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A mangrove forest in the Rufiji delta. “Not much of the forest looks like it does in this picture.” Quote and photo provided by David Lagomasino, Code 618.
MAVEN gazes at the setting stars during one of its stellar occultation campaigns, from “Mapping Mars’ Upper Atmosphere”, among credits are Animators: Brian Monroe & Michael Lentz; Visualizer: Kel Elkins; Producer/Editor: Dan Gallagher.

From “Mars Gravity Map”, among credits are Visualizer/Animator: Ernie Wright; Video Editor: Dan Gallagher.
We are pleased to offer this fifth NASA Goddard Earth Sciences, Technology, and Research (GESTAR) Cooperative Agreement Annual Report for the period: 11 May 2015 – 10 May 2016. NASA awarded GESTAR to the team of Universities Space Research Association (USRA), Morgan State University (MSU), Johns Hopkins University (JHU), I.M. Systems Group (IMSG), Institute for Global Environmental Strategies (IGES), and Ball Aerospace for a period of five years (2011-2016). We welcomed Global Science and Technology (GST) to our team in 2012.

During the past year, GESTAR continued to be among major NASA Goddard Space flight Facility partnerships. We completed this fifth (and final) year of the original agreement approximately 16 percent greater (with respect to funding) than was originally anticipated, thanks to the hard work and excellence of the GESTAR staff. Everyone at GESTAR worked diligently with our NASA sponsors/collaborators to ensure success of critically important projects that support NASA’s mission in Earth Sciences and beyond. Their efforts have resulted in many substantive accomplishments, highlighted in this report. Our sincerest thanks go out to all for their commitment and professionalism.

This report summarizes multidisciplinary efforts of GESTAR-affiliated researchers, technologists, students, visitors, and staff. We describe accomplishments for the past year and technical progress in all research areas identified in the GESTAR Annual Research Program Plan, submitted to NASA on 31 July 2015. Within the report and its appendices are: a) abstracts and papers published by GESTAR-affiliated staff; b) GESTAR-affiliated presentations at conferences, seminars, and workshops; c) education and public outreach engagements by GESTAR-affiliated staff; d) awards received by GESTAR-affiliated staff; and e) engagement of GESTAR-affiliated staff in reviewing/advising/committee participation activities.

With NASA’s extension of GESTAR for another five years (2016-2021), we look forward to applying our knowledge and experience in the upcoming year to ensure GESTAR continues to exceed all of our expectations.

William Corso
Director, GESTAR

Joseph Whittaker (Associate Director – Morgan State University)
Darryn Waugh (Associate Director – Johns Hopkins University)
Le Jiang (Associate Director – IMSG)
The GESTAR Team

Founded in 1969, Universities Space Research Association (USRA) is an independent nonprofit research corporation that conducts basic and applied research and operates programs and national facilities for government and industry, many of which are in support of NASA. USRA currently manages 20 programs and facilities that employ more than 400 scientific, technical, and professional staff. With 105 university members, USRA provides a unique and special value that other research organizations do not. Only PhD-granting universities in Earth and space sciences with demonstrated outstanding research abilities are eligible for membership in USRA. USRA’s mission is to advance Earth and space sciences and exploration through innovative research, technology, and educational programs, and to develop and operate premier facilities and programs by involving universities, the private sector, and governments.

Founded in 1876 as the first research university in the United States, The Johns Hopkins University (JHU) is one of the leading research institutions in the nation. JHU is composed of nine academic divisions, including Arts & Sciences, Education, Engineering, the School of Public Health, plus JHU Applied Physics Laboratory. The Krieger School of Arts and Sciences is the home of the Department of Earth and Planetary Sciences. A major focus within this department is global change science, with active research groups in atmospheric, oceanic, and hydroospheric sciences as well as planetary geodynamics. The department maintains state-of-the-art design and engineering facilities, as well as laboratories for high performance computing and large-scale data analysis that are also being used for Earth system science. JHU’s Whiting School of Engineering consists of faculty who possess experimental, computational, robotic and modeling capabilities. Additionally, faculty at the School of Public Health are involved with the application of Earth system science and remote sensing to the study and teaching of public/environmental health.

Morgan State University (MSU), founded in 1867, is one of the nation’s premier Historically Black Colleges and Universities (HBCUs). The University offers a comprehensive program of studies at both the undergraduate and graduate levels. Morgan State has continuously served the community with distinction while meeting the educational needs of an increasingly diverse society. Designated as Maryland’s Public Urban University, MSU will continue its prominence in Maryland’s educational future. In many fields, particularly in engineering and the sciences, MSU accounts for large percentages of degrees received by African-Americans from Maryland institutions. At the graduate level, it awards doctoral and master’s degrees in several selected fields. The University has made a major commitment to academic excellence, investing substantial resources to enhance its research infrastructure, and stimulate research development in a broad range of disciplines, especially STEM. In addition to the Clarence M. Mitchell, Jr. School of Engineering complex, MSU has the Estuarine Research Center, the Richard N. Dixon Science Research Center, a state-of-the-art research facility that provides space for specialized research laboratories in physics, chemistry, and biology, and the modern Murphy Fine Arts Center.

I.M. Systems Group (IMSG) has over 15 years of providing environmental, scientific, technical support to the US government, as well as environmental services to government agencies in Africa and Asia. Over 60% of its workforce has advanced degrees with over 100 PhD researchers. IMSG is NOAA’s largest support service, with its largest concentration of researchers and support scientists in the Satellite Applications Research Center and the NWS Environmental Modeling Center.

Rounding out the GESTAR Team are Ball Aerospace and Technologies, The Institute for Global Environmental Strategies (ICES) and Global Science & Technology (GST). GESTAR Management continues to work to identify appropriate, GESTAR-affiliated activities in which they may become meaningfully engaged.
CODE 555: MICROWAVE INSTRUMENT TECHNOLOGY BRANCH

NASA’s Soil Moisture Active and Passive (SMAP) Mission is the first of a series of Earth Science Decadal Survey missions which was launched January 31, 2015. Dr. Priscilla Mohammed (sponsor: J. Piepmeier) has worked with a collaborative team at GSFC to develop the L1B TB algorithm which converts radiometer data into calibrated estimates of brightness temperature. The effort includes research and development of radio frequency interference (RFI) detection and removal algorithms and prototype instrument algorithm code for the L1B TB algorithm which is part of ground processing. The Science Data System at the Jet Propulsion Laboratory has been responsible for implementing the production code for the Radiometer L1B_TB Algorithm. Over the past year, Dr. Mohammed provided support to help verify the product output provided by the production code. The work involved using the prototype code in Matlab to produce outputs for direct comparison to the outputs of the production code.

Since SMAP was launched, data has been and continues to be collected and processed by the science data system at JPL. The calibration/validation tools produced in previous quarters were developed to analyze the L1B_TB products and an intermediary product available to the cal/val team to check for algorithm performance. These tools were optimized to produce arbitrary resolution of data for data analysis. These analyses were important to determine algorithm updates and improvements as well as update ancillary data files necessary for the final release of SMAP radiometer data to the public.

Analyses of preliminary SMAP radiometer data at instrument turn-on indicated a dependence of the false alarm rate (FAR) on the radiometer integration time in the kurtosis RFI detection algorithm. To produce a uniform FAR over the globe, the algorithm was updated to include a variable standard deviation in the threshold based on the radiometer integration time. Analyses of the beta release data also prompted the need to update the RFI detection algorithms to index into finer resolution threshold tables. The algorithm was updated to handle losses due to the radome and reflector and also to index into finer resolution temperature tables. All algorithm updates were tested and delivered to JPL for production code updates.

Over six months of SMAP radiometer data were analyzed using calibration/validation tools in preparation for the final release of the data. Algorithm parameters were tweaked to enhance the algorithm and these parameters were submitted as ancillary files to JPL to be used in the final release of the data. Analyses included plots of brightness temperatures, evaluating global RFI rates as well as global kurtosis values to assess the distribution and types of RFI sources. The SMAP radiometer contains products to calculate the kurtosis statistic which can be used to detect RFI. The statistic has the distinctive characteristic of having a value of 3 (if the source is Gaussian) and deviating from 3 (if not). The SMAP radiometer measures thermal emission from the Earth, which in turn is converted to brightness temperatures and eventually soil moisture products. This thermal emission is Gaussian and RFI is not. The kurtosis also has the unique capability of being able to indicate RFI type, depending on whether it deviates above or below 3. Figure 1 shows a global plot of antenna temperatures before and after RFI detection and mitigation. The figure indicates that the algorithms are working well to remove RFI from the data.

