information. Mehta will participate in a team project of assessing water quality in selected watersheds in the US in which remote sensing measurements of rainfall and vegetation will be used to estimate dissolved organic matter in water reservoirs. Mehta will teach a class on 'Weather and Climate' in the department of Geography and Environmental Systems in Fall 2014.

Task 325: **Global Retrieval of Precipitation and Latent Heating Distributions from Spaceborne Radiometer/Radar Observations (Sponsor: Scott Braun)**

NASA Grant: Development and Evaluation of Improved Ice and Mixed-Phase Precipitation Models for GPM Combined Radar-Radiometer Retrieval Algorithm Applications (NNX13AG87G)

NASA Grant: Characterizing Uncertainties in Large-Scale Atmospheric Heating Distributions Derived from TRMM Observations and Reanalysis Datasets (NNX13AC40G)

Investigators: William Olson, Associate Reserch Professor, JCET; Mircea Grecu, Morgan State University; Kwo-Sen Kuo, University of Maryland College Park; Benjamin Johnson, Assistant Research Scientist, JCET; Lin Tian, Morgan State University; Xianan Jiang, University of California Los Angeles

Collaborators: Andrew Heymsfield, National Center for Atmospheric Research; Stephen Munchak, University of Maryland College Park; Tristan L'Ecuyer, University of Wisconsin; Michael Bosilovich, Goddard Space Flight Center; Sara Zhang, Science Applications International Corporation; Guojun Gu, University of Maryland College Park; Wei-Kuo Tao, Goddard Space Flight Center

Description of Research

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

Accomplishments in FY 13–14

The GPM core mission observatory, successfully launched in February, 2014, features a spaceborne radar (14 and 36 GHz) and a multi-channel passive microwave radiometer (10-183 GHz). Data from these instruments are being used to derive our "best" estimates of precipitation and latent heating vertical profiles, and these profiles, in turn, will be used to cross-calibrate radiometer-only profile estimates from an international fleet of radiometers flying in complementary orbits, and to adjust precipitation estimates from infrared radiometers on geostationary platforms. Prof. Hirohiko Masunaga (Nagoya University) and Dr. Olson co-lead a team that is charged with the continued development and testing of a combined radar-radiometer precipitation/heating algorithm that is applied operationally to the GPM core instrument data.

In the past year, Drs. Olson and Grecu completed the development of a method for estimating precipitation profiles from a combination of GPM radar and radiometer data, and implemented that method for production and near-real-time applications at Goddard Space Flight Center's Precipitation Processing System (PPS). Dr. Olson also developed an operational algorithm for gridding the radar-radiometer precipitation estimates at different resolutions and over different diurnal sub-periods. These algorithms were applied to the first four months of GPM data at PPS and performed without interruption and within operational time constraints.

Using field data from the Midlatitude Continental Convective Clouds Experiment (MC3E) over northern Oklahoma, the group of investigators previously demonstrated that non-spherical ice particle models are required to properly represent microwave scattering properties at the higher frequencies of the GPM Microwave Imager (GMI). Assuming non-spherical ice particles, airborne 14 and 36 GHz radar data from the High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) were used to estimate vertical precipitation profiles. These profiles were then used to simulate upwelling microwave radiances consistent with simultaneous radiance observations from the nadir-viewing Conical Scanning Millimeter-wave Imaging Radiometer (CoSMIR) at 166 GHz. In contrast, an assumption of spherical particles resulted in large discrepancies with respect to the CoSMIR observations. In a second validation test, the HIWRAP-estimated ice particle size distributions were compared to in situ particle distributions derived from airborne probes.The assumed non-spherical ice particles resulted in a better match between the HIWRAP-estimates and in situ data, relative to spherical particles. These finding have important implications for snow estimation using higher-frequency passive microwave data in the GPM mission.

With support from the NASA Energy and Water cycle Study (NEWS) program, Dr. Grecu adapted the GPM radar-radiometer precipitation profile estimation method to input from the TRMM radar and radiometer, and using profile data derived from this method, Drs. Olson and Tao developed a technique for estimating atmospheric latent heating distributions. Dr. Olson extended the technique to estimate the uncertainties in both precipitation and latent heating. This "error model" can be used to derive uncertainties from the scales of individual footprints (~ 5 km) to large space and time averages (global). Such uncertainty estimates are critical for optimizing energy and water fluxes in budget assessments where energy and water are assumed to be conserved. Dr. Olson participates in a NEWS working group studying the energy and water budgets in the stratocumulus regions of subtropical highs and implemented a 1-D model to study the interplay between radiation, subsidence, turbulent fluxes, and cloud microphysics in stratocumuli.

Objectives for FY 14-15

In the scope of TRMM/GPM, the GPM combined radar-radiometer precipitation algorithm will undergo further testing, using both TRMM and GPM input data and available ground truth. Tables representing the properties of non-spherical ice phase precipitation and alternative precipitation particle size distribution descriptions will be implemented. The ice/mixed-phase precipitation physics team is extending the current models of non-spherical aggregate snow particles to melting aggregate particles and will evaluate different precipitation particle models using remote-sensing and in situ observations from the MC3E and the Integrated Precipitation and Hydrology Experiment (IPHEx), which is currently under way.

In NEWS, studies of the uncertainties in radar-radiometer precipitation and latent heating estimates will continue.These estimates will be used to evaluate model-based reanalysis heating datasets prepared by Dr. Jiang. Also, the stratocumulus model will be used to help interpret energy and water budgets in the stratocumulus region of the southeast Pacific subtropics.

Task 361: Develop a Simulation of Hurricane Helene from 2006 from NCEP Global Forecast Systems (Sponsor: Scott Braun)

Task 380: Perform Duties as Project Scientist of the Goddard Earth Sciences Data and Information Services Center (GES DISC) (Sponsor: Steven Kempler)

NASA Grant: Reprocessing of Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) Data Set for Global Water and Energy Cycle Research (NNX08AP35A)

Investigators: Chung-Lin Shie, Associate Research Scientist, JCET; Scott Braun, GSFC; Steven Kempler, GSFC; Long S. Chiu, GMU

Description of Research

Research tasks consist of two research subjects and one duty of project scientist. The first subject, involving an extended study from a completed five-year project funded by the NASA MEaSUREs Program, aims to analyzing the project-produced and widely used GSSTF datasets. The second subject, involving an extended study from another completed project funded via a NASA Task, focuses on studying the impacts of the Saharan Air Layer (SAL) on Atlantic hurricane formation and intensification. In the first subject, two major studies have been performed: (1) studying the trends and variations of the oceanic latent heat flux (LHF) based on the GSSTF2c dataset [Gao, et al. 2013], and (2) introducing and studying several turbulent flux products (including the GSSTF2b dataset) developed by different scientist teams using various algorithms [Chiu et al. 2013]. In the second subject, the study shows that the SAL impact on hurricane Helene appears to be limited to the earliest stages of development [Braun et al. 2013]. For a NASA Task, Shie also serves as Project Scientist of GES DISC since January 2013, providing insight and guidance to GES DISC.

Accomplishments in FY 13–14

The first subject includes two extended studies applying the project-produced global air-sea turbulent fluxes - GSSTF datasets. A series of GSSTF products, GSSTF2b, GSSTF2c and GSSTF3 have been produced in 2010, 2011, and 2012, respectively, through this NASA MEaSUREs funded project. The GSSTF2b (1°x1° globally; July 1987-December 2008), using an upgraded Special Sensor Microwave Imager (SSM/I) V6 brightness temperature (TB), was first produced. The SSM/I TB used to retrieve the GSSTF2b product was later found possessing artificial trends mainly due to a temporal drifting of Earth incidence angle (EIA) of the SSM/I satellites. An improved version GSSTF2c (1°x1°, Jul 1987-Dec 2008) [Shie et al., 2011; Shie, 2011] using the corrected SSM/I TBs by removing the EIA dependence was therefore produced. By further applying an updated algorithm for retrieving surface specific humidity (Qa) directly from TB [Bentamy et al., 2003], the GSSTF3 dataset of a finer spatial resolution (0.25°x0.25°; Jul 1987-Dec 2008) [Shie et al., 2012; Shie, 2012], containing further improved temporal trends, was distributed in November 2012. In the first study, a statistic data analysis, using the method of Empirical Orthogonal Function (EOF), has been applied on LHF of GSSTF2c [Gao et al. 2013]. The first EOF is found as the conventional El Niño Southern Oscillation (ENSO) mode. However, the trends in LHF are found independent of conventional ENSO phenomena, but primarily determined by the pattern of air-sea humidity difference trends. In the second study [Chiu et al 2013], four turbulent flux products such as the satellite-based (1) Hamburg Ocean Atmosphere

Parameters and Fluxes from Satellite Observations (HOAPS), (2) the Japanese Oceanic Fluxes with the Use of Remote Observations (J-OFURO), and (3) the GSSTF2b, plus one reanalysis with merged approach, i.e., (4) the Objectively Analyzed Air–Sea Fluxes (OAFlux) for the global ocean, are introduced. Their error and uncertainties are also briefly discussed. Incidentally, according to the accumulated monthly metrics recorded by the ESDIS Metrics System (EMS), there have been 479,098 numbers of product (granules) and 3.84 TB data volume of the GSSTF products delivered to 895 distinct users from October 2010 to May 2014.

The second subject focuses on studying the influence of the SAL on Atlantic hurricane formation and intensification. In this study, a suite of satellite remote sensing data, global meteorological analyses, and airborne data are used to study the evolution of the SAL in the environment of Helene and assess its possible impact on the intensity of the storm. Dry air observed to wrap around the periphery of Helene is diagnosed to be mainly non-Saharan in origin (the result of subsidence) and appears to have little impact on storm intensity. The eventual weakening of the storm suggests as a result of an eyewall replacement cycle and substantial reduction of the sea surface temperatures beneath the hurricane as its forward motion decreases. Shie also serves as Project Scientist of GES DISC, providing insight and guidance to GES DISC. Shie also routinely helps the GES DISC Manager coordinating interactions/meetings between GES DISC and its User Working Group (UWG) aiming to bridge together the user community, the data providers, and GES DISC (the data distributor and the service provider) for improving the user/data services, and developing new services at DISC. A 1.5-day GES DISC UWG meeting (held every 18 months) has recently been successfully held at Goddard in early May 2014, following three telecom meetings held in April, August and December 2013, respectively. Shie also helps inviting guest speakers for giving scientific talks at the GES DISC Weekly Lunch Seminar Series. At last, a few additional collaborative studies achieved during this past year include: (1) the effects of carbonaceous aerosols on climate [Hsieh et al, 2013], (2) the dry air impact on Tropical Storm Derby [Gao, et al. 2013], and (3) the sea surface response to Typhoon Morakot [Lai, et al. 2013].

Objectives for FY 14-15

The first project (GSSTF) has officially ended in May 2013. Shie may seek future funding opportunity for resuming the data production by considering using the upcoming GPM satellite retrievals. The second project, study of SAL's impacts on Atlantic hurricanes, may continue with possible task funding. For the third task, Shie will continue serving as project scientist at GES DISC, providing insight and guidance for further developing and improving data services, as well as enabling technologies for environmental remote sensing research.

NASA Grant: Synthesis of GPM GV Hydrometeor Datasets for Combined Precipitation Retrieval Algorithms (NNX 13AI86G)

Task 327: Measurements of Hydrometeor Size Distributions during Global Precipitation Measurement (GPM) Field Campaigns (Sponsor: Matthew Schwaller)

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

Description of Research

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

Accomplishments in FY 13–14

A manuscript has been published in Journal of Atmospheric and Oceanic Technology [Tokay et al, 2013]. The manuscript documents the shortcomings of impact-type, laser-optical, and two-dimensional video disdrometers through collocated six-month long measurements of raindrop size and fall velocity in Northern Alabama. The parametric form of the size distribution, which is determined through surface and airborne measurements, plays an important role in spaceborne precipitation retrieval algorithms such as the one from upcoming Global Precipitation Measurement (GPM) mission.

A manuscript has been published to the Journal of Hydrometorology [Tokay et al. 2014a]. This manuscript investigates the spatial variability of rainfall through five-year long rain gauge network (11 sites) observations in Eastern Shore, Maryland/Virginia. The sub-pixel space variability is one of the key issues of the spaceborne precipitaton retrieval algorithms. This study was conducted through summer intern, Rigoberto Roche of Florida International University.

A manuscript has been published to the Journal of Hydrometorology [Tokay et al. 2014b]. This manuscript presents the performance of the new version of Parsivel through comparative field study with impact-type disdrometer, old version of Parsivel, and rain gauges have been conducted.

A visiting doctoral student, Leo Pio D'Addrico of University of Ferrara, Italy, worked on three diferent projects. The student investigated the role of drop brek-up in size distribution parameters; examined the spatial variability of raindrop size distribution; studied to determine the maximum drop diameter in modeling size distribution.

A former master degree student, Heidrun Horchen of University of Bonn, completed her master thesis. Her work focused on the microphysical aspects of falling snow utilizing field campaign data from Southern Ontairo Canada. A visiting summer intern Jorel Torres of South Dakota Shool of Mines is studying the snow microphysics from past winter at Wallops Island, Virginia.

A disdrometer and radar based dataset shows that Hurricane Sandy (2012) had two distinct characteristics. At a given reflectivity, rain rates were lower and mean mass diameters were higher at the early state of the superstorm where mid-latitude frontal system was dominant. The rain rates were higher and mass diameters were lower during the latter part of the storm where more small drops and less large drops were observed. The findings of this study were presented during 36th radar meteorology conference.

The investigator is recently appointed as the associate editor for the Journal of Applied Meteorology and Climatology.

Objectives for FY 14-15

The investigator is expected to complete ongoing studies and submit two manuscripts to peer-reviewed journals. The recently completed field campaign datasets including Iowa Flooding Studies and Integrated Precipitation Hydrology Experiment brought new opportunities to investigate the microphsyics of rainfall in orographic terrain. The small-scale variability of rainfall is currently evaluated through a specialized rain gauge network in mid-Atlantic region. The new network will include dual 25 gauge sites, which will over 5 x 5 km array. The gauge network in Souther Delmarva Peninsula has also expanded to 16 sites. Measurements of raindrop size distribution have been continuously collected at NASA GSFC building 33 roof. A new collaboration with Dr. Molly Brown focused on the flooding modeling at GSFC using gauge data. Collobrations with Patrick Gatlin is on the maximum drop size distribution observation and with Liong Liou on parametric aspects of size distribution is undergoing.

Climate and Radiation Laboratory (Code 613)

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NASA Grant: Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) (NNX10AR41G)

NASA Grant: Improve EPA's AIRNow Air Quality Index Maps with NASA Satellite Data (NNX11AI76G)

Investigators: D. Allen Chu (Grant PI; Associate Research Scientist of JCET/UMBC and NASA GSFC Code 613), Jim Crawford (DISCOVER-AQ Project PI, NASA LaRC, Science Directorate), Ken Pickering (DISCOVER-AQ Project Scientist, NASA GSFC Code 614), Phil Dickerson (Air Now Project PI, EPA)

Description of Research

Both projects have used airborne HSRL aerosol extinction measurements to serve as the baseline study of the relationship between AOD and $PM_{2.5}$ while DISCOVER-AQ also provides extensive surface networks of sunphotometer and lidar measurements during a series of field campaigns over CONUS. These surface networks are aimed to provide the baseline evaluation for $PM_{2.5}$ estimate derived form satellite remote sensing measurements. Lidar-derived HLH (Haze Layer Height) are the key to the linear approximation of $PM_{2.5}$. The ratio of near-surface and mean PBL extinctions is used as an indicator to classify aerosol vertical distribution. Correlation and linear regression statistics are used to assess the goodness of fit between the observed $PM_{2.5}$ and estimated $PM_{2.5}$ by sunphotometer and satellite aerosol optical depth measurements.

Accomplishments in FY 13–14

Comparative study of DISCOVER-AQ over Baltimore-Washington Corridor (BWC) in July 2011 and San Joaquin Valley (SJV) in January-February 2013 is the primary focus for the July 2013 - June 2014 reporting period. In addition to HLH and PBLH (Planetary Boundary Layer Height), MGH (Maximum Gradient Height) is also included for intercomparing the linear approximation used for normalizing AOD. Both atmospheric environments of summer (July 2011) and winter 2013 lead to the maximum regional $PM_{2.5}$ as expected. Though the maximum $PM_{2.5}$ levels are similar (~60-70 g/m^3) over the periods, the maximum AOD values are rather different – 25%-50% of AOD values were measured in SJV (<0.3) than those in BWC (<0.6). The former is due to summer stable atmosphere and latter is subject to the dominance of temperature inversion of synoptic systems. As a result, well-mixed $PM_{2.5}$ environments are generally seen in the summer environment of BWC (monthly mean $PM_{2.5}$ ~16-18 μg/m^3) whereas more isolated pollution distribution is typical in the winter environment of SJV (monthly mean $PM_{2.5}$ ~26-32 μg/m^3).

HSRL and HSRL2 measurements were acquired during BWC and SJV field campaigns, respectively. HSRL and HSRL2 are denoted as different instruments deployed during July 2011 and January-February 2013, respectively. Overall, the mean AOD abundance over BW (~0.26) in July is twice larger than that over SJV (~0.11) in January-February period. The mean percent of AOD below PBL is found in the range of 0.35-0.8 and 0.4-0.8 over BW and SJV, respectively. The zigzag feature of the percent AOD within PBL (hereinafter AOD-PBL) generally corresponds to a.m. vs. p.m. flight leg. Larger percentages show higher AOD values within PBL in the afternoon as a result of the entrainment of aerosols aloft into boundary layer and increasing secondary aerosol production as a result of increasing atmospheric temperature. In regard to the correlation with mean PBL extinction, the linear approximation by normalizing AOD with respect to HLH, PBLH, and MGH, it is clear to see higher correlation resulted from AOD/HLH, followed by AOD/PBLH and AOD/MGH over both BW and SJV. Correspondingly, RMSE is much smaller as derived by AOD/HLH (< 0.01; mostly less than 0.005) compared to those derived by AOD/PBLH and AOD/MGH. The approximation of using PBLH does not account for elevated aerosols above PBL while the use of MGH would either underestimate or overestimate the height of homogeneously mixed aerosols since the derivation of MGH does not assume uniform mixture of aerosols below MGH. It is important to note correlation > 0.9 over SJV by AOD/HLH as opposed to BWC that temperature inversion compresses aerosols to lower altitudes resulting in better mixing of aerosols.

Estimated $PM_{2.5}$ values versus $PM_{2.5}$ measurements also depend upon the distance as AOD is in linear regression, namely, the closer to the targeted sunphotometer station the higher the correlation. The pattern of correlation of estimated and observed $PM_{2.5}$ generally reflects to a decreasing trend (0.9 to 0.7) with increasing distance from 0° to 0.7° in SJV. As expected, the best correlation is obtained by AOD/HLH. It is worth noting the differences of AOD/MGH and AOD/MGH are small within 0°-0.7°. By contrast, the distance dependence of correlation between estimated and observed $PM_{2.5}$ appears to be less significant in BW Corridor (including Beltsville, Edgewood, and Fair Hill). The change in correlation is less than 5% within the range of 0°-0.5°, which is most likely attributed to homogeneously mixed summer environments over BWC. The zero-order approximation derives the exponent of f(RH) based upon the best correlation of NSE (Near Surface Extinction) and the product of $PM_{2.5}$ and f(RH), where $f(RH)=(1-RH/100)^{-r}$. Due to the lack of conventional surface measurements of aerosol scattering and absorption of various aerosol components, the zero-order approximation is only to test the sensitivity of f(RH) to a range of exponent, not specific values of chemical components. As high spatial variability is shown by AOD, f(RH) results are examined over the range of 0° to 1° with an incremented of 0.1°. Two distinct ranges of exponent are obtained over SJV – 0.1-0.2 at around Bakersfield and 0.3-0.5 at around Fresno. In comparison, the exponents of f(RH) over BWC are shown in the range of 0.8-0.11, 0.4-0.7, and 0.1-0.4 at Edgewood, Beltsville, and Fair Hill, respectively.

Objectives for FY 14-15

The objectives of FY 14-15 will focus on summarizing the statistics derived from DISCOVER-AQ field campaigns based upon the linear approximation $PM_{2.5}$ with respect to AOD, AOD/HLH, AOD/PBLH, and AOD/MGH. The critical component is the availability of the airborne aerosol extinction profiles. The monitoring system building will continue in conjunction with a sophisticated statistical model (pending on implementation of inputs of GEOS-5 data and CALIPSO measurements). Detailed tasks include 1) comparison of aerosol optical and chemical properties in SJV and Houston because of complex pollution sources, 2) analysis of aerosol extinction profiles from multiple MPL lidars in BWC in collaboration with PIs of surface measurements, and 3) near-real time MODIS AOD map in DISCOVER-AQ Field campaign in Denver in July-August 2014, and 4) continuing collaborations with DISCOVER-AQ colleagues in NASA Langley Research Center and Universities on a number of manuscript preparations.