A journal article was written on the first year of SMAP radiometer on orbit results focusing on the performance of the RFI detection and mitigation algorithms. The paper summarizes updates to the SMAP RFI processing algorithms based on pre-launch tests and on-orbit measurements, as well as RFI information and statistics obtained from SMAP’s first year on orbit. Results indicate that the RFI detection and mitigation algorithms are working successfully to reduce the impact of RFI and improve the quality of SMAP brightness temperature measurements. This paper was submitted to the IEEE Transactions on Geoscience and Remote

![Figure 1 shows a global plot of antenna temperatures before (left) and after (right) RFI detection and mitigation. Image provided by P. Mohammed.](image-url)
Sensing journal in early April 2016. Additionally, Dr. Mohammed presented results using SMAP radiometer data from the first year on-orbit at the 14th Specialist Meeting of Microwave Radiometry and Remote Sensing of the Environment in Espoo, Finland.

In the coming year, her role will be to monitor data and instruments, since the algorithm development for the SMAP L1B_TB radiometer ground processing has been completed. Any algorithm updates will likely be changes to ancillary files to enhance algorithm performance. She will also continue with RFI analyses in support of geolocating RFI sources on the ground. This will lead to efforts of reporting illegal transmitters operating within the protected band that SMAP uses to make observations.

Dr. Jinzheng Peng (sponsor: J. Piepmeier) worked in a collaborative team developing NASA’s Soil Moisture Active/Passive (SMAP) radiometer. He was specifically responsible for developing the SMAP L1B correction algorithms, the SMAP Level-1 brightness temperature forward simulator, pre- and post-launch calibration, and calibration/validation tools. On January 31, 2015, the SMAP satellite was launched into a 685-km near-sun-synchronous 6AM/PM orbit. After reflector deployment/spin-up and radiometer power-on, the post-launch calibration/validation to the radiometer began in late March 2015 and has now reached its milestone of one year of successful operation.

Dr. Peng is responsible for the radiometer post-launch calibration to remove the bias and drift in the calibrated antenna temperature due to 1) internal noise diode drift; 2) solar eclipse effect on the radiometer temperature, and 3) SAR transmitter off. He uses the global ocean and the Cold Sky as the external calibration targets and the expected antenna temperatures, which are generated by the simulators that he developed, over these external calibration targets to evaluate the radiometer antenna pattern and radiometer internal calibration. Bias and drift over the global ocean are significantly reduced, and the results, including the error in ocean TB, satisfy the requirements on the radiometer L1B data product. Calibration results have been submitted/validated and used for the SMAP radiometer L1B data release to public.

Dr. Peng was involved with developing an algorithm for generating the Earth’s surface brightness temperature from calibrated antenna temperature. The algorithm has been validated during the cal/val period. He upgraded the algorithm based on validation results and delivered the upgraded Matlab protocode to SDS (Science Data System) for translation into production code to produce new radiometer L1B data for public release. He has been working on the radiometer data resolution enhancement due to coarse radiometer resolution and SAR transmitter’s failure in July 2015. Several algorithms have been proposed by the SMAP team to improve radiometer data resolution. He has provided the simulation datasets over the U.S. for resolution enhancement of algorithms’ development and performance evaluation. The results were presented at a Science Team Meeting for selecting an algorithm to use for SMAP resolution enhancement data product.

Dr. Peng also worked on integrating the WISM (8-40 GHz Wideband Instrument for Snow Measurements) X-band radiometer onto existing Ku- and Ka-band radiometers. Integration was completed in time for the field campaign last year. He also is responsible for the maintenance and upgrades of the SMiR-7 radiometer, a 7-channel microwave radiometer at 22, 36 and 89 GHz frequency band for measuring precipitable water vapor and cloud liquid water from ground. A polarization channel is planned for addition to the 89 GHz-frequency band for research on the polarization of cloud liquid water.

CODE 606.2: HIGH PERFORMANCE COMPUTING

Dr. Gerald Potter (sponsor: P. Webster) prepares and documents the Collaborative REAnalysis Technical Environment - Intercomparison Project (CREATE-IP), an international project to bring all of the major reanalyses together to a common format and distribute them though the Earth System Grid Federations. Dr. Potter has continued to make presentations about CREATE-IP to the scientific community. In the past year he gave poster presentations at the Climate Diagnostics Workshop in October, at the 2015 AGU Fall meeting in December, at the AMS meeting in January and at NCEP CPC in March. All presentations were well received and interest in the project continues to grow.

He is responsible for the quality control of the reprocessed reanalysis data. This has become a critical step in the publication of the data; even though each reanalysis center already performs some sort of quality control, the CDS must often recalculate variables to adhere to the CMIP5 standards. An example of reprocessed monthly average global averaged surface temperature from MERRA-2 is shown in Figure 2. It is interesting to note that 2015 has the warmest global average surface temperature in the reanalysis period.
When studying a reanalysis, Dr. Potter and colleagues found unusual transient wave-like patterns in the June-August 250hPa meridional wind anomaly in a band that spans 50-60 degrees north latitude (see Figure 3). This pattern is revealed as westward propagation of the meridional wind from one northern summer to the next, starting around the year 1997. If associated with a real physical phenomenon, this pattern is quite remarkable in that it survives the major change in the basic state flow that occurs due to the seasonal cycle. There is no evidence of the wave prior to 1997, when the anomaly patterns are more stationary. This westward propagation persists to the present. This apparent wave is most prominent in the MERRA reanalysis but it also appears in ERA-interim, CFSR, JRA-55 and surprisingly, even in 20th Century Reanalysis, which is only initialized with observed sea level pressure and sea surface temperature. It is possible that the wave is a random event; tests are currently underway to test the statistical significance of the pattern. They also are in the process of isolating the possible lower atmospheric and surface weather links. For example, the wave magnitude occasionally intensifies results from stationary Rossby wave events linked to heat waves (e.g., the 2003 European heat wave and the 2010 Russian heat wave).

Dr. Potter is preparing a paper for BAMS announcing and describing the CREATE-IP project. After completing this paper, he plans to investigate the necessary steps to prepare the reanalysis increments for inclusion into CREATE-IP.

**CODE 606.3: INFORMATION SCIENCE & TECHNOLOGY RESEARCH**

Dr. Benita Bell (sponsor: J. Harrington) works toward developing research initiatives in Astrobiology for minority-serving institutions, as well as strengthening the existing MIRS and MIAC programs, the two signature astrobiology programs targeted for faculty and students at minority-serving institutions. Dr. Bell serves as Chair of the Astrobiology Standing Committee on Diversity (ASCD), which will serve to ensure that underrepresented colleges and universities are well represented in the field of astrobiology, which will support NASA’s goal of increasing diversity and inclusion in STEM. As Chair, Dr. Bell will lead the ASCD core team to develop and recommend actions and propose policies to 1) support NASA’s goal of increasing diversity within its astrobiology programs, 2) to advance educational and research initiatives in astrobiology at minority serving institutions and 3) advance the participation of underrepresented scientists and educators in astrobiology at non-MSIs.

Dr. Bell continues to serve as a recruiter for the MIRS Faculty Sabbatical. To date, the sabbatical has supported 30 faculty scientists since its inception. Scientists from Minority Serving Institutions collaborate on a particular research project of mutual interest with host scientists, PI’s funded through the NASA Astrobiology Institute and the NASA Astrobiology Program. The pool of potential applicants for 2016 included faculty from Howard University, University of Puerto, Arecibo, California State University, San Marco, California State Polytechnic and Morgan State University.

Dr. Bell and the MIAC team have worked collaboratively to design a research project. Under the leadership of her MIAC collaborator, Dr. Michael Ceballos, the 4th cohort of summer research interns from underrepresented institutions will participate in an international research project during summer 2016. The selected students will travel with Dr. Ceballos to
Sarawak, Malaysia for five weeks to collect samples and perform experiments. Dr. Bell will assist the students with their research assignments from their international summer project experience. The project will be followed up by an additional five weeks of data analyses and manuscript/poster presentations for publication/presentation of their research accomplishments.

In summer 2016, Dr. Bell will serve as faculty scholar at Faculty Resource Network, New York University; previously, Dr. Bell served as a Scholar-In-Residence in the Chemistry Department at NYU. She plans to attend the seminar “Ethnicity and the Media”. Her long-term goal is to develop a Women-In-Science Seminar Course at an underrepresented college or university.

Upcoming plans include the development of a virtual mentorship program at minority-serving institutions across the U.S. Plans also include increasing participation of faculty within MIRS and MIAC, expanding the astrobiology framework to include minority faculty and underrepresented students at majority institutions. Dr. Bell will continue to work with students to establish undergraduate organizations and clubs in astrobiology at minority-serving institutions.