Task 311: **Instruments and Methods to Study the Radiative Properties of Aerosol and Cloud Particles (Sponsor: Charles Ichoku)**

Subtasks: **313, 314, 315, 316, 317, 318**

NASA Grant: A Statistically Robust Evaluation of the AERONET Retrieval Algorithm (NNX12AH30A)

NASA Grant: Deployment of the PACS Imaging Polarimeter and the Polarized Imaging Nephelometer for the Measurement of Cloud and Aerosol Properties during the SEAC4RS and DC3 Campaigns (NNX12AC37G)

NASA Grant: Development of Algorithm and Instrumentation for Integration of the PACS Imaging Polarimeter in the ER-2 Aircraft (NNX11AN11G)

NASA Grant: Airborne, Polarized Imaging Nephelometer for Measuring Aerosol Phase Matrix: In Situ Experiments and Comparison to the New Generation of Remote Sensors (NNX11AL61H)

DOE Grant: **Airborne Open Polar/Imaging Nephelometer for Ice Particles in Cirrus Clouds and Aerosols (160790)**

NASA Grant: Development of the PACS polarimeter system in preparation for the ACE mission (NNX12AR35G)

NASA Grant: Support for the detailed aerosol characterization (NNX12AR34G)

NASA Grant: HARP CubeSat Launch Initiative (NNX13AN11G)

NASA Grant: HyperAngular Rainbow Polarimeter HARP-CubeSat

NASA Grant: Communicating scientific findings concerning aerosols NASA Grant: Assessing contributions of foreign aerosol sources (NNX12AK81G)

Investigators: J. Vanderlei Martins, Fellow, JCET, Associate Professor, Physics; Roberto Fernandez-Borda, Assistant Research Scientist, JCET ; Dominik Cieslak, Research Engineer, JCET; John Hall, General Associate, JCET, Oleg Doubovik, General Associate, JCET, Hamilton Townsend, General Associate, JCET; Frank Harris, General Associate, JCET

Students: Gergely Dolgos, PhD Student; Adriana Rocha Lima, PhD Student; William Espinoza, PhD Student; Jitin Krishnan, Ms. Student, UMBC; Haotian Sun, Undergraduate Student, UMBC, Jesse Sheldon, Undergraduate Student, UMBC; Brent McBride, Undergraduate Student, UMBC; Gordon McDonnell, Undergraduate Student, UMBC; Kailas Metha, Undergraduate Student, UMBC; Ryan Morgan, Undergraduate Student, UMBC; Benjamin Sparr, Undergraduate Student, UMBC; Steven Lavenstein, Undergraduate Student, UMBC; Daniel Christner, Undergraduate Student, UMBC

Description of Research

The optical properties of aerosol particles and their 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 issues are addressed in this task with a variety of new techniques and methodologies that cover instrument development, laboratory and field measurements from the ground and aircraft, algorithm development, satellite remote sensing, and model calculations.

The impact of aerosol in clouds and precipitation is another very important topic in aerosol research. These tasks address this topic via the study of aerosol microphysical properties and via the measurement of cloud spectral properties using novel instrumentation developed in the team's laboratory. Major efforts in these tasks are also devoted to the development of new ground based, airborne, and satellite techniques to measure aerosol, clouds, and its interactions and consequences. Prototype instruments were built and are being applied to the measurement of cloud properties from the ground and from aircraft, like the PACS polarimeter as part of the ACE Mission development, the PI-Neph and the Open INeph in situ instruments for the measurement of the polarized angular properties of aerosol and cloud particles.

Accomplishments in FY 13–14

The investigators have continued their efforts on the development of algorithms, instrumentation and methods for the measurement of aerosol absorption and scattering properties via remote sensing and in situ techniques, on the development and application of instrumentation for the measurement of the effect of aerosols on the vertical profile of cloud effective radii and thermodynamics, and on the development of instrumentation and methods for the measurement of multi-angle polarized radiances for the retrievals of aerosol and cloud microphysical and thermodynamic properties. The team has also continued the collection and analysis of in situ data from several field campaigns and ground stations. Significant efforts were made towards the development of new remote sensing measurement concepts from aircraft and space. Important efforts were also dedicated to the understanding of the effect of aerosol particles on cloud formation, evolution, and lifetime. The team continued the effort to build and fly the airborne simulator of the PACS polarimeter which is being proposed as part of the ACE Decadal Survey Mission. Martins and his team have completed the construction of two PI-Neph (Polarized Imaging Nephelometer) instruments that flew in the DEVOTE, DC3, DISCOVER AQ, and SEAC4RS field campaigns measuring polarized, angular scattering properties of aerosol particles on board the NASA DC8, P3, and B-200 aircrafts.

Specific developments include: the completion and flight test of the VNIR PACS airborne multi-angle imaging polarimeter prototype for the ACE Mission proposal, development of algorithms and methods for the measurement of cloud microphysical propertied using the polarized cloud-bow, application of dry and wet aerosol generators developed in the group for the production and measurement of various types of aerosols in the laboratory, development of the Open I-Neph instrument for the measurement of the polarized aerosol phase function under the wing of the NASA P3 aircraft, in open air without the use of inlet or enclosed chamber, development and application of techniques for the measurement of the spectral absorption properties of aerosols from 200-2500nm, and development of a concept and instrumentation for the measurements of hyperangular polarized radiances using Pico Satellites for the HARP project.

The team has also developed new algorithms for the processing of multi-angle polarized images acquired by the PACS polarimeter in the NASA ER-2 aircraft during the PODEX experiment and is currently analyzing the data to retrieval of aerosol and cloud properties.

Objectives for FY 14-15

The team will participate in the DISCOVER AQ experiment in 2014 flying by the first time the Open INeph system for the measurement of polarized phase function in open air, under the wing of the NASA P3 aircraft. This is the first time this instrument will be flown and tested in airborne conditions. In addition to the Open INeph, the team will also have one PI-Neph instrument inside the NASA P3 aircraft measuring polarized phase function through the aircraft inlet, and a second PI-Neph instrument on the ground, inside the UMBC trailer, measuring the humidification properties of the aerosol phase matrix. The team will continue the development of new in situ instrumentation for aerosol sampling and for the measurement of aerosol scattering and absorption properties, as well as the development of remote sensing techniques for the measurement of aerosol absorption and direct radiative forcing, and polarization algorithms for the detailed retrieval of aerosol and cloud particles. As part of this effort the team will continue the development of the PACS SWIR telescope, and will continue the development and construction of the HARP CubeSat satellite. The team will also continue to analyze data collected from multiple field campaigns with the PI-Neph, RPI and PACS instruments.

Task 319 : CALIPSO- CloudSat (Sponsor: Lazaros Oraiopoulos)

NASA Grant: Evaluate and constrain aerosol indirect effect in the trade cumulus regime with NASA data and models (NNX13AM19G)

Investigator: Tianle Yuan, Research Assistant Professor, JCET

Description of Research:

Yuan's research is in the area of aerosol-cloud-climate interactions. This is among the least understood aspects of climate change. His efforts are targeted at reducing the uncertainties surrounding the interactions among aerosol, cloud and climate. Specifically, how aerosols change trade cumulus cloud properties and the consequences of these changes using modeling and observational tools.

Accomplishments in FY 13 -14

A paper was published in Journal of Geophysical Research- Atmosphere [Yuan and Oreopoulos, 2013] showing the global character of overlap between low and high clouds is examined using active satellite sensors. Low-cloud fraction has a strong land-ocean contrast with oceanic values double those over land. Major low-cloud regimes include not only the eastern ocean boundary stratocumulus and shallow cumulus but also those associated with cold air outbreaks downwind of wintertime continents and land stratus over particular geographic areas. Globally, about 30% of low clouds are overlapped by high clouds. The overlap rate exhibits strong spatial variability ranging from higher than 90% in the tropics to less than 5% in subsidence areas and is anticorrelated with subsidence rate and low-cloud fraction. The zonal mean of vertical separation between cloud layers is never smaller than 5 km and its zonal variation closely follows that of tropopause height, implying a tight connection with tropopause dynamics. Possible impacts of cloud overlap on low clouds are discussed.

Objectives for FY 14-15

Work will continue on the issue of aerosol-cloud interactions. A comprehensive study [Yuan et al., 2014] that investigates the impact of aerosols on ice particle size and glaciation temperature will be finalized this year. This study investigates how aerosols may change cloud top ice particle size and cloud glaciation process. Furthermore, it studies the variation of aerosol effect that changes with aerosol type. Two additional manuscripts will be drafted that address the statistics of deep convective cloud size and macrophysics as well as their thermodynamic control [Wilcox, Yuan et al., 2014a]. In addition, how aerosols affect the size of deep convective clouds and why with both modeling and observational tools will be investigated. [Wilcox, Yuan et al., 2014b].

Task 322 : Collaboration on solar forcing of climate change (Sponsor: Robert Cahalan)

Task 358: Observational study of solar variability impacts on the troposphere, stratosphere and mesosphere (Sponsor: Dong Wu)

Investigators: Jae N. Lee (Science PI: co-I), JCET; Dong L. Wu (PI), GSFC Code 613; Alexander Ruzmaikin (co-I), JPL/Caltech; Robert Cahalan (PI), GSFC Code 613

Description of Research:

Research has focused primarily on analyzing multi-sensor spaced based observations of physical variables and atmospheric tracers in conjunction with the solar irradiance data from SORCE to develop appropriate Sun-Earth interaction processes.

Accomplishments for FY '13 - '14:

As a science PI of the NASA's Living With a Star program, under the task 358, the primary accomplishments during this period are focused on the solar rotational variability from space-based observations of solar irradiance. In her recent work with the TSI variation, she clearly identifies solar rotational variations from SORCE/TIM, ACRIM III, and SOHO/VIRGO Total Solar Irradiance (TSI) observations [Lee et al., 2014] throughout the whole observation periods of each instrument. The rotational variations of TSI from the three independent observations are generally consistent with each other, despite different mean TSI values. Lee characterizes the amplitude of TSI 27 day variations in terms of W/m^2 and in percent, during the declining phase, minimum phase, and rising phase of the solar cycle 23-24.

Lee is continuing a quantitative examination of the significant temporal variability (e.g., 11 year and 27 day period) of atmospheric water vapor and temperature, extending an earlier study of Lee et al. [2007; 2009a; 2009b; 2011; 2013]. Lee investigated the variability of the stratospheric water vapor composition in the tropical middle atmosphere and its relation to the dynamics and chemistry. She finds that the interannual anomalies in water vapor tape recorder display upward propagation below about 10 hPa, but at higher levels show obvious downward propagating signals. Her analysis clarify the principle roles in temperature anomalies induced by the QBO at the tropopause for upward propagation, and those in mean vertical gradient of water vapor and QBO's residual vertical velocity for downward propagation [Kawatani et al., 2014].

Under the task 322, Lee is working as a member of the Polar Free Flyer TSIS (Total Solar Irradiance Sensor). As a member of the team, she is participating in the progress of TSIS and TCTE (TIM Calibration Transfer Experiment) missions. She was awarded with an

“Outstanding Scientific Support”, by NASA climate and radiation laboratory, for SORCE science and of TSIS instrument development for the NASA/NOAA JPSS free-flyer mission. She was also awarded with a “Certificate of Recognition”, by NASA and NOAA JPSS Directors, in recognition of her contributions to the successful completion of the JPSS Program’s Key Decision Point-I and Key Decision Point-C milestones.

Lee has been an active reviewer for the Geophysical Research Letters and Journal of Geophysical Research and 2012 and 2014, 2015 science team meeting organizer for SORCE.

Objectives for FY '14 - '15:

Lee’s primary objective is to keep developing and validating the solar impact on Earth’s climate using a variety of existing satellite observations and model results. Additionally, she is investigating the modes of the solar spectral variability, which will combine all aspects of the solar variability from the solar spectral observations and models. The new objective is to analyze the existing TIM (Total Solar Irradiance Monitor) and SIM (Spectral Solar Irradiance Monitor) measurements from SORCE in conjunction with TCTE (TIM Calibration Transfer Experiment) instrument, launched with STP Sat3 in 2013, which can be used as TSI data gap filler between the SORCE and TSIS.

Lee will also work on the recent changes of temperature and cloud and their feedbacks over Greenland for the IDS project, which is newly awarded in 2014. She will validate AIRS and MODIS temperature products with in situ measured station data. She will collaborate with Joel Susskind, who performed a series of AIRS temperature and tracers retrievals.

Task 326: **Statistical Modeling of Rainfall Data Sets from Ground Based Radar and Rain Gauge Measurements (Sponsor: Mathew R. Schwaller)**

Investigators: Prasun K. Kundu, Research Associate Professor, JCET Physics and Mathematics; James E. Travis, Graduate Student, Department of Mathematics and Statistics, UMBC; David. A. Marks, SSAI and NASA WFF.

Description of Research

There are four major goals of the research performed under this task: 1) developing mathematical models of rainfall statistics that quantify the natural space-time variability of rain; 2) applying these models to describe statistical behavior of precipitation data sets from a variety of sources including satellite and ground based radar and rain gauge measurements including the Global Precipitation Measurement (GPM) Mission; 3) development of statistical techniques for validation of ground radar observations of rain against rain gauge observations at the GPM ground validation (GV) sites including one being set up at the Wallops Flight Facility in Virginia; and 4) inter-comparison of satellite and ground observations of rain from GPM.

Accomplishments for FY 13-14

With Mr. James Travis, a JCET Fellow for Academic Year 2012-13 and a Ph.D. candidate at the Department of Mathematics and Statistics, UMBC, the team has formulated a comprehensive statistical model of area- and time-averaged precipitation from co-located radar and rain gauge measurements at a TRMM GV site. A new statistical model based on a linear stochastic differential equation of fractional order for the point rain rate field is introduced to describe the second moment statistics of space- and/or time-averaged rainfall data. It improves upon a previous model of Bell and Kundu [1996] and Kundu and Bell [2003] that was originally devised to primarily describe the statistics of radar rainfall observations. Two generalizations of the previous models are introduced: a fractional order time derivative in order to fit the temporal covariances of radar averages better a small lags, and a spatial wave number cut-off at small spatial scales to account for the leveling off of the variance of gauge averages at small time scales instead of a power law divergence predicted by the earlier models. The new model yields a unified theoretical description the second moment statistics of precipitation data over a much larger range of length and time scales that encompass both radar and gauge measurements. The model has been successfully applied to rainfall data from TRMM ground validation sites at Melbourne, Florida and Kwajalein Atoll, Republic of Marshall Islands in the Pacific Ocean. The model yields the space-time Fourier spectrum of the local instantaneous rain rate which can be mathematically related to the space-time covariance functions of area- and time-averaged rain rate. The parameters of the model are estimated from the covariance statistics of area-averaged rain rate from the Melbourne and Kwajalein radars (TRMM standard product 2A-53). The model predictions for the covariance statistics of time-averaged point rain rate are then computed and tested against the measured statistics from a network of rain gauges located within the radar field of view (TRMM standard product 2A-56). The model is found to fit the observed statistics remarkably well at spatial scales extending to tens of kilometers and time scales from minutes to a few hours. A full-length paper on the model has now been published in Journal of Geophysical Research – Atmospheres [Kundu and Travis 2013].

The practical goal of the model has been to quantify the statistical difference between radar and gauge observations of rain at the same spatial location over a period of time [Bell and Kundu 2003] and thus help calibrate the radar using the gauge observations as reference. A statistical method of inter-comparison between rain rates estimated from a specific gauge and the corresponding radar pixel based on the spectral model has been developed and tested using the TRMM ground validation data sets in collaboration with David Marks from SSAI and GSFC who is an expert on the observational aspects of both data sets. A paper on the subject has been submitted for publication to Journal of Geophysical Research – Atmospheres. The work constitutes the topic of Mr. Travis' Ph.D. Dissertation.

Objectives for FY 14-15

In the coming year, contingent upon available fnding, the immediate goals are: 1) to apply the new fractional stochastic dynamics model of rain to various radar-gauge inter-comparison scenarios relevant for GPM validation as the Wallops data becomes available; 2) examine spatial statistics of TRMM PR (Precipitation Radar) derived rain data and test the model predictions with regard to the multiscaling behavior; and finally 3) pursue the problem of obtaining a parameterized model of the probability distribution of area-averaged rain rate [Kundu and Siddani, 2007, 2011] and the joint distribution as function of time lag in terms of a suitably chosen copula using existing ground radar data from the validation sites.

Task 321: **Retrieval of Cloud and Sea Ice Properties from THOR Lidar Measurements (Sponsors: Robert Cahalan and Alexander Marshak)**

Investigators: Tamás Várnai, Research Associate Professor, JCET, Physics, UMBC; Alexander Marshak, Fellow, JCET, GSFC; Robert F. Cahalan, Fellow, JCET, GSFC; Frank Evans, University of Colorado; Charles Gatebe, USRA; Guoyong Wen, Morgan State University; Weidong Yang, USRA

Description of Research

The ultimate goal of this work is to help better understand and characterize the role atmospheric aerosols and aerosol-cloud interactions play in our climate. The research focuses on two main areas. First, it examines the systematic changes in aerosol properties that occur near clouds. This includes characterizing the way these changes are dependent upon season, location, and scene properties, as well as understanding their causes and estimating their radiative impacts. This work also includes examining the abundance and radiative impact of undetected cloud droplets that occur outside clouds identified in satellite images. Second, the research investigates the uncertainties 3D radiative processes cause in satellite retrievals of cloud properties and aerosol properties near clouds. This involves combining data from several satellites with radiation simulations, and also developing a correction method that allows satellite data interpretation algorithms to consider the impact of 3D radiative processes.

Accomplishments in FY 13–14

Várnai and team continued their research on the systematic changes in satellite observations near clouds [Várnai and Marshak, 2014]. They focus on this issue because several studies found strong and systematic changes in clear-sky observations in the vicinity of clouds, and also because the surroundings of clouds cover huge areas, with about half of all clear areas being within five kilometers from clouds.

This year, the team first examined whether the fact that satellite-estimated aerosol properties change systematically with distance to clouds may be explained by correlations between aerosol properties and regional cloud coverage. For this, the team analyzed aerosol data from two instruments in the NASA A-train satellite constellation: MODIS (Moderate Resolution Imaging Spectroradiometer), and CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization). Data from both instruments showed that correlations between cloudiness and aerosol parameters do indeed contribute to the observed near-cloud increase in aerosol concentration and particle size, but the results also revealed that most of the near-cloud increases are present even if one considers only areas within a narrow range of cloudiness [Marshak et al., 2014a].

Várnai and colleagues further examined near-cloud particle changes by combining aerosol data from two MODIS products: atmospheric correction parameters in the ocean color product and aerosol parameters in the atmospheric product. In examining the northeast Atlantic Ocean, they found that most of the near-cloud aerosol changes come from changes in large particles such as sea salt, while the populations of small particles such as industrial pollution are much less affected. As a result of processes such as aerosols swelling in the humid air that surrounds clouds or the presence of undetected cloud particles in almost perfectly cloud-free atmospheric columns, the mass concentration of particles was found to increase substantially near clouds.

The team also continued its work toward improving the accuracy of satellite-based aerosol measurements. Their specific goal is to enable satellite data interpretation algorithms to consider the impact of 3D radiative processes through which clouds scatter light into nearby clear areas. This year the team expanded their model for estimating the impact of these 3D processes enhancing the brightness of clear areas around clouds. They pursue this goal because not considering the 3D enhancement can cause errors in estimated particle concentration and size if the observed extra brightness is mistakenly attributed to an elevated concentration of small light-scattering aerosols. The expanded 3D correction model now accounts not only for the radiative interactions between cloud droplets and air molecules, but also incorporates aerosol particles and underlying surfaces [Wen et al., 2013].

In addition, Várnai and team developed a technique to extend the blue wavelength 3D correction estimated by their model to longer wavelengths. This is important for practical use, as corrections at a single wavelength would cause problems in the operational aerosol data processing algorithms that combine observations taken at multiple wavelengths [Marshak et al., 2014b].

Finally, the team explored the concept of spectral invariance across cloud edges for a certain combination of radiative parameters. The work is based on the fact that theoretical considerations, MODIS observations, and simulations of solar radiative processes all indicate that a certain combination of radiative parameters doesn’t change across the entire cloud-to-clear transition region near cloud edges. This finding raises the prospect of accurate satellite measurements through the entire cloud-to-clear transition at cloud edges, a region that is especially challenging for both cloud and aerosol measurement algorithms.

Objectives for FY 14-15

Next year the team plans to further explore near-cloud changes in particle populations and radiation fields. This will include separating the contributions of undetected cloud particles and aerosols by using MODIS observations at longer wavelengths. The team also plans to analyze in more detail the way near-cloud changes depend on time, location, and scene properties, and to expand the analysis to areas over land. They also plan further testing and refinement of their method for removing 3D cloud-induced radiative enhancements from satellite-observed radiances, and testing its impact on aerosol properties estimated from the corrected radiances. The plans also include further exploring the possibility of using a spectral invariance feature to enable continuous satellite measurements of cloud and aerosol properties across cloud edges. Finally, they plan to examine the way 3D radiative processes in partly cloudy areas affect the amount of solar radiation observed at the surface.

Atmospheric Chemistry and Dynamics Laboratory
(Code 614)

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Task 303: Atmospheric composition, atmospheric radiation, and satellite refurbishment (Sponsor: Jose Rodriquez)

Subaward from Harvard Smithsonian Astrophysical Laboratory: Tropospheric Emissions, Monitoring of Pollution (TEMPO) (SV3-83018)

Investigator: Jay. R. Herman, Senior Research Scientist, JCET

Description of Research

Using the Pandora spectrometer system, determine ozone and nitrogen dioxide altitude profiles in the atmosphere and validate the results comparing with in-situ balloon instrumentation.

For the DISCOVER-AQ (for, Ground-based and Aircraft Campaigns for Trace gases and Aerosols) campaigns near Houston, Texas and near Denver Colorado, deploy 12 Pandora instruments to measure total column NO2 and O3 amounts, analyze the data, and supply the data in standard format to the project.

As Instrument Scientist for EPIC satellite instrument on board the DSCOVR (Deep Space Climate Observatory) satellite, lead the effort to characterize the optical performance of the EPIC instrument including stray light determination, laboratory and flight calibration, and provide algorithms for retrieving ozone, aerosol index, and surface reflectivity.

The Harvard Smithosonian subaward focuses on planning for validation for the TEMPO satellite instrument for O3 and NO2 measurements using Pandora spectrometer system.

Accomplishments in FY13-14:

The operation of the Pandora spectrometer system was modified to determine both total column amounts and altitude profiles of ozone (O3) and nitrogen dioxide (NO2) in the atmosphere. Several instruments have been deployed on a short-term basis at remote sites in California, Texas, and Colorado, and on a long-term basis in Four-Corners, New Mexico, Boulder Colorado, and Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. Methods were successfully developed for the retrieval O3 and NO2 profiles throughout each day of operation and compared the results with in-site aircraft and balloon instrumentation.

Twelve (12) Pandora instruments were deployed in the Houston Texas area for the campaign in December 2013 to January 2014. The data was analyzed and provided to the DISCOVER-AQ project. Twelve (12) Pandora instruments were also deployed in the Boulder Colorado area for the upcoming campaign during July and August of 2014. The analysis of the campaign data has yielded a publication by Tzortziou et al. [2013] on the retrieval of ozone data from Pandora and the validation with standard Brewer instruments.