**CODE 610: EARTH SCIENCES DIVISION**

Among his many responsibilities, **Mr. Charles Cote** (sponsor: K. Mohr) is responsible for coordinating and overseeing the annual preparation and submission of IRAD (Internal Research and Development) proposals, coordinating and prioritizing annual technical equipment proposals, recommending candidates for and preparing nominations for internal and external honor awards and promotions, and preparing position descriptions and hiring packages for management and research positions. Mr. Cote served as a member of the Earth Sciences Division Review Panel for the 2016 IRAD proposals, and evaluated 29 Step 1 proposals for this program call. Those satisfying the program goals and objectives of IRAD were submitted to the IRAD office with a recommendation to prepare a more detailed Step 2 proposal. The Earth Resources evaluation panel then prioritized the Step 1 proposals that were invited to proceed to the Step 2 process.

One of his primary responsibilities is coordinating and drafting the Annual Atmospheric Research Report, which summarizes all research and administrative activities carried out during the year. The 2015 draft report is approximately 125 pages.

Various portions were written; material for other sections has been collected and compiled from information provided by Laboratory scientists. The draft report was submitted to the TIMS group for editing, layout and printing. Final reports for all years can be found at: www.atmospheres.gsfc.nasa.gov. The 2016 report preparation is now underway. Also, science research highlights are prepared each month by the Atmospheric Laboratories and the Wallops Support Office. Submissions were reviewed and edited by Mr. Cote for accuracy and format as well as persuasiveness to attract readers, and the highlights were forwarded to Atmospheres management for final review and distribution to Goddard, NASA Headquarters and colleagues among universities and other science organizations. During the year, highlights were submitted in accordance with an updated format that is intended to catch more attention of readers. The revised format for images (maps, photos, graphs, cartoons) required clear, discernable messages without relying on captions. Mr. Cote reviewed all submissions and consulted with numerous scientists throughout the year on conforming to the new standards. The reports are posted on the atmospheres webpage at atmospheres.gsfc.nasa.gov, along with those of previous years.

Mr. Cote drafted two award nominations for Division scientists. These nominations are based on outstanding accomplishments in their respective science fields, are highly prestigious awards and attest to the world-class quality of Goddard atmospheric scientists. These included the NASA Leadership Award for Ed Masowka and the Goddard Award of Merit for P.K. Bhartia. Mr. Cote also provided text and recommendations to the 2016 Arthur Flemming Award for Matt Rodell. In addition, a career summary was prepared for Anne Thompson in recognition of her AGU Roger Revelle Award, to be included in the 2015 Atmospheric Research report; likewise, a career summary was prepared for Steve Platnick to be included in the report in recognition of his selection for the 2015 AMS Suomi Award. A 50-year service letter was written for Jack Richards, which is to be signed and sent by the Center management or the NASA Administrator, and a career retirement letter was written for Jose Rodriguez sent from Center Management. He also wrote the retirement letter for Larry Wharton, which is signed by the Center Director, he made suggestions to the nomination of Ralph Kahn for a Goddard Science Award, and he reviewed and updated the justification letter for the ongoing AGU Fellow nomination for W.K. Tao. As of this writing, Mr. Cote is helping to prepare the nomination of a senior scientist for an AMS early career award. The nomination package will consist of justifications, critical background information and professional endorsements.
Mr. Cote attended a planning meeting convened by Dr. Karen Mohr to consider the 2016 contractor awards process, announcement and schedule. The awards are offered each year for Best Senior Authored Publication and for outstanding performance in multiple categories. Nominations were reviewed and recommendations were prepared for final review by Steven Platnick. The Award Ceremony will be held in the fall of 2016, and each winner will receive a plaque and appropriate recognition from the employee’s organization.

The March-April 2015 issue of the Earth Observer Publication of the Earth Observatory (EO) featured the Nimbus 50th anniversary event that included introductions by Chris Scolese, Director, GSFC, Dr. Ellen Stefan, Chief Scientist, NASA, Dr. Richard Spinrad, Chief Scientist, NOAA, Rick Obenschain, Deputy Director, GSFC as well as presentations by key invited scientists. Mr. Cote played a key role in planning and coordinating the event, including speaker recruitment and preparation of introductory remarks for speakers, preparing the list of invitees, closing remarks and preparation of material for a Nimbus historical document. He also served as MC for the event and delivered a presentation on the Nimbus Data Collection and Location Systems experiments he managed in meteorology, oceanography and Search and Rescue (SAR). The event was inspired and promoted by Mr. Ralph Shapiro, the former Nimbus Operations Manager. Mr. Shapiro has recently prepared a summary of the Nimbus program with material taken from the anniversary presentations and accompanying documents, and it is intended to be a handout at the GSFC Visitors Center. Mr. Cote and others are reviewing the document, and he will coordinate the efforts to have the material edited and printed for distribution. The objective is to enlighten the public about Goddard contributions to science and societal benefits brought about through the Nimbus program.

Dr. Allison Leidner (sponsor: J. Richards) supports two major activities for the NASA Earth Sciences Division. First, she coordinates and leads activities with the purview of the Biodiversity research and Ecological Forecasting applications programs. Second, she coordinates activities related to the National Climate Assessment (NCA), a set of climate change assessment activities conducted under the auspices of the U.S. Global Change Research Program (USGCRP).

In August 2015, Dr. Leidner attended the International Congress for Conservation Biology (ICCB), a biennial meeting of the Society for Conservation Biology that was held in Montpellier, France. At the beginning of the meeting, she co-organized and led a half-day workshop on an introduction to remote sensing, in collaboration with colleagues from the European Union Joint Research Centre and the Royal Society for the Protection of Birds. The workshop was filled to capacity. She also organized a well-attended oral symposium on the use of remote sensing for regional conservation management. Additionally, Dr. Leidner helped organize a meeting of the Conservation Remote Sensing Network and led the NASA booth at the career fair. During the ICCB meeting, Dr. Leidner and her colleagues were approached by Cambridge University Press to develop a book proposal based on the organized symposiums. This proposal was submitted in the winter and has been provisionally accepted by Cambridge University Press.

Dr. Leidner has been advancing the development of remote sensing Essential Biodiversity Variables, both within the Committee on Earth Observation Satellites and externally. As part of this effort, she was co-author on a manuscript that was recently published in Remote Sensing in Ecology and Conservation, and is a main contributor to another manuscript under development that outlines the role of space agencies in supporting the Essential Biodiversity Variables. In the coming months, she will continue to provide support to the Biodiversity and Ecological Forecasting programs, with a particular focus on the World Conservation Congress and liaising with CEOS regarding Essential Biodiversity Variables.

Another key activity in support of the Biodiversity and Ecological Forecasting programs is Dr. Leidner’s coordination of NASA’s involvement in the 2016 IUCN World Conservation Congress. She led the submission of one Congress proposal and was a collaborator on a second proposal, both of which were accepted. Additionally, she is working with the Earth Observing System Project Science Office (EOSPSO) to organize NASA’s involvement in the conference exhibition space, which will be open to the several thousand Congress attendees and the public.

Dr. Leidner continues to be involved with planning for the NCA sustained assessment and preparations for the Fourth NCA Report. This past August she attended and presented at the Climate Change and Water Working Group to help connect NASA’s NCA-related research to water resource managers. She also gave a talk and sat on a panel discussion at the NASA MUREP (Minority University Research and Education Program) Tribal College and University STEM Education Projects Principal Investigator (PI) and co-PI Meeting about NASA’s role in the NCA, and gave another talk for the NASA Earth Systems, Technology, and Energy Education for MUREP webinar series. In November, she was invited to give a talk about NASA’s involvement in...
the NCA during a climate literacy session that was part of the Geological Society of America annual conference. In December, she gave an invited talk in a session about developing coordinated global change scenarios for the United States.

**Dr. Fredric Lipschultz** (sponsor: J. Richards) works toward broadly coordinating Federal climate activities, especially the sustained climate assessment, that support regional science needs and activities within USGCRP, while actively interacting with other USGCRP leaders to meet the broader goals of the program. In addition, he supports the U.S. Head of Delegation to the Arctic Council’s Arctic Monitoring and Assessment Programme (AMAP), bringing expertise from the U.S. sustained assessment process to bear on AMAP programs. USGCRP is nearing the completion of its legislatively mandated process to update the goals in its 2012-2022 strategic plan, and Dr. Lipschultz has played a central role as the lead author for Goal 3 – Sustained Assessment – in setting the path forward for the program over the next three years. Over the past year, he actively participated to plan and implement aspects of the USGCRP’s Sustained Assessment goal from its 2012 Strategic Plan, including the next quadrennial report due in 2018. To coordinate these activities with NASA, he participated in weekly meetings with NASA HQ about NCA activities and monthly briefings with all NASA HQ staff involved in USGCRP activities. At USGCRP, he regularly participates in a range of working group meetings, including Global Modeling, National Climate Assessment, Adaptation and the Scenarios Task Force.

Dr. Lipschultz spent increasing amounts of time working on issues related to federal provision of climate data and coordination with federal agency efforts, especially in areas such as climate adaptation and scenario development. His primary effort has been leading the USGCRP team in developing an updated tool for climate information that is a central component of NOAA’s Climate Resilience Toolkit, with rollout expected in June 2016. In addition, OSTP has been working on a public-private partnership around climate resilience and preparedness. Dr. Lipschultz represents USGCRP on the executive steering team that has worked on defining the partnership and designing the web platform that is being built by the non-federal partners but supported heavily by federal datasets. He also engages with the USGCRP Climate Scenarios Task Force that is working on multiple issues of climate data provision for the next NCA. Finally, he actively participated in the interagency working group on Climate Resilient International Development (Executive Order 13677) to implement climate risk screening across all federal agencies providing overseas aid. Since screening began October 1, 2015, the Climate Screening, Data and Approaches subgroup has been working on integrating climate considerations into agency decision-making.

Dr. Lipschultz also supports the Executive Director of USGCRP, who is also the U.S. Head of Delegation to AMAP on Arctic-related matters. His primary focus is on increasing the usefulness of the Arctic Adaptation to Climate Assessment (AACA) report, which is due in 2017, for its varied audiences via improved communications. Specific tasks have included assisting with developing, writing and reviewing three regional reports and acting as advisor to the executive integration team that guides the entire AACA process. He recently was assigned a coordinating role for the USGCRP FY17 Arctic priority, coordinating priority activities and reporting across federal committees (IARPC & SOST) working on Arctic issues. In this role, he has attended the regular IARPC meetings and various Arctic-focused international meetings.

Over the next year, Dr. Lipschultz will return to a deeper engagement in National Climate Assessment activities as the process for the next report ramps up towards producing a public draft. He will continue to lead the climate explorer task team for the CRT, to participate in developing the public-private Partnership for Resilience and Preparedness, and to work on implementing climate screening for international development in response to EO13677. For Arctic activities, he will continue to act as an advisor to the U.S. Head of Delegation to AMAP, focusing on developing the AACA report by the end of the U.S. chairmanship of the Arctic Council in mid-2017.

**CODE 610.1: GLOBAL MODELING AND ASSIMILATION OFFICE (GMAO)**

**Dr. Deepthi Achuthavarier** (sponsor: S. Pawson) evaluates aspects of climate and weather variability in century-long simulations and decadal predictions made with the GEOS-5 coupled atmosphere/ocean/land model. This includes an assessment of the leading modes of coupled variability, their predictability, and their regional impacts. Areas of focus include the Pacific Decadal Oscillation (PDO), the Atlantic multi-decadal oscillation (AMO), and long-term variability in the Asian and American monsoons. She also conducts and analyzes long coupled model simulations, ensembles of predictions, as well as model sensitivity studies to assess the impacts of uncertainties in various model parameters.
Earlier in the Dynamics of the Madden Julian Oscillation (DYNAMO) project, Dr. Achuthavarier produced a high-resolution, global, reanalysis for the DYNAMO experiment period, by assimilating quality controlled, high-vertical-resolution DYNAMO upper air soundings in the latest NASA GMAO atmospheric data assimilation system. During the past year, she was involved in the data analysis of the assimilation experiment. It was found that the DYNAMO in-situ observations had a positive impact on the GMAO assimilation system, where it improved the reanalysis winds, temperature and moisture fields over the equatorial Indian Ocean, a traditionally data-sparse area. Known biases in the assimilating model, such as the cold and dry lower troposphere and warm and wet upper troposphere, were further reduced in the DYNAMO reanalysis.

Additionally, the assimilation of these observations improved the representation of the initiation processes of the Madden Julian Oscillation (MJO) in the GMAO reanalysis. This is most clearly evident in the low-level moisture anomalies and the diabatic heating. To illustrate this, composite profiles of relevant quantities are shown in Figure 1, where the composites are produced for 22 precipitation rate bins over the domain 70°E-85°E, 2°S-10°N, for Oct 1, 2011 – Dec 31, 2011. In agreement with the generally accepted notion of the MJO initiation, a step-wise progression in heating and low-level moistening in connection with the transition from shallow cumulus to congestus to deep convection was observed in the DYNAMO sounding-based moisture and diabatic heating profiles. Figure 1 shows that this feature is better represented in the DYNAMO, relative to the control. The difference plot shows an enhanced heating of 0.2-0.8 K day⁻¹ in the DYNAMO

Figure 1. Composite vertical profiles with respect to precipitation rate bins for derived diabatic heating (a, Q1, K day⁻¹), specific humidity anomalies (b, g kg⁻¹), vertical pressure velocity (c, Pa s⁻¹), and convective cloud fraction (d, fraction). Right panels show their corresponding difference from the control reanalysis (e, f, g, h). The X-axis is precipitation rate bins (mm day⁻¹) and Y-axis is pressure (hPa). The composites are obtained by averaging the grid point quantities in the NASA domain for daily mean data from October 1 - December 31, 2011. The black lines on panel (e), plotted against the right Y-axis, are the fraction of grid points averaged in each precipitation bin for the control (solid) and the DYNAMO (dotted) reanalyses. Image provided by D. Achuthavarier.
in the lower troposphere for low-medium rain rates, indicative of enhanced low-level heating during the MJO pre-onset phase. For precipitation rates 9-20 mm day⁻¹, the increase is nearly through the entire atmospheric column, reaching up to 200 hPa, suggesting an overall enhancement of convection. Similarly, the difference plot of the specific humidity profile shows enhanced low-level moisture for moderate precipitation rates of 7-17 mm day⁻¹, indicating an improved representation of low-level moisture during the pre-onset phase of the MJO.

Dr. Achuthavarier completed a preliminary MJO analysis on a new GEOS-5 run with a modified microphysics scheme developed by Dr. Donifan Barahona. Daily variance, intra-seasonally filtered daily variance, lead lag correlation and equatorial space-time spectra were computed to examine the characteristic features of the MJO. The results imply improvement of the representation of the MJO in the new model, although further calculations are necessary to confirm the findings. She also is contributing to a paper on the GEOS-5 nature run evaluation, led by Dr. Oreste Reale.

This past year, Dr. Achuthavarier as PI was awarded funding for a proposal from the National Oceanic and Atmospheric Administration Climate Test Bed (NOAA CTB) on assessing sub-seasonal scale forecast skill in the NASA GEOS-5 model. This work will enable the NASA GEOS-5’s participation in a NOAA multi-model project on subseasonal scale forecasts and skill assessments. She also gave an oral presentation and was a contributing author at the annual meeting of the American Meteorological Society in New Orleans, LA. Both presentations are related to the improved representation of the reanalysis fields as a result of the assimilation of the DYNAMO in-situ observations. Dr. Achuthavarier also gave a GMAO seminar on this topic. She has resubmitted a manuscript on her earlier research on decadal variability in the GEOS-5 atmosphere-ocean general circulation model.

Looking ahead, Dr. Achuthavarier expects to continue to work on the DYNAMO project with a focus on producing MJO forecast runs and/or data diagnosis. She also will begin to work on the NOAA sub-seasonal project, where the primary focus will be on model tuning efforts to improve the simulation of the MJO in the GEOS-5. That project will eventually focus on producing weekly re-forecasts and assessment of the forecast skill. She also plans to complete the intraseasonal variability analysis of the improved microphysics run.

Dr. Nathan Arnold (sponsor: W. Putman) performs research and development activities with the GMAO’s high-resolution GEOS-5 general circulation model, with a particular focus on the development and implementation of high-resolution physics modules. His research has included the study of the spatial organization of convection in high-resolution simulations with GEOS-5, including the 7 km Nature Run and the 12 km downscaling of MERRA-2, and he compared these with the half-degree MERRA-2 and a 4-km merged satellite record of brightness temperature. His analysis showed that both simulations tend to underestimate the spatial organization of convection, with cloud clusters that are typically too small and too widely spaced. However, relationships between the degree of organization and large-scale quantities, such as humidity, wind speed, and radiative and surface fluxes, were generally well captured. Dr. Arnold gave an invited presentation on this work at the 2015 AGU Fall Meeting and another at a GMAO Science Theme Meeting, and is preparing a manuscript for submission to the Journal of Climate.