The effort for the DSCOVR mission successfully developed a complex stray light correction, flat fielding procedure, and dark current analysis that will be applied to the retrieved radiances from the mission starting in May 2015. In addition, an in-flight lunar calibration procedure has been developed that will be applied during the days when the full moon is observed simultaneously from the earth and from the Lagrange-1 orbital position of the DSCOVR spacecraft. The analysis and flight software has been delivered to the project and is undergoing testing. Laboratory calibration was performed during thermal vacuum testing to determine the radiometric sensitivity and uniformity of the onboard 2048x2048 array detector.

The requirements of the Harvard Smithsonian subaward were to attend science team meetings and prepare for the use of the Pandora spectrometer system to validate the diurnal variation of NO2 and O3 as seen from the TEMPO geostationary satellite. As part of this effort, an additional Pandora instrument was built and delivered to the Harvard Smithsonian Astrophysical Institute. The launch data for this project is in 2018-2019, so the work done is entirely mission planning during science team meetings. The last meeting was held in Hampton Virginia during March 2014.

Objectives for FY14-15

Publish the results from the O3 and NO2 profiles comparision between the in-site aircraft and balloon instrumentation.

Analyze the data obtained from the Boulder, Colorado Pandora deployment.

Support the testing of the DISCOVER flight software

Continue to support science team meetings for the TEMPO geostationary satellite

NASA Grant: Global modeling of nitrate and ammonium at present day and the year 2050: Implications for atmospheric radiation, chemistry, and ecosystems (NNX10AK61G)

NASA Grant: A Modeling Analysis of the Impact of Aerosols from Combustion Sources on Actinic Fluxes and Photolysis Rates Constrained by Aircraft and Satellite Data (NNX11AN72G)

NASA Grant: Integrating carbon monoxide and aerosol retrievals: Improving estimates of aerosol vertical distribution, carbon component & local radiative forcing (NNX11AP62G)

FAA Grant: ACCRI Phase II

Task 350: Modeling of atmospheric aerosols and trace gases (Sponsors: Mian Chin, Jose Rodriguez, and Peter Colarco)

Investigators: Huisheng Bian, Associate Research Scientist, JCET; Mian Chin, GSFC; Jose Rodriguez, GSFC; Peter Colarco, GSFC; Henry Sirkirk (USRA); Chien Wang, MIT; David Edwards, NCAR; and Hongbin Yu, ESSIC

Description of Research

Atmospheric aerosol and gas tracers affect air quality and climate. To pursue scientific objectives of improving atmospheric aerosol simulation and understanding their impact, Huisheng Bian contributes to several scientific studies and assessments: (1) investigating the impact of aircraft emissions compiled by FAA ACET (Aviation Environmental Design Tool) dataset on surface PM level; (2) updating and upgrading the photolysis module, fastJX, in GMI to study the impact of core-shell aerosol on photochemistry; (3) assisting the study of integrating carbon monoxide and aerosol distribution from retrievals, aircraft measurements and regional model for air quality study; (4) assisting the study of decadal variations of aerosols in the upper troposphere and lower stratosphere; (5) leading AeroCom III nitrate experiment to assess driving reasons for uncertainty and perturbation sensitivities in multi-model nitrate simulations, and (6) participating in HTAP v2 experiment to investigate source-receptor relationship using GEOS-5 GOCART model.

Accomplishments in FY 13–14

Huisheng Bian is a co-I of two newly funded projects. She is in charge of the aerosol portion of a study in the FAA project that investigates aircraft emission on surface air pollution, mainly ozone and PM2.5. She has finished the model set up for the simulation including selecting model version and driving meteorological fields, preparing project-provided aircraft emission, and evaluating other emissions for harmonizing purposes. In the AURA project, she joins in designing the model framework and assists model development of new capabilities in OCS simulation. The work is needed for the study of stratospheric aerosols proposed by the project.

Huisheng Bian contributes to three continuous NASA funded projects. She is a co-I of an ACMAP project that improves the impact of aerosols from combustion sources on actinic fluxes. She has been working with other team members to evaluate aerosol optical property tables currently used by FAST-JX within the NASA GMI model using in situ observations of aerosol mass, composition, and optical properties from ARCTAS and INTEX-B. A new optical property lookup table that takes into account the core-shell internal mixture containing black carbon and sulfate and constrained by observations has been derived. She is now in charge of implementing an interface in the GMI model that can utilize the new optical table and mimic the mixing states of aerosols from an otherwise single moment GOCART aerosol model based on projection of mixing and size-dependent MIT MARC aerosol model. As a co-I of a NASA Terra-Aqua project, she assists other team members to analyze ARCTAS aircraft measurements of vertical profiles of CO and various aerosol components, summarize the correlation between CO and aerosols under various atmospheric environments using measurements and WRF-Chem simulations, and prepare a manuscript. Huisheng Bian also leads a team to study continuously the global atmospheric nitrate distribution and evolution with particular focus on the region of North America.

Huisheng Bian devotes much of her efforts to several national and international assessments of aerosols and their impacts. She is leading the AeroCom III nitrate experiment to assess the diversity of nitrate simulations by AeroCom models and understand the reasons for intermodal differences by comparing model nitrate results with various measurements and by investigating how nitrate formation changes in response to the perturbation of precursor emissions and meteorological conditions. She participates in the HTAP v2 experiment to investigate source-receptor relationship using GEOS-5 GOCART model. She has finished major experiment simulations and provided the results in a presentation on HTAP workshop. Huisheng Bian is also in charge of investigating the impact of AEDT prepared aircraft emission on surface PM2.5 level using the NASA GEOS-5 GOCART model. This work supports a harmonized assessment of aircraft emission on air quality organized by the FAA.

In addition to the aforementioned two newly funded projects, Huisheng Bian has also participated in eight other proposal submissions during the reported year with one as principle investigator.

Objectives for FY 14-15

Huisheng Bian will continue to lead the international multimodel assessment for nitrate study via AeroCom III activity. She will actively participate in HTAP v2 assessment to investigate hemispheric pollution transport using GEOS-5 GOCART model and in the assessment of the impact of aircraft emissions on surface air qualify using a harmonized approach proposed by FAA ACCRI II activity. Huisheng Bian will continuously contribute to the two on-going NASA projects that involve improving photolysis calculation by investigating the impact of core-shell aerosols and decadal variations of aerosols in the upper tropospheric and lower stratosphere.

Task 384: **Mineral characterization using Bruker D8 Discover with da Vinci XRD system, EGA system, Raman and NIR instrument (Sponsor: Paul Mahaffy)**

Task 385: **SIRCUS/SOLARIS measurements and calibration in support of CLARREO mission (Sponsor: Joel McCorkel)**

Investigators: Elena Georgieva, Research Associate Professor, JCET; P.R. Mahaffy, GSFC; Xiang Li,CREST, UMBC; Amy McAdam, GSFC; Joel McCorkel, GSFC; James Butler, GSFC; Kurtis J. Thome (GSFC)

Description of Research

For Project 8800 Georgieva is using Bruker D8 Discover with da Vinci x-ray diffraction (XRD), evolved gas analysis (EGA), Raman and near infrared NIR as a nondestructive techniques for remote sensing of minerals in support of Mars studies. This research emphasis on the mineralogy and chemistry of planetary materials and their analogs. The XRD instrument that Georgieva is operating at Goddard is most complicated and advanced X-ray Diffraction System from Bruker. The new D8 DISCOVER has a real-time component detection, and fully integrated 2-dimensional capabilities. It has several different stages (thermal, translational and rotational) which allow a switch between all materials research X-ray diffraction applications, including reflectometry, high-resolution diffraction, small angle X-ray scattering (SAXS), as well texture investigations. Using the XRD instrument Georgieva efficiently studied the kinetics and thermodynamics of more than 100 minerals at non-ambient conditions (it has a cooling with liquid nitrogen and heating up to 1600 deg C capabilities). Georgieva was using an additional, dedicated sample stage to study the effect of parameters like temperature, atmosphere, humidity or pressure. She is fully capable of making changes to the instrument and improving its functionality.

For project 8841 Georgieva is operating a Ti:Sapphire laser from Coherent with a Mira OPO Synchronously-Pumped Optical Parametric Oscillator from UV to IR. The results obtained with the SIRCUS setup are traceable to a National Institute of Standards and Technology (NIST). The SOLARIS instrument will retrieve at-sensor reflectance over the 320 to 2300 nm spectral range. The calibration approach that retrieves reflectance has to have uncertainties less than 0.3%.

Accomplishments in FY 13–14

Georgieva designed experiments for more than hundred different samples, analyzed results and prepared talks and presentations. Georgieva was analyzing terrestrial Mars analogs to gain insight into potential martian alteration processes, and the implications of those processes for the habitability of Mars. She has experience in material science, instrument development and spectroscopy and is capable of using a variety of analytical techniques, such as x-ray diffraction (XRD), and EGA, Raman and NIR instrumentation. A major research endeavor has been performing XRD and EGA studies of Mars analog minerals and materials in support of similar measurements that will be taken by the Sample Analysis at Mars (SAM) instrument on the upcoming Mars Science Laboratory (MSL) mission.

Georgieva participated in the calibration of many flight instruments.

1. Heaps, W, Georgieva, E. M., 8th International Workshop on Greenhouse Gas Measurements from Space, Oral Presentation, "AMIGO: A new instrument for Greenhouse Gas Measurement employing GLINT," International, Pasadena , California.

2. Heaps, W. S., Georgieva, E., 8 th International Workshop on Greenhouse Gas Measurements from Space, Oral Presentation, "The AMIGO Instrument," NASA, Geneva, (October 1, 2013).

Objectives for FY 14-15

Georgieva will continue to do research of Mars analog samples using an X-ray D8 DaVinci Diffractometer from Bruker. This effort will advance our measurements and characterization of mineral peak shapes and help identify phases with higher resolution. The diffraction pattern for every phase is as unique as a fingerprint and phases with the same chemical composition can have drastically different x-ray diffraction patterns. One of the goals of the Mars Science Laboratory rover instruments is to characterize the geology and investigate the planetary processes that influence habitability. She will also operate another instrument for planetary research – a SETARAM 3D Calorimeter sensor to measure the heat of transformation of a material subjected to a temperature variation in a controlled atmosphere.

Georgieva will continue with her calibration work on the linearity tester as well as using the NIST Spectral Irradiance and Radiance Responsivity Calibrations Using Uniform Sources (SIRCUS) Transfer radiometer cross-calibration output.

Task 377: **Deployment, Optimization and Maintenance of the Pandora Spectrometer Systems in support of NASA's DISCOVER-AQ project. (Sponsor: Ken Pickering)**

Investigators: Nader Abuhassan, Associate Research Engineer, JCET; Jay Herman, Senior Research Scientist, JCET; Alexander Cede, USRA; Matthew Kowalewski, USRA

Description of Research

Ground-based measurements combined with satellite and airborne observations, have played a major role in improving our knowledge of the impacts of trace gases and aerosols on local pollution episodes and its effects on air quality and human health. The most challenging problem for Earth-observing satellites measuring air quality is to distinguish between pollution high in the atmosphere and that near the surface where people live and breathe.

Tropospheric Nitrogen Dioxide (NO2), as an example, has a high diurnal variability influenced by both natural and anthropogenic emissions. Fossil fuel combustion is a major source of NO2, and high NO2 concentrations are usually confined to areas with high industrial activities. Pandora spectrometer instruments will be distributed over a large area for comparison with aircrafts and satellite NO2, O3 measurements for an accurate evaluation of the total column amounts of NO2, O3 and other key trace gases from the ground.

Accomplishments in FY 13–14

Our team was very effective in supporting the third campaign of NASA's DISCOVER-AQ , 15 Pandora spectrometer instruments were deployed in and around Houston, Texas to retrieve the temporal and spatial variability of NO2, O3 and other key trace gases. Vertical profiles were also measured at selected sites. Multiple high level scientific papers were recently published using the Pandoras spectrometer measurements. The demands for deploying more instruments is very high from local and international research centers and universities.

Objectives for FY 14-15:

16 Pandoras will be deployed in the Denver/Boulder area as part of the final Discover-AQ campaign in the summer of 2014. Several of these Pandoras has already been deployed in collaboration with NOAA and the CDPHE to both obtain a longer data record and for total column O3 comparison with NOAA's Dobson instruments.

Pandora's highly resolved spectral measurement allows further processing of the data, and our team will support scientific community in the data processing and analysis to determine other atmospheric pollutants such as SO2.

Task 323: **Management of the Applied Remote Sensing Training Program (ARSET) (Sponsor: Ken Pickering)**

Task 360: **Creating an Objective "Air Quality Applied Sciences Team (AQAST) Recommendations for AQ Satellite Missions" Document to Guide AQ Mission Planning. (Sponsor: Bryan Duncan)**

NASA Grant: Beautiful Earth: Learning Science In a New and Engaging Way (NNX11AH30G)

Investigators: Ana I. Prados, UMBC/JCET (Code 614); Amita Mehta, UMBC/JCET; Valerie Casasanto, UMBC/JCET; Cindy Schmidt, NASA/Ames; Richard Kleidman, Pawan Gupta, and Jaquie Witte, NASA/SSAI; Yang Liu, Emory University; Bryan Duncan, NASA/GSFC.

Students: David Barbato, UMBC; Ali Hoy, University of Maryland College Park, and Maria Stenborg, University of Maryland College Park.

Description of Research

Prados managed the NASA Applied Remote Sensing Training Program (ARSET), which developed online and hands-on courses on the utilization of NASA remote sensing data for water resources, flood monitoring, ecological forecasting, and air quality management internationally and in the U.S. The program also began its formal evaluation process via online surveys, sent to all past course attendees to gauge the benefit from their participation in ARSET courses and changes in use of NASA resources. Prados also collaborated with NASA's Air Quality Applied Sciences Team (AQAST) and developed one teacher training course for the Beautiful Earth project in Laredo, Texas.

Accomplishments in FY 13–14

For the sixth consecutive year, Dr. Prados managed the NASA Applied Remote Sensing Training Program (Task 323) (http://arset.gsfc.nasa.gov). The program reached a record number of stakeholders in 2013: 593 (82 of which took more than one course), relative to 350 stakeholders in 2012. During the reporting period, the program provided at total of 12 courses: 3 in water resources, 1 in flood monitoring, 1 in land management, and 7 in air quality. All courses combined, the program reached 43 countries and 297 organizations. The majority of the participants were involved in environmental management, but there was also participation from researchers and college students.

The first ARSET webinar (Fall 2013) on NASA tools and datasets for flood monitoring covered 4 decision support tools. The course featured live, step-by-step demonstrations on how to import TRMM rainfall and MODIS inundation data into GIS. There were 110 participants, 54 organizations, and 25 countries. ARSET's second water resources management overview webinar reached 171 Participants, 60+ organizations, and 25+ countries over a 5pweek period. The following web-tools for the access to NASA data were presented: Giovanni, Mirador, Reverb/ECHO, the Global Flood Monitoring System (GFMS), NSIDC Data Center, USDA/FAS, and the Drought monitoring and Hydrology portal-Princeton University. In the post workshop surveys, NASA web-tools taught were rated as moderately to very useful by all participants. In April of 2014 the program also provided a 1 day workshop on remote sensing for water resources management for the US Agency for International Development. The first land management course was held in May and June 2013 with nearly 300 registrations, primarily from the U.S Federal government sector and international conservation NGOs.

A workshop in September 2013, held in collaboration with the Bay Area Air Quality Management District built capacity in data access and use of NASA and NOAA aerosols and smoke/fire products. One of the key accomplishments was the demonstration of NASA data and tools for monitoring local air quality through case studies. One specific case study looked at the impact of wood burning on ambient $PM_{2.5}$ or fine particulate matter during the winter holiday season in the bay area using MODIS observations and EPA's air quality index. In November 2014, a 3-day air quality course was held in Albany, New York in collaboration with the Northeast States for Coordinated Air Use Management (NESCAUM) and the Mid-Atlantic Regional Air Management Association (MARAMA). There were 21 attendees from 10 states and guest speakers from the VIIRS active fire team. When asked to rate how the training impacted their knowledge of remote sensing data, half gave the highest rating of "improved a great deal", 30 – 40% "improved moderately", and 20% "improved slightly. In late March/April 2014, a 5-week webinar series for the Indian subcontinent provided an overview of satellite remote sensing for air quality applications with 100 participants from multiple countries in the region.

At the Earth Science Information Partners (ESIP) meeting on January 8-9, Prados coordinated and chaired the 4th workshop for Earth Science professionals on how to use logic models for proposal writing and program evaluation [Prados, 2014a]. The ARSET Program, in conjunction with NASA's Air Quality Applied Sciences Team (AQAST) wrote a manual for air quality professionals [Duncan, B., Prados A. I., et al., 2014] entitled "Satellite data of atmospheric pollution for U.S. air quality applications: Examples of applications, summary of data end-user resources, answers to FAQs, and common mistakes to avoid", published in *Atmospheric Environment* **http://www.sciencedirect.com/science/article/pii/S1352231014004270.** Prados also helped to coordinate stakeholder sessions at the AQAST meetings in January and June 2014.

Objectives for FY 14-15

ARSET (managed by Prados) will be reducing its air quality efforts in order to augment capacity for courses in the other three application areas, and in particular land management applications. The air quality activities will be focused on stakeholders from EPA and in the southeastern U.S. An end-user needs assessment on remote sensing needs for land management applications will be conducted to determine course topics in this area and the program will add at least two land management courses. For water resources and land management, federal agencies in the U.S and NGOs in the U.S and internationally will be the targeted end-user community. Flood monitoring online courses will be focused on building capacity among international organizations, including disaster management agencies.

Task 368: In Situ Measurements of Formaldehyde (HCHO) and the Composition of the Lower Atmosphere (Sponsor: Thomas Hanisco)

Investigator: Glenn M. Wolfe, Assistant Research Scientist, JCET

Description of Research

This research utilizes in situ measurements of formaldehyde (HCHO) and other gases to study the processes that control the composition of the lower atmosphere. Primary efforts include 1) maintaining and refining sophisticated instrumentation for measurement of HCHO, 2) deployment of these instruments on multiple airborne platforms, and 3) scientific interpretation of the data with a focus on photochemistry and surface-atmosphere interactions. Results from this work will improve our understanding of fundamental atmospheric chemistry and assist ongoing efforts to mitigate the impact of anthropogenic activities on air quality and climate.

Accomplishments in FY 13–14

Field Work: During the summer of 2013, the NASA ISAF (In Situ Airborne Formaldehyde) instrument participated in two airborne missions: the NOAA-led SENEX (Southeast Nexus) study and the NASA-led SEAC^{4}RS (Studies of Emissions, Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys) study. ISAF performed well on both missions and collected a wealth of data throughout the Southeast US. This data is currently being used by multiple groups to validate satellite formaldehyde (HCHO) retrievals and improve model representations of emissions and chemistry. In the winter of 2014, ISAF was deployed to Guam for the NSF-sponsored Convective Transport of Active Species in the Tropics (CONTRAST) mission, also with excellent results despite considerable technical challenges. For each of these missions, Wolfe trained graduate students to operate and maintain ISAF (J. Kaiser, UW Madison; H. Arkinson, UMCP; D. Anderson, UMCP). Wolfe is currently co-advising these students on data analysis.

Data Analysis: Wolfe is currently pursuing several novel topics relating to observations collected over the southeast US. Data from SENEX has been used to derive an analytical relationship between the emission of isoprene (a major reactive hydrocarbon emitted from vegetation) and the production of HCHO. Satellite-based HCHO retrievals are often used to infer isoprene emissions, and this relationship is a crucial component for accurate calculations. This work is not yet published but was presented at the American Geophysical Union Fall Meeting in December 2013. Wolfe is also co-advising a graduate student (M. Marvin, UMCP) to extend this analysis to the Community Multiscale Air Quality (CMAQ) model, which is used by the EPA for research and policy decision-making.

A second avenue of research involves using a unique subset of measurements acquired during SEAC^{4}RS to understand the production and fate of reactive gases. Specifically, this analysis involves calculation of vertical fluxes in the boundary layer using several advanced statistical techniques, including eddy covariance and wavelet transforms. These vertical fluxes are modulated strongly by both surface interactions and in situ production and loss; in other words, they contain quantitative information on the rates of key processes like emission, chemistry and deposition. This is the first time anyone has attempted this type of analysis from the NASA DC-8, which offers a broad suite of observations and thus a highly detailed picture of atmospheric composition. Unabashedly, this effort represents a new frontier for the field of atmospheric chemistry, and we are excited to unlock these new capabilities.