The tropical Madden-Julian Oscillation (MJO) is an example of convective organization on a grand scale. The MJO forms episodically over the Indian Ocean as a 10,000 km envelope of enhanced rainfall that propagates slowly eastward to the Pacific. It has a global effect on tropical monsoons, hurricane formation, and weather extremes. Despite its importance, the MJO is poorly simulated in most atmospheric models, and is exceptionally weak in the current version of GEOS-5. To understand why this is the case, Dr. Arnold has used a range of diagnostics to study model deficiencies in cloud-radiative feedbacks and the sensitivity of deep convection to humidity. These processes are known to be important to the MJO, and this analysis found that the simulated relationships among convection, moisture and radiation are currently too weak. As a result of this work, Dr. Arnold is preparing a proposal for submission to the 2016 MAP call. This proposal will fund more in-depth evaluation of the GEOS-5 moisture and radiative feedbacks, comparison with NASA A-train data, and development of a cold pool parameterization and changes to the current deep convection scheme designed to remedy feedback deficiencies.

In collaboration with colleagues at Oxford University, Dr. Arnold also studied the MJO in the MERRA-2 Reanalysis, focusing on the physical mechanisms responsible for its eastward propagation. Propagation depends on the background climate state, with the MJO extending further into the Pacific during El Niño years. By comparing MJO energy and moisture budgets for El Niño and La Niña years, this analysis has identified physical mechanisms
linking changes in propagation to the background climate. This has suggested physical processes to target for model improvement and may offer insights into MJO predictability.

In addition to using GMAO products for basic research, Dr. Arnold has contributed directly to model development efforts. The small-scale variability of moisture and heat within the atmospheric boundary layer has important effects on deep convection, but these effects are poorly represented in the current GEOS-5, with no dependence on model resolution and an unrealistic geographic distribution. Guided by the 7 km Nature Run, in which small-scale variability is explicitly simulated, Dr. Arnold began development of a more physically grounded parameterization. Several candidate schemes are now being evaluated.

Further, Dr. Arnold also began implementing a shallow cumulus parameterization. GEOS-5 is unusual in its lack of a shallow cumulus scheme, which likely contributes to a number of model biases, including the model’s weak MJO. The scheme being implemented was developed at the University of Washington and is currently used in NCAR’s Community Atmosphere Model.

In the coming year, Dr. Arnold will focus on five activities: 1) completing modifications to the GEOS-5 deep convection scheme to improve dependence on boundary layer MSE variance; 2) completing implementation of a shallow convection scheme; 3) submitting a manuscript on the organization of convection in high resolution simulations; 4) submitting a manuscript on the influence of ENSO on MJO propagation; and 5) testing and developing a doubly-periodic idealized configuration in GEOS-5.

Dr. Virginie Buchard (sponsor: A. da Silva) works on assessing the quality of aerosol estimates from the GEOS-5 Aerosol Reanalysis, and works on developing an Ensemble Kalman Filter-based scheme to assimilate lidar information jointly with Aerosol Optical Depth (AOD) from MODIS and MISR. This past year, Dr. Buchard has been working on assessing the performance of GEOS-5 aerosol reanalysis. Using independent observations, such as satellites and ground-based measurements not assimilated in the model, combined with radiative transfer simulations for Aerosol Index studies, she published a paper on the evaluation of the version 1 of MERRA aerosol reanalysis (MERRAero) absorption in Atmospheric Chemistry and Physics (ACP) and another paper on the evaluation of MERRAero surface PM$_{2.5}$ in Atmospheric Environment.

Related to her work on radiative transfer simulation, she also co-authored a paper published in ACP, and related to her work on the evaluation of MERRAero PM$_{2.5}$, she co-authored two papers that are currently under review. As a result of her research, she gave a talk at the 13th JCSDA workshop on satellite data assimilation held at the NOAA Center for Weather and Climate Prediction in May 2015.

Additionally she has been involved in the evaluation of aerosols in the GMAO’s latest reanalysis (MERRA-2). She and her colleagues have provided an assessment of the quality of the MERRA-2 aerosols for a technical memo. She has performed Aerosol Index simulations, surface PM$_{2.5}$ comparisons and vertical structure evaluations. Two companion papers, included one as a first author, are currently under preparation and should be submitted to the Journal of Climate by summer 2016. These studies help identify issues that need improvements in the forward model, e.g., such as the inclusion of nitrates, responsible for biases in the aerosol reanalyses surface PM$_{2.5}$ during winter in some regions.

The aerosol data assimilation scheme in GEOS-5 is being upgraded to an ensemble Kalman filter-based scheme using ensemble routinely produced by the meteorological assimilation. Dr. Buchard is currently working on implementing the aerosol ensemble Kalman filter (EnKF) infrastructure in the model that will include assimilation of lidar, MODIS, MISR and AERONET observations. This system enhancement is aimed at improving the representation of aerosols in GEOS-5. Preliminary results were presented at the CALIPSO Science Team Meeting held in March 2016.

As the implementation progresses, Dr. Buchard plans to continue to work on the aerosol EnKF in GEOS-5, from the development to the evaluation. Aerosol model results from the EnKF scheme will be compared to aerosol assimilated fields currently produced using the analysis splitting and local displacement methods.

The work of Dr. Yehui Chang (sponsor: R. Koster) contributes to the overall evaluation of climate variability and predictability at sub-seasonal-to-decadal timescales and the role of initialization in improving prediction skill. He also works on climate simulations and attribution studies, and conducts climate diagnostic studies using the GEOS-5 model suite in the GMAO. His research this past year included studying the impact of soil moisture anomalies on the atmospheric circulation. This explores one potential mechanism for remote dry soil moisture impacts on meteorological fields. Such remote impacts were examined in the context of atmospheric general circulation model (AGCM) simulations, leading to the identification of one
potential mechanism: the phase-locking and amplification of a planetary wave through the imposition of a spatial pattern of dry soil moisture at the land surface. Thousands of seasonal GEOS-5 GCM simulations have been completed at 1-degree resolution. Each set of AGCM ensemble experiments is designed to quantify the impact of a specific local dry soil moisture anomaly, prescribed somewhere in North America, on the general circulation. The locations tested in the different experiments span much of the continent, allowing a comprehensive picture of the circulation’s sensitivity to soil moisture anomalies.

Other work involving the GEOS-5 AGCM involved correcting its model biases. Dr. Chang has been using MERRA-2 data to explore a novel approach to reduce the model biases in an AGCM. The seasonal mean climate, with this novel approach implemented in the GEOS-5 AGCM, represents a substantial improvement over the simulated climate of the MERRA-2 version of GEOS AGCM. Six AMIP runs have been completed from 1979-2015 at 1x1 or 0.5x0.5 resolutions to assess the performance of the model. Additionally, he used a novel bias correction approach in the GEOS-5 GCM to assess the forecasting skills in the warm seasons. More than 2000 cases of 3-month forecasts have been conducted in order to study the impact of significantly reduced model bias on the forecasting skills. The forecasting skills have been greatly improved in the short- to medium-range time scales due to better model climate and the realistic Rossby wave in the GEOS-5 GCM.

Other research involved ENSO. His first study used the GEOS-5 coupled general circulation model (CGCM) to evaluate the mechanisms that allow an atmospheric state to affect ENSO development in 2014. Accumulated excess heat content along the sub-surface of the equatorial Pacific Ocean is a necessary precondition for El Niño to occur. Heat built up in early spring 2014 was sufficient to fuel strong El Niño development. Atmospheric forcing, in late spring and early summer, from intra-seasonal variability in the western equatorial Pacific is a potentially important factor in the initiation and development of El Niño. Such atmospheric impacts were examined in a large number of the CGCM ensemble simulations, leading to the identification of ENSO predictability. A manuscript based on this research is in progress.

In a related study, Dr. Chang used GEOS-5 GCM to predict 2015-2016 ENSO development. In order to access the sensitivity of likely impacts on California winter precipitation to El Niño intensity, and also to access the spread of possible outcomes even for a very strong El Niño, a very large number of ensemble forecasts were completed for both coupled ocean-atmospheric model and atmospheric model. The outlook could be expressed probabilistically from this study. Dr. Chang gave two presentations related to his study of El Niño: one paper titled “Effects of atmospheric conditions on developing weak El Niño in 2014” at NOAA’s 40th Climate Diagnostics and Prediction Workshop in Denver, CO in October 2015, and another paper titled “Effects of atmospheric conditions on development of ENSO and Strong El Niño prediction for 2015-2016” at the 2015 AGU Fall Meeting in December 2015.

Dr. Allison Collow (sponsor: M. Bosilovich) evaluates extreme precipitation and temperature events and their influences over the U.S. using MERRA-2 as a contribution to the National Climate Assessment (NCA). A large focus of Dr. Collow’s work has been on extreme precipitation events in the northeastern United States, where, according to observations, there has been a statistically significant increase in summertime precipitation and extreme precipitation events over the past two decades. Dr. Collow used a composite analysis to examine the mean state of the atmosphere before, during, and after an extreme precipitation event that showed an increase in moisture being advected into the region alongside a wave train of positive and negative anomalies in 500 hPa heights and sea level pressure. By comparing the composites from the past 18 years to the previous 18 years, Dr. Collow was able to determine how the mean synoptic structure of extreme precipitation events has changed over time. There is some indication that frontal activity has increased. The role of tropical cyclones also was evaluated in connection to extreme precipitation events in the northeastern U.S.; however, no statistically significant relationship was found when comparing the frequency and intensity of events that are tropical in nature to the time series of all events in the region. Dr. Collow presented results from this study at a GMAO Science Theme Meeting in March 2016, and a corresponding manuscript has been submitted for publication to the Journal of Hydrometeorology.

Past trends and future projections of extreme precipitation events carry considerable uncertainty, and, alongside the societal impacts of such events, warrant the need for an improved understanding of the underlying causes surrounding these events. Dr. Collow contributed to the GMAO-wide validation of MERRA-2 by examining the frequency and intensity of extreme precipitation events in MERRA-2 in comparison to observations and the original MERRA. A substantial improvement has been noted in both the frequency and intensity in summertime extreme precipitation events in MERRA-2 in relation to improvements in
the convective parameterization and forced precipitation seen by the land surface in MERRA-2. These results can be seen in Chapter 6 of the technical report titled “MERRA-2: Initial Evaluation of the Climate”, and in a science snapshot located on the GMAO website.

In December 2015, Dr. Collow attended the AGU Fall Meeting where she presented her previous work on the radiation budget in the Amazon Rainforest of Brazil and a regional analysis of large-scale influences on extreme precipitation events in the U.S. Factors that influence extreme precipitation events vary across the country and, while fronts may be responsible for an increase in extreme precipitation events in the Northeast, Dr. Collow showed that an increase in wintertime meridional winds in the western United States may be contributing to a decrease in precipitation in California.

Dr. Collow intends to continue her research on summertime extreme precipitation events in the Northeastern U.S., with a focus on events that are related to a frontal passage through the region. She hopes to expand this work to include other seasons and regions within the United States.

Dr. Ronald Errico (sponsor: R. Gelaro) works on the development, validation, and application of OSSEs. The addition of simulated observation errors is critical for a valid OSSE. For many observation types, these must be channel or spatially correlated. A new more generic algorithm for creating such errors, especially for wind observations, has been developed. Flexible, efficient, and user-friendly software for applying the algorithms has been created.

While validating the new GMAO OSSE framework, several puzzling results were obtained. One concerned large observation innovations of surface pressure that were introduced even when no simulated errors were added. Another concerned large negative Kalman gains over the extra-tropical oceans. Extensive tests have been performed to demonstrate that these strange results are not an erroneous artifact of the OSSE observation and error simulation software.

New observation types were added to the OSSE observation simulation software. The OSSE observation simulation software now also considers observations from CRIS, ATMS, GMI and SSMIS in addition to the previous set of AMSU-A, MHS, HIRS-4, AIRS, and IASI. Atmospheric motion vectors now include observations throughout the assimilation window, more consistent with the temporal and spatial distributions of real observations. Going forward, more observation types will be added. Consideration of cloud and precipitation effects and the uncertainty of surface emissivity will be refined. Further tuning of simulated observation errors will be performed to rectify some unrealism caused by the weak model error present in the GMAO OSSE when used with the GEOS-5 nature run.

Also, due to the 100-fold increase of the nature run’s data size, software for simulating observations from the new GEOS-5 nature run had to be redeveloped. The new code is more flexible, user friendly, and efficient than the previous code.

Dr. Errico will continue to examine the puzzling results observed in the GMAO OSSE. It appears these are a general property of the GEOS-5 data assimilation system, rather than peculiar to the OSSE framework. Thus, the explanation should be useful for improving the GMAO operational data assimilation and forecast system.

Dr. Manuela Girotto (sponsor: R. Reichle) worked with her sponsor and Dr. Gabrielle De Lannoy on assimilating satellite observations from the Gravity Recovery and Climate Experiment (GRACE) and the Soil Moisture Ocean Salinity (SMOS) mission into GMAO’s land surface data assimilation system. The goal is to assimilate both vertically integrated terrestrial water storage and brightness temperature (Tb) to improve surface and root zone soil moisture. Dr. Girotto has started an informal collaboration with other colleagues from GMAO (Richard Cullather and Guillaume Vernieres) and from the planetary geodynamics laboratory (Dr. Scott Luthcke) to investigate the feasibility of a GRACE Mascon product that is entirely consistent with the global land and ocean models developed at GMAO.

Dr. Girotto explored merging SMOS and GRACE assimilation components into a merged and single data assimilation system. First, she investigated the SMOS and GRACE data assimilation (DA) schemes independently. This step was necessary to understand the benefits and limits of the two systems. The GRACE assimilation system was applied over the continental United States (CONUS) and over India. Figure 2 (Girotto et al., 2016) shows the difference in skill for CONUS between DA and the model-only, ensemble open-loop (OL) estimates, in terms of ubRMSD and R versus in situ measurements of soil moisture and groundwater at the individual sites. The GRACE assimilation brought about significant improvements to the deeper water storages (i.e., groundwater), but minimal-to-zero benefits were obtained for the most superficial soil moisture layers.
Conversely, the SMOS data assimilation was found to improve model estimates of surface and root-zone soil moisture (De Lannoy and Reichle, 2016), but its effects on the deeper moisture layers and on the entire terrestrial water storage have not yet been investigated. Dr. Girotto verified the effects of SMOS data assimilation using in-situ groundwater and GRACE TWS observations, and found that SMOS data assimilation was not beneficial for improving either of these observations. In fact, in several regions estimates were degraded for groundwater and TWS with SMOS data assimilation. This result further encourages the assimilation of the GRACE and SMOS systems because of GRACE’s capabilities of improving deeper moisture layers.

SMOS and GRACE observations are characterized by different spatial resolutions and error structures; thus, it is expected that the merged SMOS + GRACE assimilation systems will benefit from the ad-hoc design of the perturbation spatial characteristics. Dr. Girotto has begun investigating differences in the spatial and vertical structures of model perturbation setups, in particular, the spatial distribution of the root-zone and catchment deficit ensemble spreads. The ensemble spread was found to depend on the depth-to-bedrock model parameter, which suggests that the perturbation scheme could be better defined as spatially variable, e.g., as a function of depth-to-bedrock. The LDAS system supports spatially variable perturbation inputs. For this, Dr. Girotto has tested the LDAS codes to verify the feasibility of such an experiment.

In her work on the verification of GRACE Terrestrial Water Storage (TWS) with MERRA products, Dr. Girotto compared GRACE global observations to TWS values obtained from the MERRA, MERRA-Land, and MERRA-2 products. With respect to TWS, MERRA-2 TWS improved the MERRA and MERRA-Land values. In fact, when compared to the independent GRACE TWS observations, MERRA-2 has the largest correlation skills. These results were presented at the AGU and AMS meetings in December 2015 and January 2016, respectively.

Going forward, Dr. Girotto will continue to examine and determine the uncertainties in GRACE and SMOS observations through triple collocation. She and her colleagues will work on manuscripts to describe 1) the original contributions obtained by joint GRACE and AMSR-E data assimilation and 2) the results of the GRACE data assimilation over India.