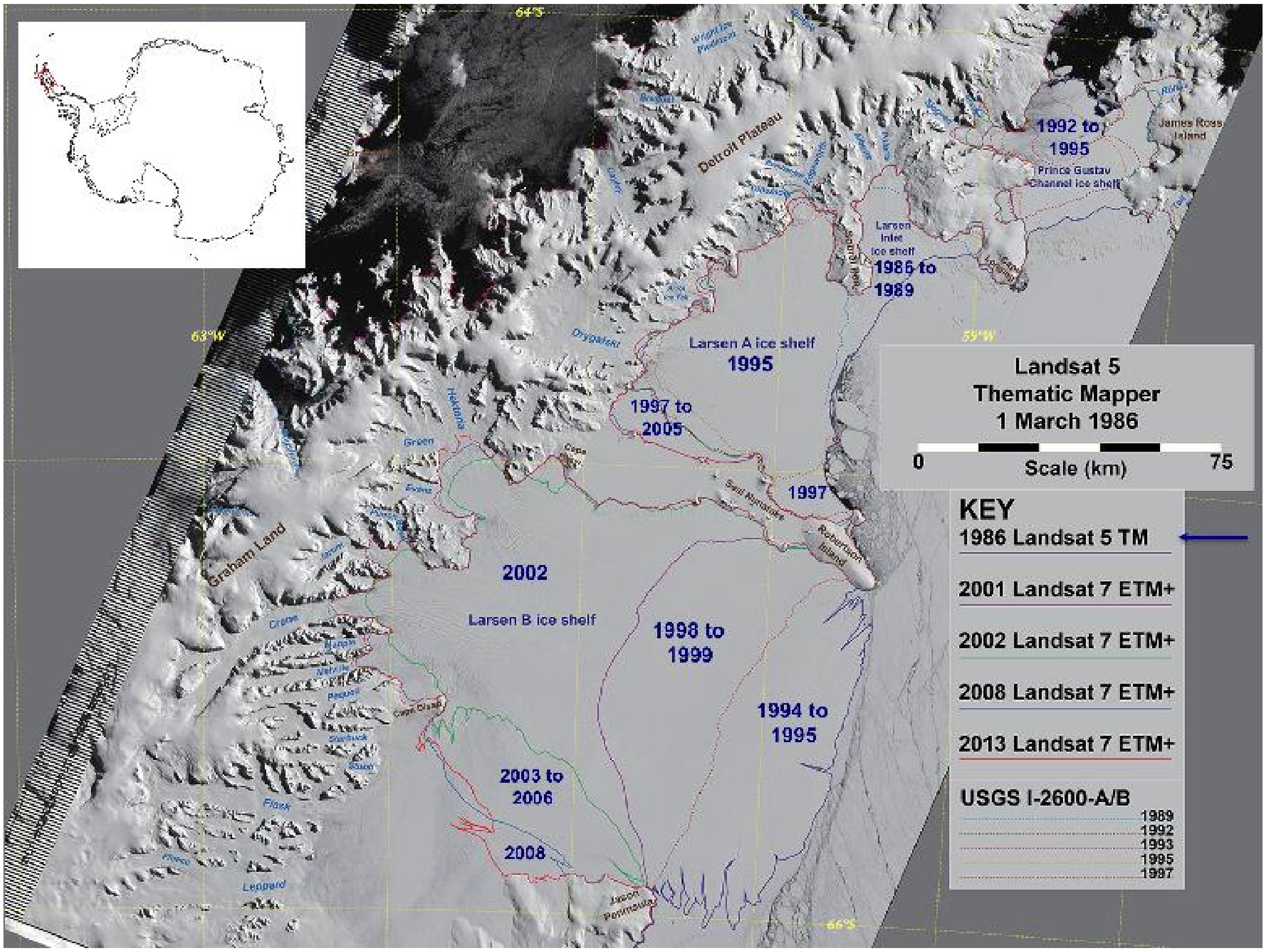
Other: Wolfe has also written a manuscript that describes the physical characteristics and performance of ISAF. This will be published before the end of 2014.

Objectives for FY 14-15

The top priority for the coming year is to complete analysis and publish results for both the SEAC4Rs and SENEX studies. After this, Wolfe will begin work on analysis of CONTRAST data with a focus on oceanic sources of HCHO and its precursors; preliminary results suggest these sources may be missing from current models. Several field campaigns are also on the horizon, including the NOAA-led SONGNEX (Studying the Atmospheric Effects of Changing Energy Use in the U.S. at the Nexus of Air Quality and Climate Change) mission, scheduled for spring 2015.

Cryospheric Sciences Laboratory
(Code 615)

Changes to the Antarctic Peninsula from Satellite Imagery, 1986–2013
Christopher A. Shuman, UMBC-JCET at NASA GSFC



As part of a multi-year study of ice mass changes in the region, multiple ice shelf collapse events have been documented with Landsat imagery during 1986-2013 along the east side of the Antarctic Peninsula (see inset location map). Ice edges visible on the imagery series (see key) are shown as colored lines and indicate where many thousands of km2 of ice shelf have been lost. For example, the collapse of the Larsen B in early 2002 was at least 3250 km2 and continued to expand in area over the next decade. Dates of collapses or date ranges of ice shelf losses are indicated with blue numbers. Further, tributary glaciers in such shelf loss areas have accelerated, thinned, and show major ice front retreat over this time period. Shelf remnants continue to thin, to lose ice area, and to form rifts suggesting further losses to come. Note that the 2013 Landsat imagery is slightly offset from the 1986 scenes and shows the impact of Landsat 7's scan line corrector problem by a series of dark lines at the left margin of the coverage area.

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Task 383: ICESat-2 Education and Outreach Development and Coordination (Sponsor: Thomas Neumann)

Investigator: Valerie Casasanto, Program Coordinator, JCET

Description of Research

The ICESat-2 (Ice, Cloud, and land Elevation Satellite) Mission to be launched in 2017 will include a robust Education and Public Outreach (EPO) program. The goals of the EPO efforts are to engage the general public in the mission and communicate its benefits, and to inspire, engage, and educate youth to pursue Science, Technology, Engineering and Math (STEM) careers. The unique aspects of the ICESat-2 mission will be communicated to the public and to the youth, through a wide array of programs and initiatives. ICESat-2 will use precision lasers to measure the height of the Earth from Space and provide a 3-D view of the Earth's elevation.

Accomplishments in FY 13–14

An array of education and outreach projects were developed and implemented for the ICESat-2 mission to be launched in 2017.

Casasanto and team completed the ICESat-2 travelling altimeter exhibit, the NASA E-clips series of education video clips, and participated in the NASA Reel Science video contest for high-school students to produce a video communicating NASA Earth Science. A hexacopter challenge was initiated for university-level students to develop an autonomous unmanned aerial vehicle. The contest will take place in FY15-16.

The art student pilot program was implemented with its first trial runs with two universities: with Bowling Green State University and the Savannah College of Art and Design (SCAD). Casasanto and team collaborated with creatively minded students and their faculty members to come up with unique ideas and prototypes for educational outreach materials such as animations and games. Ideas and prototypes were generated and students were selected to work on further development and implementation of their ideas at NASA Goddard and their home institutions.

Casasanto and team began work on the re-design and development of the ICESat-2 Website. The rewritten and redesigned website will contain interesting and accessible information on the mission and cryospheric science.

Casasanto was the lead coordinator of the ICESat-2 satellite animation working with NASA's conceptual Image Lab animators and ICESat-2 engineers.

Casasanto also coordinated the education and outreach team, and continued development and implementation of EPO goals, and milestones.

Objectives for FY 14-15

Casasanto will continue planning and developing ICESat-2's FY15 initiatives and beyond. Specifically, she will guide the implementation of the art student pilot program, and lead the redesign and development of the ICESat-2 website. She will also organize ICESat-2's participation in NASA and related events.

Task 341: **IceBridge, ICESat – 1/2 calibration validation assessment (Sponsor: Thorsten Markus)**

Task 373: **Climate data record development for surface temperature data for Greenland ice sheet locations (Sponsor: Dorothy Hall)**

Task 375: **Surface deformation of icy moons: Insights from Earth analogs and modeling (Sponsor: Jeanne Sauber-Rosenberg)**

Task 378: **NASA's Beginning Engineering, Science and Technology (BEST) (Sponsor: Susan Hoban)**

Task 388: **Evaluation of reanalysis data and satellite indicators of melt events over the Greenland ice sheet (Sponsor: Sirpa Häkkinen)**

Task 390: **Assessment of modeled temperatures over the Greenland ice sheet (Sponsor: Sophie Nowicki)**

Investigators: Christopher Shuman, Research Associate Professor, JCET GES; Thorsten Markus, Fellow, JCET, GSFC; Thomas Neumann, Dorothy Hall, Jeanne Sauber-Rosenberg, Sirpa Häkkinen, Sophie Nowicki, GSFC; Susan Hoban, Senior Research Scientist, Michael Schnaubelt, Research Associate, JCET; Kelly Brunt, UMD ESSIC; Michelle Hofton, UMD Geography; Ted Scambos, NSIDC; Etienne Berthier, LEGOS; Winnie Humberson, Wyle Information Systems

Description of Research

Dr. Shuman continues to work with Dr. Hall at GSFC to compare temperature records in central Greenland's 'Summit' Station area as well as at some additional AWS sites elsewhere in Greenland. Shuman's efforts with Drs. Häkkinen and Nowicki have expanded these studies more broadly across Greenland. The project with Dr. Sauber concluded during the reporting period. Shuman is also working with Dr. Markus and Dr. Neumann at GSFC, among others, to develop the ATBD for the ATL03 product for ICESat-2 (its launch is now planned for late 2017). He continues efforts to refine ICESat-1 elevation data through collaborations. Dr. Shuman continues to collaborate with Dr. Scambos and Dr. Berthier to assess ongoing changes to the Antarctic Peninsula's ice cover. Because of the scale of these changes and the ease of visualizing them, Dr. Shuman has been able to use historic remote sensing imagery to show the ice changes on NASA's hyperwall at Earth Day at Union Station and at AGU. Such education and outreach activities have been expanded through a project led by Dr. Hoban.

Accomplishments in FY 13–14

The past year's efforts generated a paper led by Dr. Hakkinen that is related to Greenland ice sheet surface melt and was published in AGU's GRL. A related activity led by Dr. Shuman and former UMBC Graduate Student Michael Schnaubelt (also supported by Dr. Hall on Task 373) was able to extract and quality control near-surface temperature data from NOAA ESRL TAWO sensors installed at Greenland's Summit Station. The primary goal was to use these high-temporal resolution data to assess MODIS IST data that Dr. Hall is using as a CDR. This effort produced a paper led by Shuman that has been submitted to the Journal of Applied Meteorology and Climatology (in second round of reviews). Also, because of continued interest after the large melt events in 2012, Shuman and Schnaubelt were able to show that Greenland experienced a far more normal melt season in 2013 and contributed to the blog "Greenland Ice Sheet Today" (http://nsidc.org/greenland-today/2013/08/late-season-warmth-extends-2013-greenland-melt-seasonbriefly/). Dr. Shuman also produced a new hyperwall presentation in support of Ms. Humberson's outreach activities on behalf of the EOSPSO using Landsat data spanning 1986-2013 when most of the ice shelves on the east side of the Antarctic Peninsula collapsed (http://www.nasa.gov/content/nasa-celebrates-earth-day-2014-in-the-nations-capital/#.U6LuKxar-uc). Shuman's efforts are now being focused in collaboration with Dr. Hoban on Task 378 to bring 'stories of polar change' to the NASA's BEST activity.

Dr. Shuman was also engaged on other tasks at GSFC. For Task 341, he worked closely with Dr. Neumann on the evolving and complex ATL03 ATBD document "Global Geolocated Photons". This effort will help ensure measurement consistency of the ICESat-2 laser altimeter called ATLAS. Part of the challenge is that ICESat-2 is a photon-counting lidar as opposed to ICESat-1 that used analog waveforms to derive altimetry measurements. There is growing recognition that not all the biases in the ICESat-1 time series have been resolved in the final data release as was documented in a recent GRL paper led by Dr. Hofton that Dr. Shuman supported. Finally, as part of the previous NASA Chief Scientist's first SIF program designed to catalyze scientific research across NASA, Dr. Shuman worked with Dr. Brunt and others on Task 375 by analyzing remotes sensing imagery of terrestrial ice. In addition to these activities, Dr. Shuman continued his collaboration with Drs. Scambos and Berthier to help publish an additional paper in a multi-year research series. Their latest effort updated and expanded assessments of ice area and ice mass losses from the Antarctic Peninsula during 2001- 2011. This paper is now in review at The Cryosphere Discussion. http://www.the-cryosphere-discuss.net/8/3237/2014/tcd-8-3237-2014.html.
Three presentations related to this work were given recently by Dr. Shuman; two were in Innsbruck, Austria and one was in Chamonix, France.

Objectives for FY 14-15

Obtaining continuing research funding from a ROSES or NSF proposal is clearly the highest priority for the coming year. Shuman's goals and Objectives for FY 14-15 include: to finish the broader Antarctic Peninsula study of glacier and mass changes now under review; to support the ICESat-2 mission and the new science team as ATLAS develops; to contribute to teaching at UMBC; to continue to explore new opportunities with Drs. Häkkinen and Nowicki; to complete the team's assessment of temperature records from central Greenland as well as available MODIS IST data for other quality-controlled AWS locations as part of Dr. Hall's research team.

Ocean Ecology Laboratory
(Code 616)

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Task 370: **Suomi-NPP Science Team Ocean Color Science (Sponsor: Carlso Del Castillo)**

Task 382: **HyspIRI Aquatic Studies Group (Sponsor: Betsy Middleton)**

Task 387: **Coastal and Inland Water Remote Sensing (Sponsor: Antonio Mannino)**

Task 389: **JPSS/VIIRS Prelaunch Instrument Performance Analysis (Sponsor: Jim Butler)**

NASA Grant: Constructive Assessment of VIIRS Ocean Color Data Quality Toward NASA Climate Data Record Continuity (NNH10ZDA001N)

NASA Grant: VIIRS Sea Surface Temperature Retrievals (NNH10ZDA001N)

Investigators: Kevin R. Turpie, JCET (Science PI/Ocean Discipline Lead/Co-I); Bryan Franz, GSFC (Admin PI).

Description of Research

Remote sensing of the ocean biosphere on global and synoptic scales provides vital information for research applications such as large-scale modeling biogeochemical cycles and their response to climate change. Kevin Turpie led research efforts in the development and evaluation of ocean color remote sensing for the Suomi National Polar-orbiting Partnership (S-NPP) Visible Infrared Imaging Radiometer Suite (VIIRS). He is a subject matter expert for the testing program for the next VIIRS instrument aboard the J1 spacecraft, part of the Joint Partnership Satellite System (JPSS) mission. He is also the founding chair of the Hyperspectral and Infrared Imager (HyspIRI) Aquatic Studies Group (HASG), overseeing the development of coastal and in-land water aquatic remote sensing and is a member of the HyspIRI Science Study Group. Turpie also began work with the GSFC Coastal Interdisciplinary Science Task Group early in 2014.

Accomplishments for FY 13-14

As funding to support the S-NPP science team was extended, Turpie continued his work with the evaluating the ocean color data products from the VIIRS sensor. We worked with both NASA and NOAA teams to evaluate changes in performance observed from 2013 to 2014. He also conducted a study of uncertainty in ocean biospheric data trends that could stem from undetectable calibration drift. In particular, drift in VIIRS NIR bands could products regional trend effects that could lead to spurious geophysical interpretation. The results indicated that the minimal detectable trend from VIIRS in global chlorophyll concentrations could not be smaller than a few percent per year given current artifacts in the solar calibration. Turpie also explored the trend effects of S-NPP VIIRS mirror degradation on measurements of the Earth, resulting in identifying temporal measurement drifts on the order of 0.1-0.3%. Turpie initiated development of a systematic approach to quantify the propagation of error from instrument artifacts to derived remote sensing data products for ocean observations.

Turpie collaborated with the Ocean Biology Processing Group (OBPG) in improving the calibration of the sensor and identifying artifacts and their correction. He compared global trends in ocean data products from VIIRS to those from the contemporary mission MODerate resolution Imaging Spectroradiometer (MODIS), and to the historical record from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). His results, and those of the NOAA calibration/validation team and the OBPG, showed that the VIIRS ocean biology data products were diverging from the MODIS and SeaWiFS records starting in late 2012. This realization was subsequently followed by considerable effort to identify possible improvements to the calibration trending. Collaborative work was coordinated with the VIIRS Calibration Support Team (VCST) and findings were shared with related NOAA teams.

Turpie contributed to requirements and testing discussions for the JPSS VIIRS instruments, including participating in meetings of the Data Analysis Working Group during ambient testing of J1 VIIRS and the Crosstalk Requirements Working Group for J2 VIIRS. He also contributed to the evaluation of the science impact of various anomalies observed in the J2 VIIRS response to polarization of light at the top of the atmosphere. In this capacity, Turpie quantified the impact of spectral properties of VIIRS polarization response characteristics to VIIRS Earth measurements, which were found to be very small.

Work continued with the HyspIRI Science Study Group (SSG) and Turpie continued to chair the HASG. The HASG is an internationally scoped organization of dozens of researchers and scientists charted to collect and synthesize input from the hyperspectral aquatic community and literature to define an aquatic hyperspectral data product suite for HyspIRI. Turpie led the HASG in developing a white paper report covering a broad range of remote sensing data products. One chapter of the report was published in a special issue of Remote Sensing in December of 2013. Up to four additional papers from the report were recently submitted to a special issue of Remote Sensing of Environment. The group plans to organize a meeting at Ocean Optic XXII in October of 2014 and also begin to develop a website.

Objectives for FY '13 - '14:

The study calibration drift on ocean data trend uncertainty will continue. A paper on the measurement effects of the VIIR mirror degradation is also expected later this year. New improvements to the S-NPP VIIRS calibration are expected and trends in the ocean data will be reevaluated. If the OBPG can expand the *in situ* matchups for VIIRS, those too will be analyzed and published. An updated assessment on the capability of VIIRS for ocean color and SST will be submitted to peer-review journals. As JPSS J1 VIIRS now enters its next phase of testing and characterization, Turpie will be expected to participate in the review, analysis, and science impact assessment of test data from the JPSS VIIRS instrument. Finally, Turpie will lead the wrap up of first edition of the HASG HyspIRI Aquatic Data Product white paper. Of the four recent submissions, Turpie is lead author on a wetland remote sensing paper and a co-author on one other. He will lead the organization and chair the upcoming Ocean Optics XXII HASG meeting and pilot the effort to establish the HASG website.

Biospheric Sciences Laboratory
(Code 618)

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Task 306: Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency, Diversity and Urban Boundaries using Surface Reflectance, Fluorescence and Emissivity at Various Spectral Scales (Sponsor: Dr. Elizabeth Middleton)

Investigators: Petya K.E. Campbell, JCET; Dr. Elizabeth Middleton, NASA/GSFC

Description of Research

This research task also includes NASA Earth Observing - 1 (EO-1) Mission Scientific support for Hyperion data analysis and product development; and Scientific support for the development of NASA's HypIRI mission concept.

Measuring, monitoring, and modeling the carbon dynamics of our terrestrial ecosystems is a critical goal of NASA. Much effort has been devoted to developing remote sensing (RS) techniques for monitoring plant stress and photosynthetic status and it is recognized that these processes can most efficiently be achieved at a regional and global level from space-borne platforms. However, the majority of conventional RS approaches, using reflectance measurements are not sensitive to the rapid changes in plant photosynthetic status associated with common environmental stressors, such as diurnal fluxes in radiation, heat and water fluctuations. This is due to the fact that most reflectance derived vegetation indices have no direct link to photosynthetic functioning beyond their sensitivity to changes in canopy structure and pigment concentration. Plants commonly absorb more solar radiation than can be used for photosynthesis and the excessive energy is expelled in the form of fluorescence (Fs), and/or is dissipated through non-photochemical quenching (NPQ). Consequently, Fs and NPQ provide sensitive indicators of photosynthetic function.

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 vegetation diversity, photosynthetic function and efficiency. This project addresses a NASA's program on plant functional types and physiology, and supports research to justify missions currently under development by several agencies, including NASA and the European Space Agency (e.g. FLEX, Fluorescence Explorer). The team will supplement our existing datasets with focused field measurements where necessary for model parameters and with EO-1 Hyperion satellite imagery. From the combined in-situ information (including spectral, structural, flux, and micro-meteorological data) and remote sensing (spectral, structural) data, the team will determine how the carbon uptake/efficiency is affected by the partitioning of the canopy into functionally different sunlit and shaded foliage fractions, as expressed with the PRI and other stress indices including solar-induced chlorophyll fluorescence (SIF), as well as chlorophyll-related spectral indices. The stusy will verify that the daily and seasonal changes in the sunlit and shaded canopy fractions constitute an important ecological factor in carbon balance that affect the GEP as determined for the whole ecosystem by eddy covariance methods. This research will support future missions (e.g., HyspIRI) by providing optimal remote sensing strategies and a critical modeling tool for monitoring ecosystem stress (i.e., down-regulation of GEP) and a better understanding of the role of canopy structure in defining ecosystem carbon uptake.

Accomplishments for FY 13-14

In the "**HyspIRI: Assessing Ecosystem Diversity and Urban Boundaries using Surface Reflectance and Emissivity at Various Spectral Scales**, and NASA/GSFC: **Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency"** efforts Dr. Campbell lead the AVIRIS and MASTER data processing and analysis. The use of simultaneously acquired surface reflectance and emissivity data enables the simultaneous evaluation of a number of ecological parameters (e.g. canopy water, pigment content and photosynthetic function). Such analyses are required for assessing the effects of urban expansion on ecosystem function, diversity and local climate. The study established strong relationship between vegetation reflective and thermal properties, which provides strong potential for improved species characterization and separation. The 60m HyspIRI-like data provides a powerful capability for the assessment of vegetation function and the detection of stress, and the combination of high spectral resolution optical and thermal infrared imagery of the proposed HyspIRI mission provides a much more powerful capability for ecosystem analysis and monitoring than is presently possible using the current satellite systems. The synergistic applications of optical spectroscopy and thermal emissivity satellite data are of importance for the development of improved and more effective operational natural resources monitoring system, including vegetation, soil, water and natural disaster assessments; for providing understanding of ecosystem function and sustainability, and sound predictions regarding the effects of climate change.

The **EO1-Hyperion data inter-calibration and analysis effort** contributed toward the comparisons of current data products, generated by multiple systems. Reflectance data having contemporaneous photosynthetic data is being assembled in concert with flux and environmental data provided by AmeriFlux collaborators, from tower sites representing a range of ecosystems. High performance of candidate spectral bio-indices, ascertained from an *a priori* list compiled from previous research, are being evaluated for remote sensing application at ecosystem scales at the AmeriFlux and intensive sites using several radiative transfer modeling tools and atmospheric correction modules. The initial datasets and comparisons for a set of core EOS sites were used to publish a paper outlining the methods in the JSTARS EO-1 Special Issue.

Objectives for FY 14-15

The "**HyspIRI and Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency"** research will develop algorithms and cost-effective remote sensing techniques for assessing vegetation stress and physiological condition.

The goals of this research are to quantitatively characterize the interrelationship and partitioning of the primary and competing processes affecting photosynthetic function (photosynthesis, Fs, and NPQ) under different nutrient and water availability conditions, to facilitate the establishment of remote sensing strategy for their monitoring. In FY14-15 we will examine the daily, seasonal, and inter-annual changes in vegetation photosynthetic processes as a function of water availability and nutrient supply at the leaf, plot, and canopy levels. By implementing new, fully automated measurement and modeling approaches of we will assemble unique datasets for optimal and stressed conditions, link leaf and canopy estimates, and guide the strategy for measuring photosynthetic function from space. We will perform spectral analysis; exploit hyperspectral observations along with newly available physiologically based models to track photosynthetic function.

We will address the following science questions: Q1. Can fluorescence (Fs) and reflectance (R) measurements provide sensitive tools for remote sensing assessment of net photosynthesis and light use efficiency of terrestrial ecosystems, subjected to water and nutrient deficiency and excess, at leaf and/or canopy levels? Q2. Using current modeling approaches, how accurately can we scale Fs and R, and their indicative responses to stress (e.g. water and nutrient deficiency and excess), from foliar to canopy scale, and above?