Dr. Daniel Holdaway (sponsor: S. Pawson) works on developing advanced data assimilation methods. This past year, Dr. Holdaway was involved with the DSCOVR EPIC instrument, investigating temporal sampling. He assisted the EPIC cloud algorithms team by examining the appropriate temporal sampling frequency to be used on this instrument. An important product from DSCOVR will be a time series of mean outgoing radiation from the sunlit hemisphere of Earth. This will help with monitoring the rate at which greenhouse gases are contributing to a radiation budget imbalance. In order to ascertain what temporal sampling will be required to capture the various scales in this time series, DSCOVR observations were simulated from the GEOS-5 Nature Run. This is a very high-resolution two-year climate simulation. The study was presented in two parts: looking at the complete outgoing radiation time series from the Nature Run and looking only at the cloud fraction. After carefully analyzing the time series of these two quantities for all possible scales, a recommendation for the sampling frequency was provided. Two papers have been completed, one in print and one currently undergoing minor corrections. Across the two-part study, a particularly interesting finding was that selecting the highest sampling frequency did not always result in a reduction in errors. For example, it was noted that a sampling frequency of 4 hours would have larger uncertainty than 5 hours. This is due to underlying signals in the time series, revealed through a Fourier analysis of the full signal.

Dr. Holdaway developed a framework to use the GEOS-5 adjoint model to examine sudden stratospheric warming. These
significant events occur during the northern hemisphere winter every 3 to 4 years on average and can have a dramatic impact on the weather. He is interested in understanding what led to the only southern hemisphere stratospheric warming, which occurred in 2002. By using the adjoint, it is possible to quickly identify the origin of the wave structures that led to the warming. The methodology involves generating an optimal perturbation based on the adjoint sensitivity and running a new model forecast. By contrasting the two forecasts, relevant wave structure is highlighted. Using this same method Daniel is now investigating the series of minor warmings that led to the major warming. This should help shed some light onto what was unique about the southern hemisphere troposphere in 2002 that resulted in the complete breakdown of the stratospheric vortex and ozone hole. He is currently preparing a paper on this research.

A large source of uncertainty when modeling quantities, such as carbon dioxide, comes in determining the surface fluxes of that quantity. Typically this is achieved using a so-called inverse model with a fixed set of winds. Dr. Holdaway is working to develop an adjoint model that will be capable of providing sensitivity to surface fluxes for any arbitrary tracer and thus in estimating its surface fluxes. A potential advantage of using the adjoint method is that it does not necessarily rely on the need to prescribe the winds. Indeed, the concentration of a constituent at a given location and time is highly dependent on the winds. Dr. Holdaway has completed the required modifications to the tangent linear version of GEOS-5 and has demonstrated that the model can accurately represent the evolution of tracer perturbations. He is now undertaking the modifications to the adjoint version of GEOS-5. A particular challenge has arisen, since the previous version of the adjoint made certain assumptions about the vertical advection of tracers in order to improve efficiency. These assumptions need to be relaxed which likely requires recoding the adjoint of the dynamical core. Despite the challenges, this work will serve to modernize the dynamical core and ease the planned transition to non-hydrostatic dynamics.

Additionally, Dr. Holdaway worked with the OSSE research group within GMAO to help diagnose an issue with that system using the adjoint of the GSI system. While performing this work, the researchers noted a rather large discrepancy with the way the GPS bending angle is computed in GSI versus at certain other centers where the ROPP system is used. In the past, it has been noted that GMAO generally gets a smaller impact from GPS observations than other centers. As such, Dr. Holdaway decided to implement the ROPP bending angle observation operator into GSI and compare the skill with the two approaches. A month-long integration using the ROPP system demonstrated a small increase in skill across 100hPa, 500hPa and 700hPa correlation and RMS metrics. In this first iteration of the system, the quality control is not modified to account for the different operator. Given the positive direction of the skill, it motivates a retuning and second iteration, which Dr. Holdaway is currently reviewing.

In the coming months, he plans to complete experiments looking at the southern hemisphere’s sudden stratospheric warming and compile the results for publication. He also plans to write up results of a study on Atlantic hurricane formation. Dr. Holdaway will complete a second iteration of the GPS bending angle with modified quality control. He intends to transition to examining non-Gaussian data assimilation. He plans to construct a one-dimensional model and 4DVAR for the assimilation of observations of precipitation from the GPM radar.

Dr. Jianjun Jin (sponsor: R. Gelaro) conducts radiance data assimilation using the GEOS-5 atmospheric data assimilation system (ADAS) in order to improve GEOS-5 precipitation and cloud analyses, and to develop and improve the procedure and algorithm of assimilating microwave radiance observations made by the satellite instrument TRMM/TMI and the new instrument GPM/GMI. Dr. Jin contributes to the evaluation, analysis, and development of ozone and temperature assimilation in GEOS-5 in the middle atmosphere and conducts scientific investigations related to precipitation, atmospheric composition, and structure using GEOS-5.

Dr. Jin continued to develop and improve the procedure to assimilate precipitation microwave radiance observations made by TRMM and GPM satellites with GEOS5 ADAS. Microwave imager instruments have been observing Earth’s hydrological cycle for the past 30 years. GEOS-5 assimilates these observations made by Special Sensor Microwave Image (SSM/I) between late 1980s and 2009. TRMM/TMI and GPM/GMI are two other microwave imager instruments that make these types of observations. GPM/GMI was launched in February 2014, and its observations are being tested and are going to be used in GEOS-5 ADAS. In the GEOS-5 reanalysis data sets, there is a microwave imager data gap between 2009 and 2014. In order to bridge this data gap, Dr. Jin conducted research focused on assimilating TMI data into a future GEOS-5 reanalysis. His study shows that TMI data can provide valuable atmospheric moisture information to the analysis and are able to bridge the data gap. Observations from this study show less moisture in the lower atmosphere in the east Pacific, Indian and Atlantic oceans and more moisture in the troposphere above the tropical Indian
and West Pacific oceans. This hydration results in a stronger convection above the tropical Indian and West Pacific oceans and produces more rainfall in these regions. This impact from TMI observation is similar to the impact from SSM/I observations. Therefore, TMI data are able to provide consistent constraints on GEOS-5 hydrological cycles in future re-analysis. In addition, Dr. Jin’s research finds that the use of TMI observations benefit the use of other observational data sets, such as observations made by AMSU-b onboard NOAA and European satellites.

Dr. Jin began assimilating observations made by the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the Japanese GCOM-W satellite. AMSR2 measures microwave radiance emission from Earth’s surface and atmosphere by conically scanning Earth’s surface at dual-polarization frequencies ranging from 6.9 GHz to 89 GHz. Therefore, its data includes sea surface temperature, atmospheric moisture, cloud, and rain information. In collaboration with a scientist at Joint Center for Satellite Data Assimilation (UCSDA), Dr. Jin produced an AMSR-2 BUFR brightness temperature (Tb) data set that can be processed by GEOS-5 ADAS. This procedure of data assimilation was then tested in the new GEOS-5 hybrid ensemble ADAS. Dr. Jin has improved the data quality control procedure in order to make good use of these observations.

Dr. Jin is a Co-I on a NASA ROSES Precipitation Measurement Mission Science Team (PMM) proposal that was selected for funding (PI: Dr. Min-Jeong Kim (GESTAR/MSU)). The goal of the proposal is to enhance the use of GPM/GMI in GEOS-5 ADAS in support of GPM mission. In addition to working on this proposal, Dr. Jin’s work in the coming year will involve developing, testing, evaluating and/or improving, where applicable, the procedure to assimilate precipitation microwave radiance observations with GEOS-5, the assimilation procedures for TMI, GMI, and AMSR2 observations in GEOS-5, and the evaluation of clouds and moisture analysis in the new GEOS-5 development of hybrid-ensemble variation system as well as the assimilation of GPM/GMI brightness temperature data in all-sky conditions.

**Dr. Emma Knowland** (sponsor: L. Ott) joined GESTAR in November 2015 after successfully defending her thesis at the University of Edinburgh, Scotland. She contributes to the evaluation of assimilated ozone (O3) in the MERRA2 products. During the last six months, Dr. Knowland imported the objective feature tracking algorithm, TRACK, onto Discover for analysis of the GMAO-combined meteorological and chemistry products. TRACK is a powerful tool for the study of tropical and extra-tropical cyclones. Dr. Knowland is assisting other members of GMAO in compiling and using the TRACK model.

In December at the 2015 AGU Fall Meeting in San Francisco, CA, Dr. Knowland gave an oral presentation titled “The influence of the North Atlantic Oscillation on tropospheric distributions of O3 and CO”. In this presentation, she showed the location of the main storm track, which tilts towards high latitudes (toward the Arctic) during positive NAO phases to a more zonal location in the mid-latitudes (toward Europe) during negative NAO phases, impacts the location of both horizontal and vertical transport across the North Atlantic and into the Arctic. Dr. Knowland also gave a presentation as part of this year’s first GMAO Science Theme Meeting on February 11, 2016. As a new employee, she saw this as an important opportunity to showcase her knowledge, skill sets and research interests to GMAO. Her talk was titled “The influence of mid-latitude cyclone tracks on the distribution of ozone and carbon monoxide”, and she showed case studies of stratospheric intrusions identified in different reanalysis products. Finally, in March 2016, she gave a presentation at the 10th International Conference on Air Quality Science and Application, held in Milan, Italy. In her oral presentation titled “The influence of mid-latitude cyclone tracks on surface ozone at remote European coastal monitoring sites”, Dr. Knowland made comparisons between the MERRA2 reanalysis product and the MACC reanalysis product.