The EO1-Hyperion data and analysis will focus in FY 14-15 on the development of new products assessing vegetation physiology and will contribute toward the development of the recommended in the NRC Decadal Survey: HyspIRI (Hyperspectral/IR Imagery) and GEO-CAPE (Geostationary Coastal and Air Pollution Events) missions. The EO-1 Spectral Bio-Indicators of Ecosystem Stress will be expanded, adding new research sites the testing which spectral algorithms link photosynthetic function and *in situ* measurements of carbon flux. This project addresses a NASA's program on plant functional types and physiology, and supports missions currently under development by several agencies, including NASA (HyspIRI) and the European Space Agency (FLEX, Fluorescence Explorer).

Specific goals include: 1] Data analysis and product generation in support of future satellite missions; 2] Developing new demonstration Level 2 science products, as prototypes for HyspIRI; 3] Assistance in the collection/generation of an EO-1 archive of research Level 0, Level 1 and 2 data; Hyperion seasonal and yearly composites over cal/val sites and targeted vegetative sites; and 4] Providing scientific support for the user community including the HyspIRI team.

Task 320: **Joint development of algorithm and analytic techniques from a variety of data sources (Sponsor: Jon Ranson)**

Investigator: Forrest G. Hall, Senior Research Scientist

Description of Research

Hall's research in FY2013 involved six activities: (1) PI on the final year of a radar/optical satellite project (BioPhys) to combine radar and passive optical satellite data for biophysical parameter estimation (2) Development of a new satellite concept for direct measures of light use efficiency and gross primary production (3) Hall continues to collaborate with Dr. Thomas Hilker, Dr. Compton Tucker, and Dr. Piers Sellers, Deputy Director of the Goddard Science Directorate and former astronaut, to use the spectrally based techniques for measuring photosynthesis, evapotranspiration and respiration at tower sites. A new model (Hall et al 2012, Hilker et al 2012) to extend these in space and time has also been developed and published. (4) Dr. Hall and Dr. Masek led the development of an EVs proposal entitled, Rapid Arctic Methane Pulse RAMP, schedule for selection announcement in July or August. This is a $30M proposal to quantify the flux of methane from a rapidly warming Arctic and to develop and test global positive feedback models to evaluate future consequences to accelerated climate warming. (5) Developed an EVi proposal entitled Earth Photosynthesis Imaging Constellation (EPIC) to fly spectrometers aboard multiple cubesats to monitor vegetation photosynthesis and structure. Dr. Thomas Hilker is the PI. (6) Hall continues to collaborate with a team to improve the processing of MODIS data (Lyapustin, et al 2012).

Accomplishments in FY 13–14

Dr. Hall participated in the submittal of two new grant proposals. He worked on concluding his work on the BioPhys project and continued his active collaborations.

Objectives for FY 13–14

Continue to complete work on BioPhys linking radar and optical data to quantify biophysical characteristics. If RAMP is funded, as deputy project director will begin to set up RAMP field experiment scheduled to operate in 2016 through 2019 in the Arctic. If EPIC is funded, will serve as a staff scientist in support of Dr. Hilker.

Task 305: **NASA Earth Observing-1 (EO-1) Mission, Scientific support for Hyperion data analysis and product development and NASA HyspIRI Mission, Scientific support for HyspIRI mission planning (Sponsor: Elizabeth Middleton)**

Investigators: E. Middleton, PI, GSFC Code 618; K. F. Huemmrich, Research Associate Professor, JCET; P. Entcheva-Campbell, Research Assistant Professor, JCET; Y-B. Cheng, ERT; Q. Zhang, USRA; L. Corp, Sigma Space Corp.

Description of Research

The focus of this work is to develop and evaluate approaches for using satellite-based imaging spectroscopy to answer NASA Earth Science and Applications questions. The EO-1 mission carries the Hyperion imaging spectrometer, that has been collecting data for over 13 years and acquiring over 70,000 images in that time. HyspIRI (Hyperspectral Infrared Imager) is a proposed NASA mission to fly an imaging spectrometer and multispectral thermal imager. Research focuses on the use of hyperspectral imagery of landscapes to determine biophysical characteristics of vegetation, and to link those characteristics to carbon fluxes, plant growth, biodiversity, and disturbances. Hyperspectral and narrow-band multispectral data can detect changes in apparent leaf spectral reflectance due to biochemical status or fluorescence associated with plant stress. Combining reflectance data with *in situ* measurements of carbon flux provides opportunities to link vegetation photosynthetic rates to spectral reflectances. Leaf level measurements are used in models merging canopy reflectance with photosynthesis models to examine relationships between spectral reflectance and carbon, water, and energy fluxes. These relationships are also explored at a canopy level using canopy-level reflectance measurements combined with ecosystem carbon flux measurements from flux towers and extended to wider scales using aircraft and Hyperion data. This understanding provides the basis for algorithm development for HyspIRI.

Accomplishments in FY 13–14

To examine vegetation spectral reflectance changes associated with stress in a detailed manner, field experiments were conducted where measurements of leaf level reflectance and carbon exchange were made in conjunction with measurements of whole canopy reflectance and carbon exchange. This fieldwork was performed in a cornfield in collaboration with Department of Agriculture scientists. Hyperspectral reflectance data were collected at multiple times diurnally in a cornfield and compared with carbon fluxes measured in the same field. A tower-mounted automated spectrometer has been developed to measure diurnal and seasonal changes in canopy-level spectral reflectance, surface temperature, and fluorescence. This automated system is a prototype for future systems for calibration and validation of HyspIRI and other proposed missions. Results find short-term changes in apparent spectral reflectance are associated with photosynthetic down-regulation and the reduction of carbon uptake by the plants. Results were presented at the Fall American Geophysical Union meeting.

Further field work was performed at sites in North Carolina in September and October to support a joint NASA/European Space Agency (ESA) flight campaign that flew an instrument suite containing a lidar, thermal imager, and hyperspectral imager from Goddard Space Flight Center combined with the ESA's imaging spectrometer and high-spectral resolution imager for observing solar induced fluorescence. Ground measurements included leaf level photosynthesis, spectral reflectance and transmittance, pigment concentrations, and fluorescence. Fluorescence was also measured on conifer needles *in situ.* The tower-mounted automated spectrometer was moved from the cornfield to a tower in the Duke Forest. Ground measurements of the reflectance of calibration tarps and surface temperature were collected during aircraft overpasses for aircraft instrument calibration. This joint campaign was a test run for a proposed NASA Earth Ventures Suborbital mission called VegFusion. Huemmrich is Deputy PI on that proposal.

Huemmrich combined field measurements of tundra vegetation reflectance and carbon flux to identify optical-functional tundra plant types, such as lichens, mosses, and vascular plants. The relationships developed from the field measurements were used to map regional patterns of the coverage of these plant types for an area around Barrow, Alaska using Hyperion imagery and relating vegetation patterns with carbon fluxes.

Hyperion imagery was matched with ecosystem carbon flux data from the global network of eddy covariance towers, with data from 33 globally distributed flux tower sites, representing a variety of different vegetation types, during the middle of the growing seasons from 2001 to 2007. Spectra were compared with ecosystem respiration and Light Use Efficiency (LUE) calculated from the flux tower data. The best spectral vegetation index (SVI) for LUE, out of 107 tested, was based on spectral derivatives (R2=0.5). Going beyond traditional SVI, data mining approaches were applied to this diverse dataset to provide insights into other productive approaches. Partial Least Squares (PLS) which utilizes all of the spectral information, trained using randomly selected subsets, and applied to the rest of the data produce R2 values over 0.7 for LUE. A second analysis using imagery from only four tower sites but sampled throughout the entire growing season indicate PLS regressions can also describe seasonal change in different vegetation types. Further analysis is required as the regression equations do not transfer between these two datasets.

Objectives for FY 14-15

Continue the work on remote sensing of plant stress. Publish analysis using MODIS and Hyperion data to detect light use efficiency for multiple vegetation types, leading to the development of a model for ecosystem carbon uptake driven only by satellite data. Examine the use of narrow spectral band data to detect chlorophyll fluorescence and its relation to carbon fluxes. Work with combining thermal and spectral data to determine ecosystem water and energy fluxes along with carbon flux. Continue to work on the development of research activities on monitoring high latitude ecosystem change. Examine the use of high temporal frequency reflectance data from automated sensors for describing vegetation seasonality and temporal patterns of carbon flux. Support airborne campaigns to collect fluorescence, thermal, and spectral reflectance data for monitoring vegetation stress and carbon fluxes

USRA subaward: Carbon Monitoring and Ecosystem Feedbacks Prediction Using fAPARchl and the Community Land Model (CLM)

Investigators: Q. Zhang, USRA, PI; Y-B. Cheng, ERT; Jiangfeng Wei, U. Texas Austin; K. F. Huemmrich, Research Associate Professor, JCET; E. Middleton, GSFC

Description of Research

The focus of this research is to retrieve the fraction of photosynthetically active radiation absorbed by chlorophyll (fAPARchl) from available spaceborne observations (e.g. Terra/MODIS and Aqua/MODIS, Landsat, and EO-1 Hyperion) for quantifying both spatial variation and temporal dynamics of chlorophyll content for the continental US. fAPARchl is a key limiting factor in determining ecosystem gross primary production (GPP). Time series of geospatial datasets of fAPARchl and derived GPP for the continental US region will be derived from MODIS data as 8-day composites at 1000-m spatial resolution for 2000 – 2011. The fAPARchl product from MODIS will be integrated into the most recent version of the Community Land Model (CLM) to improve the model's simulation of surface fluxes reducing uncertainties due to ecosystem feedbacks.

Accomplishments in FY 13–14

Worked on a paper using the photochemical reflectance index (PRI) from MODIS, relating it to ecosystem light use efficiency, a variable linked with GPP, as measured by flux towers. PRI is related to fAPARchl.

Evaluated flux tower sites to determine the uniformity of vegetation in the area around each tower at the scale of a MODIS pixels (500 m and 1000 m). Relationships between PRI or fAPARchl and GPP can vary with vegetation type, so that establishing the variability of vegetation types around flux towers at the MODIS pixel scale is important for the interpretation of the data.

Objectives for FY 14-15

Work with MODIS and Hyperion data, combining fAPARchl and PRI to find if the combination improves determination of terrestrial ecosystem carbon fluxes.

Task 363: A Comprehensive Operational and Science Evaluation of Algorithm MAIAC for the MODIS Land Processing (Sponsor: Alexei Lyapustin)

Investigators: Yujie Wang, Associate Research Scientist, JCET; Alexei Lyapustin, GSFC

Description of Research

The main objective of Dr. Wang's research consists of three areas: 1) Operational performance of the Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm; 2) Adapting the MAIAC algorithm for GOES-R related risk reduction activities; and 3) Conducting MODIS/VIIRS calibration-validation analysis for surface reflectance products.

The MAIAC is a newly developed atmospheric algorithm which uses a time series approach and an image-based rather than pixel-based processing system to perform simultaneous retrievals of atmospheric aerosols and surface spectral bi-directional reflectance (BRF)/albedo without empirical assumptions. The contemporary paradigm of atmospheric correction algorithms developed for instruments such as MODIS and AVHRR are pixel based and depend on only single-orbit data. It produces a single measurement for every pixel characterized by two main unknowns, AOT and BRF. This raises a fundamental concern: the remote sensing problem cannot be solved without either a priori assumptions or ancillary data. These priori constraints are approximate, and limit the accuracy and/or applicability of the current operational aerosol/atmospheric correction algorithms. On the contrary, The *MAIAC* algorithm is an algorithm for simultaneous retrieval of the aerosol optical thickness and surface bidirectional reflectance from MODIS. It uses the time series of gridded geolocated and calibrated L1B MODIS measurements, and an image-based rather than pixel-based processing. If we take into account the facts that the surface changes much slower than measurement frequency and the AOT varies over rather large scale, the number of measurements will be more than the number of unknowns, which becomes a solvable problem. The new algorithm is generic and works over vegetated regions of the Earth as well as over bright deserts. The aerosol retrievals are performed at high 1 km resolution, which is a highly requested product in different science and application disciplines, such as Air Quality/Urban Pollution. MAIAC has an advanced cloud mask (CM) and an internal dynamic land-water-snow classification that helps the algorithm to flexibly choose a processing path in changing conditions.

Accomplishments for FY13 -14

Dr. Wang continuously conducted large scale test over North America and Europe regions. The current MAIAC code was successfully tested for these regions in NASA NCCS supercomputers. Various ancillary software such as ozone data pre-processor, DEM data pre-processor, MODIS L1B downloading tool, as well as some MAIAC data analysis tools such as MAIAC data browse image creator, MAIAC pixel geolocation extractor, MAIAC data subset tool, were also developed and tested in the supercomputer. The MAIAC outputs include surface reflectance (BRF), BRDF model parameters, Aerosol Optical Thickness (AOT) and cloud Mask (CM). Both MODIS Terra and Aqua full time series for these regions was processed. The results were distributed to user communities and used in air quality, ecosystem studies.

To count for the calibration errors caused by sensor polarization sensitivity, Dr. Wang also developed a new Polarization Correction (PC) algorithm to removes residual scan angle, mirror side and seasonal biases from aerosol and surface reflectance (SR) records along with spectral distortions of SR for land surface, based on the PC algorithm developed by the MODIS ocean biology processing group (OBPG). This is an enhanced C6+ calibration of the MODIS dataset which includes an additional PC to compensate for the increased polarization sensitivity of MODIS Terra since about 2007. Using the MAIAC algorithm over deserts, Dr. Wang has also developed a de-trending and cross-calibration method which removes residual decadal trends on the order of several tenths of one percent of the top-of-atmosphere (TOA) reflectance in the visible and near-infrared MODIS bands B1-B4, and provides a good consistency between the two MODIS sensors. MAIAC analysis over the southern USA shows that the C6+ approach removed an additional negative decadal trend of Terra DNDVI~0.01 as compared to Aqua data. This change is particularly important for analysis of vegetation dynamics and trends in the tropics, e.g., Amazon rainforest, where the morning orbit Terra provides considerably more cloud-free observations compared to the afternoon Aqua measurements.

Objectives for FY 14-15

In the coming year, Dr. Wang will continue to perform large scale test of MAIAC algorithm. The newly developed PC approach will be applied and tested. Dr. Wang will also continue to develop the MAIAC operational code to prepare for the global data processing. The MAIAC algorithm will also be adapted to VIIRS sensor and the calibration/comparison analysis will be conducted.

Heliophysics & Solar System Divisions
(Codes 670-690)

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NASA Grant: Understanding Near-Equator Geomagnetic Spots via data assimilation (NNX12AP31G)

Investigators: Andrew Tangborn, Research Associate Professor, Mathematics; Weijia Kuang, , Goddard Space Flight Center

Description of Research

Research for this project is carried out in the field of geomagnetic data assimilation, which involves the technique of combining geomagnetic observations with a geodynamo m_Thedat

a assimilation research group, funded by both NSF and NASA during the past 10 years, is a collaborative project that has involved scientists and graduate students from UMBC, Goddard Space Flight Center, Oregon State University and Harvard University. We 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.

Accomplishments in FY 13–14

The geomagnetic data assimilation work continues on improving the ability to forecast future changes to the geomagnetic field, and to improving estimates to the dynamics of the Earth's core. The assimilation algorithm has been rewritten so that it can now make use of observation – forecast (O-F) statistics to improve the error estimates for the covariance matrix. We also have begun to include more realistic observation errors, which generally increase back in time. The system now also has greater flexibility to handle a wide range of forecast error correlation length scales, which should improve the magnetic field deeper within the outer core.

We have used this new system to demonstrate how geomagnetic data assimilation can be used to improve our knowledge of geodynamo parameterization and error estimates for both geodynamo models and geomagnetic observations. This is done through regular comparison of model forecasts with the observations. Changes to model parameters (such as Rayleigh number) or observation error estimates can then be assessed by comparing the changes to the accuracy of the geomagnetic forecast. Using this approach we have shown that we can find an optimal set of model parameters (for a given model resolution), and have shown that this corresponds to a generally accepted "earth-like" parameter regime in geodynamo modeling (Tangborn, et al., 2014). We have also shown that forecast accuracy is sensitive to observation error estimates used in the assimilation system. This shows that data assimilation can be used as a tool to improve estimates of geomagnetic observation errors as well.

Objectives for FY 14-15

During the coming year we are focusing on developing new techniques that will enable the assimilation of geomagnetic secular variation (SV) into a geodynamo model. Secular variation, the rate of change of the geomagnetic field, is directly related to the fluid motion in the Earth's core through the magnetic induction equation. This means that assimilating SV into a geodynamo model has the potential to improve estimates of fluid flow in the core. We have submitted a proposal to NSF for the development of an SV assimilation system, and will continue with this work during the coming year.

Office of Education
(Code 160)

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NASA Grant: **NASA's BEST Students: Dissemination and Expansion to Other Centers (NNX11AI16G)**

NASA Task 378: **NASA's Beginning Engineering, Science and Technology (BEST): Educator Professional Development (EPD) (Sponsor: Dean Kern)**

Subcontract: **Anne Arundel County Public Schools (from NASA Grant: NASA Earth & Space: Online "Missions" for High School Students and Accompanying Professional Development for Educators) (PO#01B10010400257)**

CRSST Task 690.002: PDS College Student Investigators

Subcontract: **Howard County Public Library System (HCLS) (from IMLS Grant: HiTech: The Road to a STEM Career)**

Investigators: Susan Hoban, Associate Director, Academics, JCET; Anuradha Koratkar, JCET; Laurie Cook; UMBC GEST; Michelle Graf, UMBC GEST; Carmel Conaty, GSFC; Catherine Kruchten, JCET; Maureen McMahon, Anne Arundel County Public Schools; Richard Cerkovnik, Anne Arundel Community College; Charles Wood, Wheeling Jesuit University; Ed Grayzeck, GSFC; Tom Morgan, GSFC; Angela Brade, HCLS.

Students: Laurie Cook, JCET; Michelle Graf, GEST; Catherine Kruchten, Paragon/GSFC; Carmel Conaty, GSFC; Russ Billings, DFRC; Nancy Hall, GRC; Susan Currie, MFSC; John Boffenmyer, SSC

NASA Co-Investigators: Anuradha Koratkar, GEST; Maureen McMahon, AACPS.

Description of Research

The JCET STEM (Science, Technology, Engineering and Mathematics) Education team is active in several projects. The NASA's BEST Students project involves research, development and application of educational technologies to communicate NASA science and engineering concepts to educators and students. The NASA's BEST Students team provides professional development for educators and curriculum support resources with a space exploration theme for engineering clubs for elementary and middle school students and for robotics clubs for high school students. More information may be found on the NASA Portal: www.nasa.gov/audience/foreducators/best/

The JCET STEM Education team also collaborates with Anne Arundel County Public Schools, Anne Arundel Community College and Wheeling Jesuit University on the development and implementation of NASA Earth & Space, an online course for high school students and the accompanying professional development for educators. This innovative course places students in the roles of scientists, as they solve problems and collaborate on-line with actual scientists around the world.

The JCET STEM Education team also collaborates with the Howard County Public Library System (HCLS) on providing STEM educational content to the Library's HiTech program. The team provides content directly to youth learners and professional development to Library staff. HCLS was recognized as Library of the Year in 2013, partly due to the innovations in HiTech.

The JCET STEM Education team works with the NASA Planetary Data System (PDS) to involve undergraduate students in planetary science research. NASA's Planetary Data System (PDS) Student Investigators (SI) are undergraduates, funded to conduct research using data from the PDS. The objective of the program is to introduce young scientists to the research process using data from the PDS. The team works with the PDS Student Investigators in a scientific mentoring capacity. In conjunction with mentors at the PDS Nodes, the team works with the students on their research proposals, discusses their research results, helps prepare conference abstracts and posters, and assists the students in the writing of their final paper. The group meets online monthly during the academic year and bi-weekly during the summer and winter breaks.

Accomplishments in FY 13-14

During the reporting period, the NASA's BEST Students (NBS) project directly impacted 2,141 educators, 1,464 students, and 215 education outreach participants. NBS also utilized the Distance Learning Network (DLN) to reach educators with limited access to NASA Centers. Professional development sessions included both short-term and long-term face-to-face engagement using a "train the trainer" model to optimize NASA resources. Additionally, NBS models focused partnerships with Districts, as with the D.C. Public School District, wherein educators were granted up to 54 seat hours of professional development credit; the credit exchange model is pursued by NBS when possible. Additionally, the Los Angeles Unified School District (LAUSD), the second largest school district in the nation with nearly 700,000 students, adopted the NASA's BEST Students curriculum for their acclaimed afterschool program, "Beyond the Bell." During the reporting period, the pilot of NASA's BEST in LAUSD was expanded to reach upwards of 5,000 students. In addition to professional development provided to Anne Arundel County Public Schools, the team provided an extensive robotics course to 100 middle school students at the Old Mill Middle South middle school in Anne Arundel County Public Schools. The NBS team provided two robotics workshops to the HCLS HiTech program, reaching 40 students.

The NASA Earth and Space course was offered for the third year in Anne Arundel County Public Schools during the reporting period. Revisions to the course materials are completed, and the final report to NASA has been submitted.

A new cohort of NASA Planetary Data System Student Investigators was brought onboard this year. Two students are researching the effects of planetary atmospheres on the potential for life on other planets, and one student is study cometary dust and plasmas.

Objectives for FY 14-15

The NBS team will continue to provide professional development on the extant NBS engineering education and robotics curriculum. The team will work with HCLS HiTech to develop new STEM content for youth. NASA PDS Student Investigators will continue their research projects and present a poster at a professional meeting. One of the PDS Student Investigators will spend summer 2014 at UMBC to work directly with the team and scientists at Goddard.

III. SUPPORTING INFORMATION

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III.2 Peer-Reviewed Publications

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Berkoff, Timothy A.

Journal Article, Professional Journal (Published) Knepp, T., Pippin, M., Crawford, J., Szykman, J., Long, R., Cowen, L., Cede, A., Abuhassan, N., Herman, J. R., Delgado, R., Compton, J., Berkoff, T. A., Fishman, J., Martins, D., Stauffer, R., Thompson, A., Weinheimer, A., Knapp, D., Montzka, D., Lenschow, D., Neil, J. Towards a Methodology for Estimating Surface NO2 and SO2 Mixing Ratios from High Spatial and Temporal Resolution Retrievals, and its Applicability to High-resolution Space-based Observations. *Journal of Atmospheric Chemistry*, 10.1007/s10874-013-9257-6.

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Mišurec, J., Kopačková, V., Lhotáková, Z., Hanuš, J., Weyermann, J., Entcheva-Campbell, P. K., and J. Albrechtová, 2012. Utilization of hyperspectral image optical indices to assess the Norway spruce forest health status, *Submitted to Journal of Applied Remote Sensing.*

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Williams, C. R., and the co-authors, Describing the shape of raindrop size distributions ssing uncorrelated raindrop mass spectrum parameters. *Journal of Applied Meteorology and Climatology*, 2014, 53, 1282-1296.

Yuan, T., and L. Oreopoulos (2013), On the global character of overlap between low and high clouds, Geophys. Res. Lett., 40, 5320–5326, doi:10.1002/grl.50871.

III.4 Courses Taught

First Year Seminar 102 : Transforming Technologies

First Year Seminar 103: Monitoring Global Environmental Change with NASA Satellite Imagery

Geography and Environmental Systems 311: Weather and Climate

Geography and Environmental Systems 481: Remonte Sensing of the Environment

Honors 300: Robots in Society

Math 423: Differential Geometry

Physics 112: Basic Physics II

Physics 450: Special Topics in Physics

Physics 622: Atmospheric Physics II

Physics 650: Special Topics in Experimental Atmospheric Physics

II.5 Proposals Submitted by JCET Members
(Sorted alphabetically by proposal title, then by funding agency.)

Proposal Title	Funding Agency	PI (JCET)	CO-I(s) (JCET)	Status
21st century mass balance rates and projections of surface melt of land-terminating glaciers in Southwest Greenland	Columbia University (NASA)		Shuman, Christopher	Pending
A Consistent Aerosol Data Record from MODIS and VIIRS	NASA	Remer, Lorraine		Pending
A Modeling Analysis of the Impacts of Particulate Pollution on Tropospheric Chemistry in Past Decades Constrained by Surface Measurement and Satellite Data	MIT (NASA)		Bian, Huisheng	Pending
A Near-Global Exploration of Aerosol-Convection-Lightning Interactions and Their Impacts with NASA Data	NASA	Yuan, Tianle		Not Awarded
A Program of Satellite Ground Truth Measurement in the Eastern United States	NASA		Georgieva, Elena	Not Awarded
Adaptation to Decadal Climate Variability for Sustainable Water, Food, and Energy Security in the Missouri and Nile River Basins: A Regional Study Integrating Earth System Data, and Hydrologic, Agricultural, Land Use, and Economic Models	NSF		Mehta, Amita	Pending
Advancing Broadband LIDAR Technology Readiness for the ASCENDS Mission	NASA		Georgieva, Elena	Not Awarded
Advancing MODIS Climate Data Records with Algorithm MAIAC	NASA		Wang, Yujie	Awarded

Aerosol absorption retrievals from base-line OCI observations: Risk reduction for atmospheric correction of the PACE mission	NASA	Remer, Lorraine		Pending
Aerosol Optical and Physical Properties Measured from the Polarized Imaging Nephelometer	NASA	Martins, Vanderlei	Remer, Lorraine	Pending
Aerosol Trans-Pacific transport, deposition, and interactions with clouds and radiation: A perspective from decadal satellite measurements and model simulation	NASA		Bian, Huisheng	Not Awarded
AIRS Forward Model Improvement	NASA	Strow, Larrabee	DeSouza-Machado, Sergio, Tangborn, Andrew	Awarded
An integrated cross-scale analysis of the physical, biological and chemical context of forest diversity	NSF		Campbell, Petya K.E.	Not Awarded
An Inter-comparison reanalysis and flux inversion for CO2 using observations from AIRS, ACOS GOSAT and OCO-2	NASA	Tangborn, Andrew	Imbiriba, Breno	Not Awarded
Applications of MODIS, ASTER, and MISR to Ice Sheet Processes and Modeling	NASA		Shuman, Christopher	Not Awarded
Applying Aircraft and satellite measurements in evaluation and improvement of photolysis model for photochemistry simulation in GEOSCCM	NASA	Bian, Huisheng		Pending
Bowie State University and National Education Partners (BNEP): STEM Advances Professional Learning for Educators (STAPLE) “Teaching and Preparing K-20 Students for the Future”	Bowie State University (NSF)		Hoban, Susan	Pending
Carbon Monitoring and Ecosystem Feedbacks	NASA	Huemmrich, K.F.		Awarded

Changes in forest land cover extent, function and productivity in Central Europe: a prototype assessment of their driving factors, and their impacts on climate and society	NASA	Campbell, Petya		Pending
Characterization of boundary-layer cloud properties during cold-air outbreaks with MODIS and MISR	NASA		Lee, Jae N.	Not Awarded
Characterization of Spectral Solar Irradiance Short-Term Variability with SORCE SIM Observation	NASA	Lee, Jae N.		Not Awarded
Characterizing aerosol effects on the heating profiles and atmospheric stability from MODIS, AIRS, OMI and CALIPSO products	NASA	Remer, Lorraine	Martins, J. Vanderlei Koren, Ilan	Not Awarded
Characterizing Lidar Backscattering Profiles and MERRA Reanalysis for Aerosol-Cloud and Air Quality Related Studies	NASA	Chu, Allen		Pending
Climate Studies using Time Evolution of probability distribution functions from 10+ years of AIRS measurements	NASA	De-Souza-Machado, Sergio	Tangborn, Andy	Awarded
Climate Trends Using Hyperspectral Infrared Satellite Sounders	NASA	Strow, Larrabee	DeSouza-Machado, Sergio; Tangborn, Andrew	Pending
Collaborative Proposal: Full Scale Development, HiTech: The Road to A STEM Career	NSF	Hoban, Susan		Pending
Collaborative Research: A new ensemble-OI hybrid approach to geomagnetic data assimilation	NSF	Tangborn, Andrew		Not Awarded
Collaborative Research: HiTech: The Road to STEM Career.	NSF	Hoban, Susan		Pending

Combining surface reflectance and emissivity to assess the changes in ecosystem diversity and function due to natural and anthropogenic stress factors / disturbance effects	NASA	Campbell, Petya		Not Awarded
Community Engagement: STEM DiRBE (Distributed Robotics Build Event)	Ann Arundel County Public Schools (NSF)		Hoban, Susan	Pending
Community Health using Air Quality Surveillance System (CHASS)	University of Miami (NASA)		Chu, Allen	Pending
Continuity of the AIRS/AMSU cloud products for Suomi NPP	JPL (NASA)		Strow, Larrabee	Pending
Convective cloud life cycle and aerosol impact: ASR based observational and modeling investigation	DOE	Yuan, Tianle		Not Awarded
Convective cloud system size and structure: Linking atmospheric thermodynamics and aerosols to convective cloud cover	Desert Research Institute (NASA)		Yuan, Tianle	Not Awarded
Core Flow estimates using assimilation of geomagnetic secular variation	NSF	Tangborn, Andrew		Pending
Data assimilation of GPP across northern latitudes from direct satellite observations	Oregon State U (NASA)		Hall, Forrest	Not Awarded
Data assimilation of GPP across northern latitudes from direct satellite observations	Oregon State U (NASA)		Hall, Forrest	Not Awarded
Decision Support System (DSS) to Enhance Source Water Quality Modeling and Monitoring using Remote Sensing Data	Benjamin, Stanford, & Sawyer (NASA)		Mehta, Amita	Pending
Defining a MODIS Light Use Efficiency Product	NASA	Huemmrich, K.F.		Awarded

Deteriming aerosol properties and radiative forcing over heterogeneous land surfaces	NASA		Remer, Lorraine	Not Awarded
Development of a Laboratory Based Data Base of Aerosol Optical Properties	NASA	Martins, Vanderlei	Borda, Roberto	Pending
Development of an Advanced Earth Sciences Imager for CubeSat Applications	NASA	Borda, R. Fernandez		Not Awarded
Development, Validation, and Scientific Evaluation of a Multi-Year Sounder Based Climate Data Set Using Products Derived from AIRS/AMSU, CERES, MODIS, and TOVS Observations	NASA		Lee, Jae N.	Not Awarded
Diagnostic and modeling studies of the relationship between ozone and water vapor using Aura satellite observations, in situ measurements and the	USRA (NASA)		Bian, Huisheng	Not Awarded
Dimensions NASA: Collaborative Research: Integrating and extrapolating the biodiversity of forest carbon flux across time and space	NASA and NSF		Huemmrich, K.F.	Not Awarded
Earth Photosynthesis Imaging Constellation	Oregon State U (NASA)		Hall, Forrest	Pending
Evaluate and constrain aerosol indirect effect in the trade cumulus regime with NASA data and models	NASA	Yuan, Tianle		Awarded
Evaluating marine boundary layer clouds in a MMF model using collocated CloudSat and MODIS observations with a focus on cloud microphysics and warm rain	NASA	Zhang, Zhibo		Not Awarded
Evaluation of ICESat-1 Inter- Campaign Bias Assessments Using Operation IceBridge Altimetry Data Over Ice Sheets	NASA	Shuman, Christopher		Not Awarded

Evaluation of NCAR CAM5 simulated MBL cloud properties using a combination of satellite and surface observations	DOE	Zhang, Zhibo		Pending
Evaluation of the Synergy Between Airborne BRDF and Lidar Measurements In Remote Sensing of the Canopy Structure and Biophysical Properties of Forested Landscapes	NASA		Várnai, Tamás	Not Awarded
Exploiting Suomi NPP OMPS nadir mapper observations for the retrieval of NO2 columns and free-tropospheric NO2 mixing ratios	GSFC (NASA)		Herman, Jay	Pending
Farmland and Agriculture Remote	NASA		Huemmrich, K.F.	Pending
Fine tuning the MODIS dark target aerosol algorithm and products: comprehensive error analysis	NASA		Remer, Lorraine	Not Awarded
Fire and land use perturbations on the energy and water cycles of the American West	NASA	Remer, Lorraine	Martins, J. Vanderlei Koren, Ilan	Not Awarded
Generation of Advanced VIIRS Land-Atmosphere Product Suite with Algorithm MAIAC	GSFC (NASA)		Wang, Yujie	Pending
High Clouds Overlapping Low Clouds: Observational Characterization and Impact Assessment	NASA	Yuan, Tianle		Not Awarded
HiTech: The road to a STEM career, Institute of Museum and Library Services	Howard County Library System (NASA)	Hoban, Susan	Cook, Laurie	Awarded
Hyperspectral Remote Sensing of Terrestrial Ecosystem Carbon Fluxes (HRS TECF)	CASIS	Huemmrich, K.F.	Campbell, Petra	Awarded
Identifying sources of ionospheric variability from above and below	University of Texas, Dallas (NASA)		Lee, Jae N.	Pending

Improved understanding and modeling of Nox emissions and distributions, using observations from multiple airborne campaigns, surface-based networks and OMI satellite data	NASA	Herman, Jay		Pending
Improving and exploiting global satellite hyperspectral measurements for ecosystem assessment and modeling	NASA		Huemmrich, K.F.	Pending
Improving the representation of aerosol-cloud-precipitation processes in global climate models using observations from CloudSat, CALIPSO and other A-train sensors	PNNL (NASA)		Yuan Tianle	Not Awarded
Inferring drought stress through remotely-sensed leaf chemistry: seeing the forest through the leaves	NASA		Huemmrich, K.F.	Not Awarded
Integrating NASA Earth Observations into EPA's Worldwide AirNow Program to Improve Public Health	NASA	Chu, Allen		Pending
Interpreting and Utilizing MPL Net Data: A Combined Measurement and Modeling Study	Atmospheric and Environmental Research (NASA)		Lewis, Jasper	Pending
Investigation of Arctic Atmospheric and Surface Albedo Changes with MISR, MODIS and GEOS-5 Model	NASA	Várnai, Tamás		Pending
Investigation of boundary-layer cloud changes and their impacts on the Arctic warming	NASA		Lee, Jae N.	Not Awarded
Linking Changes in Aerosol Loading to Changes in Cloud Properties Over Time	GSFC (NASA)		Remer, Lorraine	Pending
Long-term Satellite Data Fusion Observations of Arctic Ice Cover and Methane as a Climate Change Feedback	NASA		Yurganov, Leonid	Awarded

Low Cost, High Precision Measuring, Reporting and Verifying System for Greenhouse Gas Total Column	NASA		Georgieva, Elena	Not Awarded
Mini Fourier-Transform Spectrometer for Cubesat-Based Remote Sensing	Appalachian State (NASA)		Hewagama, Tilak	Awarded
Multiangle Optical–Lidar Approach to Canopy Structure Measurements	USRA (NASA)		Várnai, Tamás	Not Awarded
NASA Snow Modeling Airborne Spring Snowmelt Experiment (SnowMass)	USRA (NASA)		Várnai, Tamás	Pending
New angular distribution models for satellite estimation of direct radiative forcing by wildfire aerosols	USRA (NASA)		Várnai, Tamás	Pending
New CO and O3 Products for Climate and Air Quality Studies Using Data Fusion from Multiple Sensors on A- train Satellites	UMCP (NASA)		Tangborn, Andrew	Not awarded
Observational Characterization of Extreme Precipitation Events over Global Tropical and Midlatitude regions	NASA	Mehta, Amita		Pending
Ocean Color and Chlorophyll Trend Uncertainty for the Suomi National Polar-Orbit Partnership (NPP) Mission	NASA	Turpie, Kevin		Pending
Quantification Of Shortwave Direct Radiative Effects Of Above-Cloud Aerosols Over Global Oceans Using Multiple Satellite Data Sets	NASA	Zhang, Zhibo		Awarded
Quantifying contributions of variability in stratospheric mean transport and mixing and its connection to STE using Aura observations	GSFC (NASA)		Lee, Jae N.	Pending
Regional methane surface fluxes inverted from GOSAT radiances	UMD (NASA)		Bian, Huisheng	Pending

Remote Sensing Application and Evaluation of Pelagic Net Primary Productivity Models	NASA	Turpie, Kevin		Not Awarded
Respiratory health effects of air quality regulations in Delhi	University of Miami (NSF)		Chu, Allen	Pending
Retrieval Studies in Support of Cloud Property Products From the Pace Ocean Color Imager	GSFC (NASA)		Zhang, Zhibo	Pending
Retrievals of Precipitating Snow Using CloudSat Reflectivities and Radiometric Brightness Temperatures	NASA (GSFC)		Johnson, Benjamin	Not Awarded
Satellite and sub-orbit observations to improve boundary layer ammonia and PM2.5 mixing ratios associated with agricultural emission and its effects on climate and air quality	NCSU (NASA)		Bian, Huisheng	Pending
Satellite Thermal IR Retrievals and Modeling of the Arctic Methane: Towards Quantification of Emission from Clathrates and Permafrost	NASA	Yurganov, Leonid		Not Awarded
Satellite-Derived Surface- Temperature CDRs and Melt Maps of the Greenland and Antarctic Ice Sheets	NASA	Shuman, Christopher		Not Awarded
Single-footprint retrievals of atmospheric properties from CrIS	JPL (NASA)		Strow, Larrabee	Pending
Solar Excited Chlorophyll Fluorescence System for the Assessment of Vegetation Photosynthetic Function	NASA		Campbell, Petya K.E.	Not Awarded
Spatial scaling of vegetation biogeochemical cycle from pan arctic remote sensing data	NASA	Hall, Forrest		Not Awarded
Spatially and temporally continuous vegetation dynamics derived from MODIS using the multi-angle	Oregon State U (NASA)		Hall, Forrest	Not Awarded

implementation of atmospheric correction (MAIAC) algorithm				
Spectral Bio-Indicators of Ecosystem Photosynthetic Efficiency III	NASA	Huemmrich, K.F.	Campbell, Petya	Not Awarded
Spectral Bio-Indicators Successor Study	NASA		Huemmrich, K.F.	Not Awarded
STEM Innovation Incubator	USDE	Hoban, Susan		Not Awarded
Study of aerosol properties in the vicinity of clouds using multiplatform and multisensor data fusion	NASA	Várnai, Tamás		Not Awarded
The Effects of Atmospheric Composition on UTLS Structure and Stratosphere-Troposphere Exchange	GSFC (NASA)		Bian, Huisheng	Pending
The Global Ecosystem Dynamics Mission (GEDI)	NASA		Hall, Forrest	Not Awarded
The sensitivity of marine boundary layer cloud retrievals and derived products to spatial resolution: an integrated study using (e)MAS and other field campaign data, satellites, and 3-D radiative transfer	USRA (NASA)		Zhang, Zhibo	Pending
Time Series Approach for Ocean Color and Aerosol Retrievals Over Coastal and Turbid Waters	GSFC (NASA)		Wang, Yujie	Pending
Total aerosol radiative forcing caused by urban intrusion into the Amazon	DOE	Remer, Lorraine	Martins, J. Vanderlei Koren, Ilan	Not Awarded
Trade Cumuli Variability and Interactions with Aerosols: Diagnostic and Modeling Studies with A-Train Data and an LES Model	NASA	Yuan, Tianle		Not Awarded

Transition of GIFS-IIP Prototype to Science Campaign-Ready Airborne Chlorophyll Fluorescence Instrument (ACFI)	NASA		Huemmrich, K.F.	Pending
Understanding the response of tropospheric chemistry to trends in natural and anthropogenic emissions through in situ and remote observations of formaldehyde	NASA	Wolfe, Glen		Pending
Use of co-located CALIPSO and MODIS observations in understanding aerosol properties in the vicinity of clouds	NASA		Várnai, Tamás	Not Awarded
Use of the Pandora Spectrometer Network to Validate NPP/OMPS, AURA/OMI, AURA/MLS Ozone Column Amount and Profiles and OMI Trace Gases (NO2, HCHO, BRO)	NASA		Herman, Jay	Awarded
Using MODIS, ASTER, CloudSat and Large-eddy-simulation to better understand the microphysical and optical properties of heterogeneous and precipitating marine boundary layer clouds	NASA	Zhang, Zhibo		Selected
Utilizing Aerosol Vertical Profile Observations and MERRA Reanalysis data for Air Quality and Aerosol-Cloud Interaction Studies	NASA	Chu, Allen	Yuan, Tianle	Pending
Value of High Signal to Noise Hyperspectral and Multi-angle Data: The FARMS-Ground Simulator	NASA		Huemmrich, K.F.	Not Awarded
Waste Dumping in Drainage Channels in Port-au-Prince, Haiti: A Method for Floating Trash Separation During Periods of Storm Water Flow	USAID	Bulmer, Mark		Not Awarded

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III.6 Biographies

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Dr. Nader Abuhassan received an electrical engineering degree from the University of Damascus, Syria in 1983 and a PhD in Geophysics from the University of Pierre and Marie Curie Paris 6, France in 1995. Since 1997, he has been working at NASA's Goddard Space Flight Center. During the past 25 years, Dr. Abuhassan participated in the design and development of multiple world recognized sensors such as the Cimel sun photometers, Solar Viewing Interferometer and the Pandora Spectrometer. He has great interest in all aspects of hardware and software sensors design.

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

Dr. Roberto A. Fernandez Borda received his Master's degree in Physics in 1996, from the University of Buenos Aires (UBA), Argentina, working in the development of a Solar Hard X ray sensor which was part of the payload of the first Argentinian Satellite, Sac-B. In 1997, he received a graduate-fellowship to finish his Ph.D at the Institute of Astronomy and Space Physics at UBA. During this period, under the framework of an international agreement with the Max Plank Institute for Extraterrestrial Physics, Germany, he was involved in the instrument automation and the calibration algorithms of a new H-alfa telescope for Solar Physics. As a result of his work, he obtained his PhD in 2001 in Physics/Applied Physics from UBA. In 2002, he got a Post-Doctoral fellowship from the National Research Council, United States, to work at the Planetary Physics branch of NASA GSFC. He was involved in the instrumental development of flux magnetometers for planetary applications (Ares Mission), as well as signal processing algorithm designs for their onboard calibrations and data analysis (Wind and Voyager Missions). In 2006, he became part of the Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County (UMBC), working in the Climate and Radiation Branch of

NASA GSFC. As a member of this team, he was involved in different instrumental projects: the Particles Aerosols & Cloud Physics Suite (PACS), the Cloud Scanner Cube-sat, and many field experiments: Milagro campaign (Mexico), Co-Claim Campaign (Brazil), and Vocals Campaign (Chile). In 2009, he received an award from the Climate and Radiation branch of GSFC for his contributions to the optical design of PACS and the Rainbow Camera. In 2010, he joined JCET as a Research Assistant Scientist.

Dr. Petya K. Entcheva Campbell received a BS in Forestry from the Academy of Forest Engineering, Sofia, Bulgaria in 1988, MS in Forest Sylviculture and Ecology from the University of Massachusetts at Amherst, MA and a Ph.D. in Natural Resources Management / Remote Sensing in 2000 from the University of New Hampshire, Durham, NH, where her research focus was on the development of remote sensing techniques for forest health assessment. In 2000, Dr. Petya 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. Her experience and expertise are in remote sensing for natural resources (PhD), with a specific interest in remote sensing, especially spectral analyses and assessments for the development of methods (algorithms and measurement techniques) for vegetation stress assessments and land cover change detection. Dr. Campbell started work in this direction as a post doctoral research associate of Dr. Midleton at NASA/GSFC, and later continued as a Prime Investigator on a NSF project for the “Evaluation of vegetation Solar Chlorophyll Fluorescence properties”. Of high interest to this end is the currently under development at ESA FLEX mission, which targets the assessment of solar exited ChlF. At GSFC she participates in the NASA’s “Light Use Efficiency and Carbon Science” research led by Dr. Middleton and have participated in the development of the satellite hyperspectral mission/s Flora/SpectraSat/HyspIRI for vegetation assessment led by Drs. Green, Ungar and Asner. Currently, she is a part of a research effort to develop spectral bio-indicators of vegetation stress, to facilitate the remote sensing assessment of vegetation photosynthesis and carbon sequestration. As part of the spectral research she has used various spectrometers and simulated/compared the abilities of the currently available earth observing sensors for vegetation stress detection. Currently, she participates in an EO-1 Hyperion data intercalibration and analysis effort, with the goal to compare existing and suggest new land cover products, addressing vegetation type and function. At the University of Maryland, Baltimore County (UMBC) Dr. Campbell teaches the class “Introduction to Remote Sensing for Environmental Applications” for undergraduate and /graduate students at the department of Geography and Environmental Systems (GES).

Ms. Valerie Casasanto has been the Program Coordinator for the University of Maryland, Baltimore County’s Joint Center for Earth Systems & Technology (JCET) since 2005 and the Education and Public Outreach Lead for the ICESat-2 mission since 2013. Ms. Casasanto is Principal Investigator for the NASA ROSES Education and Public Outreach (E/PO) award, Beautiful Earth: Experiencing and Learning Science in a New and Engaging Way (beautifulearth.gsfc.nasa.gov) engaging students and the general public in NASA Earth Science through music, art, and indigenous perspectives. Ms. Casasanto has more than 20 years of experience in designing, managing and implementing small and large-scale earth and space science educational programs to diverse age groups in multicultural environments. She has successfully managed and integrated student designed and PI science microgravity payloads on 15 space missions. Ms. Casasanto is a graduate and former employee of the International Space University (ISU), where she organized summer programs in a different host country each year. Ms. Casasanto is member and Vice-Chair of the International Astronautical Federation (IAF) Space Education and Outreach Committee (since 2002), member of GSFC's Education Implementation Team (since 2006), and member of GSFC's Native American Advisory Committee (since 2008).

Dr. Hyoun-Myoung Cho obtained a M.S. and B.S. in Atmospheric Sciences from Seoul National University in 1999 and 2002, respectively. He then worked at Forecast Research Laboratory at the National Institute of Meteorological Research, Seoul, Korea as assistant researcher. Following that position, he received a Ph.D. from Texas A&M University in Dec. 2011. His research interests are in the area of satellite-based remote sensing of clouds and aerosols. In Jan. 2012, he joined the Joint Center for Earth Systems Technology at University of Maryland Baltimore County, where he worked on the development of an enhanced infrared cloud property retrieval algorithm with Dr. Zhibo Zhang.

Dr. D. Allen Chu received a BS in Atmospheric Sciences from the National Taiwan University in 1982 and a Ph.D. in Atmospheric Sciences from Georgia Institute of Technology in 1988. In 1989, he joined ISAMS (Improved Stratospheric and Mesospheric Sounder) team at NASA Langley Research Center where he worked on the ozone and nitric acid retrievals using ISAMS measurements as well as radiance simulations using line-by-line/broadband radiative transfer models. In 1996, he was recruited by MODIS (Moderate Resolution Imaging Spectroradiometer) aerosol team at NASA Goddard Space Flight Center to work on MODIS aerosol retrieval and lead quality assurance for the MODIS atmosphere products. In 2004, he joined the JCET of UMBC as an associate research scientist. Since then, he has been heavily involved in a number of projects including the application of MODIS AOD to air quality, evaluation of aerosol radiative forcing in a number of field campaigns to study of dust radiative and microphysical process on precipitation and energy budgets over the tropical Atlantic Ocean, and intercomparison of model (e.g., GOCART, GEOS-CHEM, and CMAQ) and MODIS-derived aerosol properties. In 2007, he joined the GEST to continue his researches. He served as a PI of NASA INTEX-B, NAMMA, and ARCTAS programs, and EPA AMI pilot project, as well as UMBC PI of DISCOVER-AQ and AirNow.

Dr. Ruben Delgado is a Faculty Research Assistant in JCET. He received a Ph.D. In Chemistry from the University of Puerto Rico in 2011, 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.

Mr. Keith Evans received a B.S. in Nuclear Science from Virginia Polytechnic Institute and State University in 1979, a M.S. in Physics from American University in 1984 and a M.S. in Meteorology at the University of Maryland in 1997. He has worked as a physicist on solar energy systems, submarine systems, and cruise missiles at the Vitro Corp. He has worked on the first Special Sensor Microwave Imager (SSM/I) instrument, on satellite subsystems testing, and in acoustics as a contractor at the Naval Research Laboratory. He wrote the software to retrieve data from the Broad Band X-ray Telescope, which flew on the Space Shuttle as a contractor at NASA/Goddard Space Flight Center and he received two Group Awards for this effort. Mr. Evans began working with LIDAR in 1991, performing various atmospheric studies, including: atmospheric temperature, spectral and multi-fractal analyses of atmospheric water vapor data. He is currently employed by the Joint Center for Earth Systems Technology of the University of Maryland Baltimore County as a Research Analyst. His current tasks include maintaining the volcanic so2 web pages and scientific programming and data analyses of GPS and ILRS and NASA satellite data.

Dr. Sergio DeSouza-Machado obtained a B.A. from the College of Wooster, OH in 1988, and an M.Sc and Ph.D. in 1990/1996 from the University of Maryland at College Park (Plasma Physics). After this, he joined the Atmospheric Spectroscopy Laboratory at the University of Maryland, Baltimore County in September 1996. He has developed kCARTA, a package that rapidly computes monochromatic absorption spectra, radiances and jacobians, and does scattering and NonLTE computations. In addition, he has developed a line-by-line code that includes CO2 P/R linemixing and water continuum corrections. His current research work is on retrievals of dust heights and optical depths, radiative transfer codes and trace gas retrievals. Dr. DeSouza-Machado also actively participates in teaching Physics classes, at both the undergraduate and graduate levels.

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

Dr. Forrest Hall is a physicist and currently teaches Climatology and Astronomy at Maryland Institute College of Art (MICA) and at Johns Hopkins University's Odyssey program. He is located at NASA's Goddard Space Flight Center in the GSFC/UMBC Joint Center for Earth Systems Technology. Dr. Hall has been active since 1980 in global change research using earth-observing satellites and models to monitor human-induced and natural changes to the earth's land ecosystems and the effects those changes have had on the earth's climate. He has authored more than 60 scientific papers on satellite monitoring of the global carbon cycle and climate change, many highly cited. Dr. Hall is a regular lecturer, both nationally and internationally. He has addressed a broad range of audiences on climate science: middle and high schools, universities, women's groups, state and national congressional representatives, religious organizations, and scientific meetings. Dr. Hall has a BS in Mechanical Engineering from the University of Texas, and an MS and PhD in Physics from the University of Houston.

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

Dr. Shin-Chan Han received a Ph.D. (2003) and a MS (2000) in Geodetic Science from Ohio State University (OSU), Columbus, OH, and a BS (1998) in Earth Science from Seoul National University, Seoul, Korea. His MS thesis is on absolute point positioning from Global Positioning System (GPS) and Ph.D. dissertation is on the global and regional gravity recovery from satellite tracking data and geophysical applications. He worked for two years as a Postdoctoral Research Associate at the Space Geodesy and Remote Sensing Laboratory at OSU and for one year as a Research Scientist at the School of Earth Sciences as OSU. During this period, he made several invited talks on Earth gravity field at various institutions and universities. In 2006, he joined the Planetary Geodynamics Laboratory at NASA Goddard Space Flight Center and GEST at UMBC, as a member of the research faculty; in 2011, he joined JCET at UMBC. He has been publishing papers on gravity estimation theory, coseismic and postseismic deformation, hydrological mass variation over the large river basins, ocean tides in polar regions, GPS/INS, and gravity gradiometry.

Dr. Jay Herman received an MS in physics from Clarkson College in Potsdam, New York in 1959 followed by PhD at Pennsylvania State University in 1965. He then worked for NASA until September 2009 followed by an appointment to JCET. The current primary focus of his research is the continuing development of the Pandora spectrometer system deployed for satellite validation and for developing a long-term climate data record of cloud amount and its change since 1979. Previously, he was Project Scientist for the Triana mission 1998 - 2009, and the Principal Investigator for NASA's Meteor-3/TOMS mission. During this time, he published extensive studies of UV radiation, aerosol amounts, and ozone distribution. Prior to working on the TOMS series of instruments he developed the first complete photochemical model of the Earth's atmosphere. He has extensive experience in radiative transfer for visible and UV radiation. Dr. Herman currently has 133 peer-reviewed articles in scientific journals.

Dr. Susan Hoban is the JCET Associate Director for Academics, an Affiliate Associate Professor in the Department of Physics, and a UMBC Honors College Fellow. Dr. Hoban's research interests include dust in the universe and information technologies for science, technology, engineering and mathematics (STEM) education. She has a particular interest in contributing to the STEM foundation of our nation's K-12 educators. Prior to joining JCET, she was a Senior Research Scientist at UMBC's Goddard Earth Sciences & Technology (GEST). Susan received her Ph. D. in astronomy from the University of Maryland in 1989. She conducted research in cometary science at NASA Goddard Space Flight Center, first as a National Research Council fellow, then as part of USRA Visiting Scientist Program, from 1989 – 1993. In 1993, she began working on information systems for science and education. In 1996, Dr. Hoban received the NASA Special Service Award for her work on web-based educational outreach. She joined UMBC's Computer Science and Electrical Engineering Department in 1996 as part of the Center of Excellence in Space Data and Information Science (CESDIS) at Goddard. From 1998-99, Dr. Hoban served as Acting Associate Director of CESDIS and from 1999 through the conclusion of CESDIS in 2000 as Acting Director. Her interests include scientific information systems, and information technologies for science, technology, engineering and mathematics (STEM) education. Dr. Hoban is the PI on the NASA's BEST Students (Beginning Engineering, Science and Technology) project that provides professional development for educators and curriculum support resources with a space exploration theme for engineering clubs for elementary and middle school students. The project also hosts engineering challenges and two-week summer bridge programs centering on lunar exploration for middle and high school students. She has a particular interest in contributing to our nation's educators' understanding of STEM subjects. She serves on the STEM Council at UMBC, the STEM Advisory Council for Anne Arundel County Public Schools, the HiTech Advisory Board for the Howard County Library System, and the Advisory Board for the STEM Achievement in Baltimore Elementary Schools (SABES) project at the Johns Hopkins University.

Dr. Ray M. Hoff is a Professor of Physics at the University of Maryland, Baltimore County. He is the Science Advisor for the Joint Center for Earth Systems. Dr. R.M. Hoff has 37 years of experience in atmospheric research. His research interests are in the optical properties of aerosols and gases in the atmosphere. Dr. R.M. Hoff has been central in formulating major research programs on Raman, differential absorption, airborne and spaceborne lidar, volcanic emissions, atmospheric transport of toxic chemicals to the Great Lakes, atmospheric visibility, Arctic Haze, and dispersion of pollutants. He has led or participated in over 20 major field experiments. He is the author of 99 journal articles and book chapters, 97 other refereed works and numerous public presentations of his work. Dr. R.M. 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. R.M. Hoff was a member of the Science Advisory Group for the NASA Laser In-Space Technology Experiment (LITE), a space shuttle experiment. He was a member of a proponent team for a spaceborne Differential Absorption Lidar (DIAL) involving NASA, the Canadian Space Agency and the Meteorological Service of Canada. He is also a science team member on the ESSP-2 spaceborne lidar, named CALIPSO. He was a member of the International Radiation Commission International Coordination Group on Laser Atmospheric Studies (ICLAS), the American Meteorological Society Committee for Laser Atmospheric Studies (CLAS) and the Stratospheric and Upper Tropospheric Aerosol focus of the International Global Aerosol Program (SUTA/IGAP/IGAC). He was Rapporteur for Long Range Transport on the WMO Executive Committee Panel of Experts/Commission of the Atmospheric Science Working Group on Environmental Pollution and Atmospheric Chemistry. He was a member of the Science Advisory Group on Aerosols to the Commission of the Atmospheric Sciences of the World Meteorological Organization. He served on a National Academy of Sciences/National Research Council Panel on Mesoscale Meteorological Observations for Multiple National Needs. He is the Chair of the NASA Applied Sciences Advisory Group and is a member of the Earth System Science Advisory Panel for the agency. Recently, he has become an external science committee member on the European Commission's ACTRIS project. He has had committee and peer-review roles at NASA, NOAA, DOE, DOD, CSA, EPA, Environment Canada, and the European Economic Community. He has held memberships in six scientific societies and served as Chairman of committees for those societies. In 2008, he became a Fellow of the American Meteorological Society. In 2012, he was awarded the NASA Distinguished Public Service Medal.

Dr. Karl Fred Huemmrich 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, boreal and temperate forests, croplands, prairies, and deserts.

Dr. Benjamin Johnson received his Bachelor of Science degree in Physics from Oklahoma State University in 1998, a Master of Science degree in Atmospheric Sciences from Purdue University in December 2001, and completed his Ph.D. degree in December 2007 from the University of Wisconsin—Madison. He is currently an Assistant Research Scientist in JCET. His research interests cover a broad spectrum of precipitation cloud modeling, radiative transfer, cloud microphysics, and radar/radiometer remote sensing from air, space, and ground. Dr. Johnson is focusing on combined dual-frequency radar and multi-channel radiometer retrievals of frozen and mixed-phase precipitation at microwave frequencies in the 10 to 340 GHz range, with a focus on the upcoming Global Precipitation Measurement (GPM) and ongoing CloudSat missions. He is a member of the GPM radiometer algorithm team, combined radar/radiometer algorithm team, and is a member of several working groups, including the International Precipitation Working Group (IPWG), and is actively involved in developing improved retrieval algorithms for measuring falling snow using passive microwave and radar remote sensing methods.

Dr. Ilan Koren received his degrees from the department of Geophysics and Planetary Sciences in Tel Aviv University, Israel. He received his Ph.D with distinction in 2002 where his major research interest was on spatial and temporal patterns in clouds and aerosols. He joined NASA's MODIS aerosols 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. Prasun K. Kundu received a B.Sc. (with honors) in Physics from Calcutta University, India in 1974 and a M.Sc. in Physics from the Indian Institute of Technology, Kharagpur, India in 1976. He then joined the High Energy Physics Group at the University of Rochester in New York where he earned his Ph.D. degree in 1981 in theoretical physics for his work on a new class of an exact and asymptotic solution to 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, as 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 the 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 the Johns Hopkins Applied Physics Laboratory. His past work in collaboration with Dr. T. L. Bell at GSFC involves theoretical development of stochastic dynamical models of precipitation and their application to rainfall sampling problems. He has recently co-supervised the Ph.D. dissertations of Mr. R.K. Siddani, and Mr. J.E. Travis, both graduate students at the Mathematics and Statistics Department, UMBC, leading to new theoretical formulations of the statistics of rainfall.

Dr. Jae N. Lee received a BS in Physics from Yonsei University, Seoul, Korea and a PhD in Marine and Atmospheric Science from Stony Brook University in 2008. The primary focus of her research activities has been in the application of remote sensing observations to climate studies, with particular emphasis on the sun-climate connections. She is currently working on the TSIS (Total and Spectral Solar Irradiance Sensor) project due for launch on the Polar Free Flyer in 2016-2017. Her current research interests include the observation of total and spectral solar irradiance, analysis of solar irradiance variability, and its impact on earth’s climate. She uses numerical models of the sun and earth’s atmosphere as well as remote sensing observations to investigate solar activities, climate variability and their interconnections. During her NASA NPP fellow years at JPL, she found interest in remote sensing of cloud and aerosols to address climate change from both the natural and anthropogenic effects, especially in the Arctic region.

Dr. Jasper Lewis received his B.S. degree from Norfolk State University (1999) and a M.S. degree from Georgia Institute of Technology (2002), both in physics. After teaching in the Virginia public school system for several years, Dr. Lewis continued his education at Hampton University and received a Ph.D. in physics/atmospheric science in 2010. He is currently a post-doctoral research associate in JCET and conducts research at the NASA Goddard Space Flight Center as a member of the Micropulse Lidar Network (MPLNET) team.

Dr. Simone Lolli received his M.S. degree in Physics, at the University of Florence on Microwave remote sensing in 1996. He joined the Microwave Remote Sensing Group of the Institute of Applied Physics IROE of the Italian National Research Council , Firenze, to study the interaction between artificial rough bare soils and microwaves. In 2001 he was a visiting scientist in the group of applied physics of the University of Geneva to develop a direct detection Doppler Wind Lidar in the framework of the ADM/Aeolus (Atmospheric Dynamics Mission Aeolus) mission of the European Space Agency (ESA). In 2008, he joined the Atmospheric Lidar Group of the Laboratoire de Meterologie Dynamique (Prof. Pierre Flamant) to complete his Ph.D in physics, obtained in December 2011 at the Ecole Polytechnique, France, with the title: “Atmospheric wind profile measurements by Doppler Lidar means: development and validation in the frame of the Earth Explorer Atmospheric Dynamic Mission (ADM-Aeolus). He is member of the American Geoscience Union, convener and member of scientific committees of several international conferences. Currently Dr. Lolli is studying the impact of aerosols on radiative transfer by Lidar measurements of MPLNET NASA Lidar network under Dr. Judd Welton.

Dr. J. Vanderlei Martins has received a Bachelor’s degree in physics in 1991, a Master’s degree in physics/nuclear applied physics in 1994, and a Ph.D. in physics/applied physics in 1999 from the University of Sao Paulo (USP), Brazil. He joined the Group of Air Pollution Studies at the Institute of Physics (USP) in 1990, and conducted research in environmental and atmospheric applied physics. In particular, he developed analytical nuclear techniques using particle accelerators for material analysis, including aerosols and tree-rings, and participated in several ground-based and aircraft field experiments studying properties of aerosols from biomass burning and biogenic emissions. He was a member of the University of Washington, Department of Atmospheric Sciences, Cloud and Aerosols Research Group, from November 1995 to August 1996, and of the NASA GSFC Climate and Radiation Branch from August to December 1996, both as a Visiting Scientist. He taught at the University Sao Judas Tadeu between 1998 and 1999 while conducting research at the University of Sao Paulo. After starting his postdoctoral work at the University of Sao Paulo, he joined JCET in December 1999 as a Visiting Assistant Research Scientist. He has authored and co-authored over 45 refereed papers and has given over 70 presentations in international conferences, the most recent being on the measurement of multiangular polarization properties of aerosols and clouds, on the spectral absorption properties of aerosol particles, on the measurement of the vertical profile of cloud microphysical and thermodynamic properties, and on the development of new instrumentation for the measurement of aerosol and cloud particles. He served as elected member of the International Radiation Comission from 2001-2008. In 2006 he assumed an Associate Professor position in the Department of Physics of the University of Maryland Baltimore County and has been promoted to Professor in Physcis in 2014, while keeping his affiliation with the Joint Center for Earth Systems Technology.

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 Geography and Environmental Sciences, UMBC. Dr. Mehta's interest and expertise are in satellite remote sensing of geophysical parameters and their analysis to understand climate variability

Dr. William Olson received an AB in Physics from Cornell University in 1978 and a Ph.D. in Meteorology from the University of Wisconsin-Madison in 1987. The primary focus of his research activities has been in the field of satellite microwave radiometry, with particular emphasis on the remote sensing of precipitation and latent heating distributions. In 1987 he developed the first minimum variance approach for the physical retrieval of rain distributions from satellite microwave data. He later designed, with Dr. William Raymond, a method for assimilating latent heating estimates from SSM/I into numerical weather prediction model forecasts, and more recently collaborated with scientists at NCEP and NASA to assimilate precipitation distributions into global models. His current work involves the development of combined radar-radiometer methods for estimating precipitation and latent heating vertical structure, and the creation of a satellite-based, atmospheric diabatic heating record for evaluating climate models and closing the atmosphere's energy budget.

Dr. Ana I. Prados is a Research Assistant Professor at the Joint Center for Earth Systems Technology, University of Maryland Baltimore County. She has a Ph.D. in Chemistry and a Master's in Public Policy from the University of Maryland, College Park. Dr. Prados currently manages the Applied Remote Sensing Training Program (ARSET) for NASA Applied Sciences, where she develops courses for end-users on the application of satellite imagery to environmental decision-making activities related to water resources, land management, disaster management and air quality. Other areas of interest include the application NASA imagery for air pollution monitoring, environmental policy making in the context of water resources management and climate change, program/project evaluation, and communicating scientific information to the public.

Dr. Lorraine Remer spent 21 years at the NASA Goddard Space Flight Center involved in the remote sensing of aerosol and the use of remote sensing data for the study of aerosols in climate processes, how aerosol particles affect clouds, aerosol transport and particulate air pollution. Her first position at Goddard in 1991 was in the role of a support scientist, employed by Science Systems and Applications, Inc. (SSAI), where she contributed to the development of the MODIS aerosol algorithms. In 1998 Dr. Remer joined the Federal civil service, and in 2012 she left NASA to become a Senior Research Scientist at UMBC/JCET. Dr. Remer has been a member of NASA's MODIS, CloudSat/CALIPSO, NPP, Glory and Global Aerosol Climatology Project Science Teams. She has contributed to the U.S. Climate Change Science Change Program (US CCSCP) and to the WMO International Task Force on Hemispheric Transport of Air Pollution (HTAP). She has contributed leadership to more than 12 major field experiments and has over 130 publications in the refereed literature. Her Ph.D. is from the University of California, Davis (U.C. Davis) in Atmospheric Science (1991). She also has a M.S. in Oceanography from the Scripps Institution of Oceanography, University of California, San Diego and a B.S. in Atmospheric Science from U.C. Davis.

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

Dr. Chung-Lin Shie received a B.S. in Atmospheric Sciences from the National Taiwan University, a M.S. and Ph.D. in Meteorology from Pennsylvania State University and Florida State University, respectively. He started working at NASA/GSFC as a research scientist since February 1993. Shie first affiliated with Science Systems and Applications Inc. (SSAI) as Research Meteorologist, then Senior Research Meteorologist before joining UMBC as Associate Research Scientist at GEST and JCET in April 2001 and May 2011, respectively. Shie also started serving as part-time Project Scientist of the GES DISC since January 2013. During his early career, Shie participated in a pioneering project in producing GSSTF (global air-sea turbulent fluxes) datasets. He won a NASA MEaSUREs proposal in 2008 and has further produced a series of improved GSSTF datasets including the most upgraded GSSTF3 completed in November 2012. Shie is also involved in diverse research interests and projects in recent years. He was once involved in research projects performing numerical simulations using cloud resolving model. He is currently still involved in a project investigating the Saharan Air Layer (SAL) impacts on Atlantic hurricane formation and intensification. Shie has won various awards in his career ranging from outstanding merit performance, meritorious science community service, to outstanding mentoring.

Dr. Christopher A. Shuman joined JCET in May 2011, after being with GEST for four years. He is currently working with Dr. Thorsten Markus and Dr. Thomas Neumann at NASA/GSFC, among others, to enable calibration and validation of the planned Ice, Cloud, and land Elevation Satellite 2 (ICESat-2, launch planned in mid-2016). He is also working with Dr. Dorothy Hall at NASA/GSFC to calibrate temperature records in central Greenland's 'Summit' Station area. He continues to collaborate with Dr. Ted Scambos (NSIDC) and Dr. Etienne Berthier (LEGOS) on the dramatic ongoing changes to the Antarctic Peninsula's ice cover. From 2001-2007, he was a Physical Scientist with the Cryospheric Sciences Branch, and the Deputy Project Scientist for the ICESat-1 Mission (2001-2005), as well as an Adjunct Research Faculty, Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, College Park. From 1999-2001 he was an Assistant Research Scientist, ESSIC, University of Maryland, College Park.

From 1996-1998, he was a Visiting Research Fellow with the Universities Space Research Association at NASA GSFC's Oceans and Ice Branch working with Dr. Robert A. Bindschadler. From 1994-1996, he was a National Research Council, associate at NASA GSFC's Oceans and Ice Branch, Greenbelt, MD working with Dr. Robert A. Bindschadler. From 1992-1994, he was a post doctoral researcher at the Earth System Science Center (ESSC) and Department of Geosciences of The Pennsylvania State University, working with Dr. Richard B. Alley. Dr. Shuman received his Ph.D. in Geosciences in 1992 and his M.S. in Geology in 1987 from The Pennsylvania State University, and his B.S. in Geology in 1982 from Moravian College.

Dr. Lynn C. Sparling is an Associate Professor of Physics at UMBC and is a UMBC affiliate member of JCET. She received a B.S. in Chemistry from the University of New Mexico in 1976, a M.S. in Physics from the University of Wisconsin-Madison in 1980 and a Ph.D. in Physics from the University of Texas at Austin in 1987. She held postdoctoral research positions in chemical engineering and pharmacology, and conducted research in biophysics at the National Institutes of Health until 1992. She joined STX Corp. In 1993, working under contract to NASA at Goddard Space Flight Center, became a member of JCET in 1998 and joined the faculty at UMBC in 2001. During her career, Dr. Sparling has performed theoretical work in a variety of different areas in statistical mechanics, biophysics and hydrodynamics, and is currently working in the areas of atmospheric dynamics and tracer transport and mixing.

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

Dr. Andrew Tangborn received undergraduate degrees from the University of Washington In Mathematics and Mechanical Engineering and MS and PhD degrees from the Massachusetts Institute of Technology in Mechanical Engineering. Since coming to JCET he has been involved in research projects in the field of data assimilation, with a variety of geophysical applications. He has been the PI on grants from the National Science Foundation on geomagnetic data assimilation and is Co-I on a NASA Earth Surface and Interiors Grant. In addition to his collaboration with scientists at NASA, he has been active in advising graduate students at UMBC and METEO-France. He has taught five different graduate and undergraduate courses at UMBC.

Dr. Ali Tokay received BS from Istanbul Technical University in 1984, MS 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 National Research Council Fellowship between 1993 and 1995. He then joined to Saint Louis University as assistant professor in 1995 and to University of Maryland Baltimore County (UMBC) as a research assistant scientist in 1997. He later promoted to the research assistant professor and became research associate professor in 2007. Dr. Tokay was a principal investigator during a series of field campaigns under NASA Tropical Rainfall Measuring Mission. He has been taught a number of undergraduate and graduate courses in both Saint Louis University and UMBC. Dr. Tokay was an advisor of a MS student who graduated in 1998. He also mentored 15 undergraduate and 8 graduate students. Dr. Tokay is an affiliated associate professor of Department of Geography and Environmental Sciences and research associate professor of Joint Center for Earth Systems Technology at UMBC. Dr. Tokay is a member of NASA precipitation science team. Dr. Tokay was the co-chair of the 34th AMS radar meteorology conference and he is a member AMS radar meteorology committee.

Dr. Kevin Turpie Dr. Kevin Turpie received a BS in Computer Science at the University of Maryland, an MS in Applied Mathematics at The Johns Hopkins University, and a PhD in Geographic Sciences at the University of Maryland. In 1993, he worked with Nobel laureate Dr. John Mather on the NASA mission called the Cosmic Background Explorer (COBE), where he mapped the distribution of foreground emission lines that marked the location of water and carbon across our galaxy. In the years that followed, he worked with the Ocean Ecology Branch (OEB) at Goddard Space Flight Center on the problem of detecting and mapping the biological signature of the Earth's oceans from space. In 2003, while still at NASA, he came to the Department of Geographical Sciences as a Ph.D. student. There he became particularly fascinated with those special regions where land and sea blend. For remote sensing of coastal wetlands, he saw that it would become necessary to draw on techniques developed by both terrestrial and aquatic scientists. Given his background in ocean remote sensing and his studies in terrestrial remote sensing, he chose this area as the focus for his Ph.D research, which he completed early in 2012. Meanwhile, he continues to work on remote sensing of the pelagic biosphere using the Visible Infrared Imaging Radiometer Suite (VIIRS) as a member of the NASA Science Team, which is part of the Suomi National Polar-orbiting Partnership (NPP) mission. On this team, he is the Ocean Color Science Principle Investigator, Ocean Discipline Lead, and lead of the VIIRS Ocean Science Team under the OEB. He is also a member of the Hyperspectral and Infrared Imager (HyspIRI) Science Study Group, where he is applying his combined experience of terrestrial and aquatic problems to help define the future HyspIRI mission. He is the founding chair of the HyspIRI Aquatic Studies Group, overseeing the definition and development of coastal and in-land water aquatic remote sensing for the HyspIRI mission.

Dr. Tamás Várnai received his M.Sc. equivalent degree in Meteorology from the Eötvös Loránd University, Budapest, Hungary in 1989. He then joined the Hungarian Meteorological Service for two years, after which he enrolled in the McGill University in Montreal, Canada. His research focused on how cloud heterogeneities influence the way clouds reflect solar radiation. After receiving his Ph.D. in Atmospheric and Oceanic Sciences in 1996, he continued his research as a post-doctoral fellow first at McGill University, then at the University of Arizona. In addition to examining the theory of three-dimensional radiative effects, his work also included the development of operational algorithms for the MISR (Multi-angle Imaging SpectroRadiometer) instrument on board the Terra satellite, calculating the amount of solar radiation clouds reflect. Dr. Várnai joined JCET in 1999, where he works on considering 3D radiative effects in satellite retrievals of cloud and aerosol properties, focusing mostly on the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite instrument, the CALIPSO satellite, and the airborne THOR (THickness from Offbeam Returns) lidar system and CAR (Cloud Absorption Radiometer) instrument.

Dr. Yujie Wang received a BS and MS in physics from the Tsinghua University, Beijing, China in 1994 and 1998 respectively, and a Ph.D. in geography from the Boston University, Boston, MA in 2002. He also received a certificate of advanced programmer in 1993. Dr. Wang joined the GEST center of UMBC in July of 2002, currently as an Associate Research Scientist. During his Ph.D. study, Dr. Wang's research was mostly focused on the prototyping and validation of radiative transfer based EOS MODIS/MISR LAI/FPAR algorithm. At present, he is developing a new generic aerosol retrieval and atmospheric correction algorithm for the EOS MISR, and NPOESS VIIRS instrument.

Dr. Glenn Wolfe is an Assistant Research Scientist at NASA/GSFC and UMBC/JCET since October 2012, where he studies the chemistry of the lower atmosphere using a combination of airborne field observations and detailed numerical modeling. Current projects include 1) in situ observations of formaldehyde, an important oxidation tracer, throughout the troposphere, and 2) investigation of biosphere-atmosphere interactions and their impact on pollutant precursors using a 1-D resolved forest canopy model. Prior to arriving at NASA, Glenn was a NOAA Climate and Global Change Post-doctoral fellow at the University of Wisconsin, Madison, WI. He holds a B.A. in Chemistry from Johns Hopkins University and a Ph.D. in Chemistry from the University of Washington. As of 2013, he has co-authored 24 peer-reviewed publications and participated in 9 collaborative field campaigns.

Dr. Tianle Yuan received B.S. in both Atmospheric Science and Computer Science from the Peking University in 2001 and a Ph.D. in atmospheric and oceanic sciences in 2008 from the University of Maryland, College Park. In 2008 he joined JCET as a research associate and became an Assistant Research Scientist in 2012. His research interest includes aerosol radiative forcing, aerosol-cloud interactions, aerosol-chemistry-climate interactions.

Dr. Leonid Yurganov is a Senior Research Scientist with UMBC, has been with JCET since 2006. His research expertise is connected with remote sensing of tropospheric composition. He graduated from the Leningrad State University in 1969 (MS) and the Institute of Atmospheric Physics in 1979 (Ph.D.) (both in Russia). For many years, he has been using grating spectrometers for atmospheric research in Moscow and St. Petersburg Russia. He studied total column and surface CO abundances in 1995 - 1996 at the Geophysical Institute, UAF, in Fairbanks, Alaska. Validation of the 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. Evaluation, validation and analysis of CO satellite data was his research focus at JCET until 2011. Currently he is working with AOD, SO2, and NO2 satellite data and is performing preliminary analysis of methane retrievals in the Arctic. He is a co-author of 45 refereed publications.

Dr. Hai Zhang received his B.S. in physics in 1992 from Nankai University and M.S. in optics in 1995 from Xi'an Institute of Optics and Precision Mechanism in China. He received his

M.S. in computer science in 2002 from Towson University. He received his Ph.D. in atmospheric physics from the University of Maryland, Baltimore County in 2006. He joined JCET in 2006 and is currently an assistant research scientist. During his PhD study, he carried out research on atmospheric circulation modeling using quasi-uniform grids. After graduation, he has been working on satellite remote sensing of aerosols and its application in air quality monitoring and forecasting. He developed and enhanced the IDEA (Infusing satellite Data into Environmental Applications) system at NOAA, which provided air quality community near-real-time satellite imagery and AQ forecasting. He also worked on the development of aerosol retrieval algorithms for geostationary satellites, such as current GOES, SEVIRI, and GOES-R.

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

III.7 Table 1: JCET Faculty (as of June 30, 2014)

NAME	TITLE	AFFILIATION
Dr. Nader Abuhassan	Associate Research Engineer	Research Faculty
Dr. William Barnes	Senior Research Scientist	Research Faculty
Dr. Huisheng Bian	Associate Research Scientist	Research Faculty
Dr. Roberto Borda	Assistant Research Scientist	Research Faculty
Dr. Petya Entcheva-Campbell	Research Assistant Professor	Geography & Environmental Sys.
Dr. Hyoun-Myoung Cho	Post-Doctoral Research Associate	Research Faculty
Dr. Allen Chu	Associate Research Scientist	Research Faculty
Mr. Dominik Cieslak	Faculty Research Assistant	Research Faculty
Dr. Laurie Cook	Faculty Research Assistant	Research Faculty
Dr. Ruben Delgado	Assistant Research Scientist	Research Faculty
Dr. Sergio de Souza-Machado	Research Assistant Professor	Physics
Dr. Elena Georgieva	Associate Research Scientist	Research Faculty
Dr. Forrest Hall	Senior Research Scientist	Research Faculty
Dr. Christopher Hepplewhite	Associate Research Scientist	Research Faculty
Dr. Jay Herman	Senior Research Scientist	Research Faculty
Dr. Tilak Hewagama	Associate Research Scientist	Research Faculty
Dr. Susan Hoban	Senior Research Scientist	Physics
Dr. Raymond Hoff	Research Professor	Physics
Dr. K. Fred Huemmrich	Research Associate Professor	Geography & Environmental Sys.
Dr. Ben Johnson	Research Assistant Professor	Physics

Dr. Ilan Koren	Assistant Research Scientist	Research Faculty
Dr. Prasun Kundu	Research Associate Professor	Physics, Mathematics & Statistics
Dr. Jae Nyung Lee	Assistant Research Scientist	Research Faculty
Dr. Jasper Lewis	Post-Doctoral Research Associate	Research Faculty
Dr. Simone Lolli	Post-Doctoral Research Associate	Research Faculty
Dr. Amita Mehta	Research Assistant Professor	Geography & Environmental Sys.
Dr. Howard Motteler	Associate Research Scientist	Research Faculty
Dr. William Olson	Research Associate Professor	Physics
Dr. Ana Prados	Research Assistant Professor	Chemistry
Dr. Lorraine Remer	Research Professor	Physics
Dr. Chung-Lin Shie	Associate Research Scientist	Research Faculty
Dr. Christopher Shuman	Research Associate Professor	Geography & Environmental Sys.
Dr. Andrew Tangborn	Research Associate Professor	Mathematics & Statistics
Dr. Ali Tokay	Research Associate Professor	Geography & Environmental Sys.
Dr. Kevin Turpie	Research Associate Professor	Geography & Environmental Sys.
Dr. Tamás Várnai	Research Associate Professor	Physics
Dr. Glenn Wolfe	Assistant Research Scientist	Research Faculty
Dr. Tianle Yuan	Research Assistant Professor	Physics
Dr. Leonid Yurganov	Senior Research Scientist	Research Faculty

III.8 Table 2: JCET Fellows (as of June 30, 2014)

NAME	AFFILIATION
Dr. Robert Cahalan	NASA GSFC
Dr. Jeffrey Halverson	UMBC Geography and Environmental Systems
Dr. Shen-Chan Han	NASA GSFC
Mr. Ernest Hilsenrath	NASA GSFC (retired)
Dr. Weijia Kuang	NASA GSFC
Dr. Thorsten Markus	NASA GSFC
Dr. Alexander Marshak	NASA GSFC
Dr. Vanderlei Martins	UMBC Physics
Dr. Harvey Melfi	Emeritus
Dr. Lazaros Oreopoulos	NASA GSFC
Dr. Steven Platnick	NASA GSFC
Dr. Lynn Sparling	UMBC Physics
Dr. David Starr	NASA GSFC
Dr. L. Larrabee Strow	UMBC Physics
Dr. David Whiteman	NASA GSFC
Dr. Zhibo Zhang	UMBC Physics

III.9 Table 3: JCET Associate Staff (as of June 30, 2014)

NAME	TITLE
Mr. Keith Evans	Research Analyst
Mr. John David Hall	Research Analyst
Ms. Catherine Kruchten	Instructional Designer
Mr. Hamilton Townsend	Research Analyst

III.10 Table 4: JCET Administrative Staff (as of June 30, 2014)

NAME	TITLE
Ms. Valerie Casasanto	Program Coordinator
Ms. Mary Dawson	Business Manager
Ms. Danita Eichenlaub	Director
Dr. Susan Hoban	Associate Director, Academics
Ms. Brizjette Lewis	Executive Administrative Assistant
Ms. Cathy Manalansan	Administrative Assistant II
Mr. Kevin Mooney	Accountant I
Ms. Margo Young	Business Manager

III.11 Acronyms and Abbreviations

3D	Three-Dimensional
7-SEAS	Seven SouthEast Asian Studies
ABI	Advanced Baseline Imager
ACARS	Aircraft Communications Addressing and Reporting System
ACE	Aerosol, Clouds, Ecosystem
ACE	Aerosol-Cloud-Ecosystems
ACPD	Atmospheric Chemistry and Physics discussion
ADM/Aeolus	Atmospheric Dynamics Mission Aeolus
AERI	Atmospheric Emitted Radiance Interferometer
AeroCom	Aerosol Comparisons between Observations and Models
AERONET	Aerosol Robotic Network
AGU	American Geophysical Union
AIRS	Atmospheric Infrared Sounder
AK	Averaging Kernels
ALEX	Atmospheric Lidar Experiment
ALG	Atmospheric Lidar Group
AOD	Aerosol Optical Depth
APAR	Absorbed Photosynthetically Active Radiation
APS	Aerosol Polarimetry Sensor
APU	Accuracy, Precision and Uncertainty
AQAST	Air Quality Applied Sciences Team
AQPG	Air Quality Proving Ground
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARM	Atmospheric Radiation Measurement
ARSET	Applied Remote Sensing Training Program
ASP	Aerosol Simulation Program
ASRVN	AERONET-based Surface Reflectance Validation Network
ASTE	Association for Science Teacher Education
ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer
ATBD	Algorithm Theoretical Basis Document
ATLAS	Advanced Topographic Laser Altimeter System
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
AWS	Automatic Weather Station
BAMS	Bio-Aerosol Mass Spectrometry
BBAERI	The Baltimore Bomem Atmospheric Emitted Radiance, Interferometer
BEST	Beginning Engineering, Science, and Technology
BOREAS	Boreal Ecosystem Atmosphere Study
BRDF	Bidirectional Reflectance Distribution Function
BWC	Baltimore-Washington Corridor
C3VP	Canadian Cloudsat/CALIPSO Validation Project

CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAR	Cloud Absorpiton Radiometer
CB	Cumulonimbus
CCD	Charge Coupled Device
CCM	Chemistry-Climate Model
CDPHE	Colorado Department of Public Health and Environment
CDR	Climate Data Record
CDRD	Cloud Dynamics and Radiation database
ChlF	Chlorophyll Fluorescence
CLM	Community Land Model
CLN	CRESST Lidar Network
CM	Cloud Mask
CMAQ	Community Multiscale Air Quality model
CMB	Core Mantle Boundary
CMIP	Coupled Model Inter-Comparison Project
COBE	Cosmic Background Explorer
COG	Center of Gravity
CONTRAST	Convective Transport of Active Species in the Tropics
CONUS	Contiguous US
CONUS	Contiguous US
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
CRESST	Cooperative Center for Remote Sensing Science and Technology
CrIS	Cross-track Infrared Sounder
CRM	Cloud Resolving Model
CRTM	Community Radiative Transfer Model
CTMs	Chemical Transport Models
CWT	Covariance Wavelet Transform
CWT	Covariance Wavelet Transform
DAAC	NASA Data Active Archive Center
DC-3	Deep Convective Clouds and Chemistry
DDA	Discrete Dipole Approximation
DEMs	Digital Elevation Models
DEVOTE	Development and Evaluation of Validation Tools by Experimenters Development and Evaluation of satellite ValidatiOn Tools by Experimenters
DIAL	Differential Absorption Lidar
DISC	Data Information Service Center
DISCOVER-AQ	Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality
DLN	Distance Learning Network (DLN)
DOE	U.S. Department of Energy
DOFS	Degrees Of Freedom for Signal

DSCOVR	Deep Space Climate Observatory
ECMWF	European Centre for Medium-Range Weather Forecasts
EDR	Environmental Data Record
EGU	European Geoscience Union
EIA	Earth Incidence Angle
ELF	Elastic Lidar Facility
EMS	ESDIS Metrics System
ENSO	El Niño Southern Oscillation
EO-1	Earth Observing-1 Mission
EOF	Empirical Orthogonal Function
EOS	Earth Observation System
EOSPSO	Earth Observing System Project Science Office
EPA	Environmental Protection Agency
EPIC	Earth Photosynthesis Imaging Constellation
EPO	Education and Public Outreach
ERA	ECMWF Re-Analysis
ESA	European Space Agency
ESDIS	Earth Science Data and Information System
ESIP	Earth Science Information Partners
ESRL	Earth System Research Laboratory
ESSIC	Earth System Science Interdisciplinary Center
EUMETSAT	European Organization for the Exploration of Metrological Satellite
fAPARchl	Photosynthetically Active Radiation Absorbed by Chlorophyll
FIFE	First International Satellite Land Surface Climatology Project Field Experiment
FIR	Finite Impulse Response
GALION	Global Atmosphere Watch Atmospheric Lidar Observation Network
GASP	GOES Aerosol and Smoke Product
GCM	General Circulation Model
GCPEx	GPM Cold-season Precipitation Experiment
GEDI	Global Ecosystem Dynamics Mission
GEO	Group of Earth Observations
GEO-CAPE	Geostationary Coastal and Air Pollution Events
GEOS-5	Goddard Earth Observing System model version 5
GEOSCCM	GMI and Goddard Chemistry Climate Model
GEP	Gross Ecosystem Production
GES	Geography and Environmental Systems
GES	Goddard Earth Sciences
GES DISC	Goddard Earth Sciences Data and Information Services Center
GEST	Goddard Earth Sciences and Technology Center
GESTAR	Goddard Earth Sciences Technology And Research
GFMS	Global Flood Monitoring System
GISS	Goddard Institute for Space Sciences
GMAO	Global Modeling and Assimilation Office

GMI	Global Modeling Initiative
GMI	GPM Microwave Imager
GMI	GPM Microwave Imager
GMU	George Mason University
GOES	Geostationary Operational Environmental Satellite
GOES-R	Geostationary Operational Environmental Satellite “R” Series
GOME	Global Ozone Monitoring Experiment
GOSAT	Greenhouse Gas Observing Satellite
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Measurement Mission
GPP	Gross Primary Production
GPROF	Goddard PROFiling algorithm
GPS	Global Positioning System
GRACE	Gravity and Climate Recovery Experiment
GRIP	Genesis and Rapid Intensification Processes
GRL	Geophysical Research Letters
GSFC	Goddard Space Flight Center
GSI	Gridspace Statistical Analysis
GSSP	Graduate Student Summer Program
GSSTF	Goddard Satellite-based Surface Turbulent Fluxes
GSSTF2b	Goddard Satellite-based Surface Turbulent Fluxes, Version 2b
GSSTF2c	Goddard Satellite-based Surface Turbulent Fluxes, Version 2c
GSSTF3	Goddard Satellite-based Surface Turbulent Fluxes, Version 3
GV	Ground Validation
HARP	HyperAngular Rainbow Polarimeter
HASG	HyspIRI Aquatic Studies Group
HCHO	Formaldehyde
HCLS	Howard County Public Library System
HDO	Hydrogen Deuterium Oxide
HIWRAP	High-Altitude Imaging Wind and Rain Airborne Profiler
HLH	Haze Layer Height
HLH	Haze Layer Height
HMT-SE	Hydrometeorological Testbed – Southeast
HOAPS	Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Observations
HPLC	