In the coming year, Dr. Knowland will continue to investigate how the different GMAO products represent stratospheric intrusions, especially those events which result in air quality ozone exceedences in the western U.S. Work will focus on the driving modes of variability in stratospheric intrusions over the high elevations of western USA compared to the eastern U.S. She will relate the findings to other populated regions at high elevations, such as communities in Switzerland. She also will utilize observational datasets, including flight campaigns and air quality monitoring surface sites, in combination with the models to assess transport of trace gas species in the troposphere and lower stratosphere. Dr. Knowland has submitted one abstract to an upcoming conference in September 2016 and will be preparing another for the 2016 AGU Fall Meeting.

**Dr. Eunjee Lee** (sponsor: R. Koster) is involved in developing a project that investigates the global Carbon cycle using GMAO’s CatchmentCN model. Along with colleagues Dr. Lee organized a collaborative effort to promote the Carbon cycle research at GMAO. The goal is to validate the CatchmentCN model’s terrestrial Net Ecosystem Exchange (NEE) carbon fluxes with
the inverse modeling product deduced from atmospheric CO2 observations.

Results from a NEE comparison showed excessive peaks in the Northern hemisphere high-latitude regions during the winter. The model’s decomposition process of soil (i.e., heterotrophic respiration), which only had an exponential dependence to temperature, may generate an overestimated carbon source. Adding a moisture constraint to the frozen soil in the model code reduced the size of the peak, thus improving the model’s ability to simulate carbon exchange fluxes between land and atmosphere, both regionally and seasonally.

Furthermore, Dr. Lee investigated the sensitivity of the CatchmentCN model’s terrestrial Gross Primary Production (GPP) to temperature, precipitation and radiation. Preliminary results indicate that the water may be a limiting factor to GPP during the dry months in the extratropical regions, which supports the recent findings from literature that emphasizes the role of semi-arid areas in the inter-annual variability of the global carbon cycle.

Dr. Lee co-authored a journal article published in Agricultural and Forest Meteorology as well as a technical note in Hydrology and Earth System Sciences that is under minor revision. She is also a lead author of one manuscript and a co-author of two other manuscripts that are currently being prepared for Geophysical Research Letters and Water Resources Research.

Going forward, Dr. Lee will continue to investigate the effect of water availability on the terrestrial productivity and the carbon exchange fluxes through the interaction between the carbon cycle and the water cycle. Additionally, she will explore how much different meteorological forcings influence the land carbon flux estimates, in particular, using GMAO’s MERRA2 and SMAP Nature Run 5. Further, a comparison will be conducted with the OCO2 satellite observation, and the GMAO Carbon group will evaluate the AGCM results driven with the CatchmentCN’s estimates of the terrestrial productivity and respiration fluxes.

Dr. Young-Kwon Lim (sponsor: S. Pawson) supports scientific research on climate variability and weather extremes using modeling and assimilation tools developed by the GMAO. This past year, Dr. Lim explored interannual variations in seasonal tropical cyclone (TC) activity (e.g., genesis frequency and location, track pattern, and landfall) over the North Atlantic by employing observationally-constrained simulations with the NASA Goddard Earth Observing System version (GEOS-5) atmospheric general circulation model (AGCM). He found that the leading climate modes that significantly determine seasonal TC activity are El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), and the Atlantic Meridional Mode (AMM). His results demonstrated that the NAO and AMM can strongly modify and even oppose the well-known ENSO impacts, such as in 2005, when a strong positive AMM (associated with warm SSTs and a negative SLP anomaly over the western tropical Atlantic) led to a very active TC season with enhanced TC genesis over the Caribbean Sea and a number of landfalls over North America, under a near neutral ENSO condition. Conversely, the weak TC activity during 2013 (characterized by a weak negative EI Niño index) appears to have been caused by a NAO-induced positive SLP anomaly with enhanced vertical wind shear over the tropical North Atlantic. During 2010, the combined impact of the three modes produced positive SST anomalies across the entire low-latitude Atlantic and a weaker North Atlantic subtropical high, leading to more early recurvers and thus fewer landfalls, despite an enhanced TC genesis. His study demonstrates that TC number and track are very sensitive to the relative phases and intensities of these three modes, not just to ENSO alone, and that the TC tracks are primarily controlled by the largest scales of the atmosphere consisting of wavelengths greater than about 4,000–5,000km over the Atlantic TC basin. Also, his examination of seasonal predictability reveals that predictive skill of the three modes for TC season by the GEOS-5 model is limited over tropics to sub-tropics, with the AMM having the highest predictability, followed by ENSO and NAO.

Dr. Lim conducted extensive investigations using MERRA-2 with a focus on Greenland. First, he investigated the relationship between leading atmospheric teleconnection patterns and Greenland Ice Sheet (GrIS) temperature, precipitation, and surface mass balance (SMB) for the last 36 summers (1979-2014) based on MERRA-2, the GMAO’s new reanalysis dataset. His results found that the negative phase of both the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), associated with warm and dry conditions for the GrIS, lead to SMB decreases within 0-1 month. Furthermore, the positive phase of the East Atlantic (EA) pattern often lags the negative NAO, reflecting a dynamical linkage between these modes that acts to further enhance the warm and dry conditions over the GrIS, leading to a favorable environment for enhanced surface mass loss. He found that the development of a strong negative NAO in combination with a strong positive EA in recent years has led to a significantly larger GrIS warming compared to when the negative NAO occurs in combination with a negative or weak positive EA.
Second, Dr. Lim compared MERRA-2 data over the Greenland region with other reanalysis products, e.g., ERA-interim and satellite-based observation, such as CERES-EBAF radiative flux data. This comparison was intended to demonstrate the validity of MERRA-2 for studying climate variability over the Greenland region. His results indicated that the temporal variation of the anomalies of MERRA-2 variables is consistent with that of the ERA-Interim reanalysis over the Greenland region. The surface hydrology (e.g., runoff) over glaciated land differs somewhat between the two reanalyses in several recent summers, which may be due to the differences in the ice sheet surface representations. In the ERA-I, snow density is assumed to be constant with depth and is restricted to 0.07 m over land ice, while MERRA-2 uses a prognostic snow density and allows for meltwater percolation and refreezing. A comparison with observed radiative flux variables indicated that both MERRA-2 and ERA-I anomalies co-vary with the CERES-Energy Balanced And Filled (EBAF) observation with small uncertainty for 2010s. However, some overestimated bias of the downward long-wave flux anomalies was found from both reanalyses in 2000s. He clarified that the MERRA-2 dataset is very relevant for studying Greenland climate variability (warming/cooling and surface melting/recovery).

The 2015-2016 winter was recorded as one of the strongest, warmest ENSO seasons. Tropical regions, where the warm ENSO impact is relatively direct and stronger than extra-tropical regions, experience a strong anomalous winter climate in terms of temperature and precipitation. Extra-tropical regions also are influenced by the warm ENSO signal indirectly. Dr. Lim began investigating the impact of warm ENSO on global climate in the 2015-2016 boreal winter using MERRA-2. Two major goals of this study are 1) to better identify how the continental area over the earth was affected by the ENSO and 2) to validate how well the MERRA-2 reproduces the observed atmospheric nature during this warm ENSO season. Interactions of the ENSO impact with the impact of the other large-scale low-frequency mode also are being investigated. Initially, a few findings are that the impact of ENSO was further enhanced over the northern part of North America due to Pacific Decadal Oscillation (PDO), which is in phase with the warm ENSO during 2015-2016. Second, he found that the eastern U.S. region was not colder than normal in December 2015, which is opposite to the conventional understanding about the ENSO impact, possibly due to the positive phase of the Arctic Oscillation that counteracts the warm ENSO effect.

In a study focused on the NAO and EA modes, he found that during the summers of 2000-2015 there was a more frequent occurrence of the negative phase of NAO and positive phase of EA. Since the combined effect of the negative NAO and positive EA enhances warming and drying over Greenland, leading to a tremendous amount of surface melting, Dr. Lim investigated the projection of the phase of the NAO and EA in a changing climate. CMIP5 data are primarily employed for this study. From CMIP5 RCP4.5 scenario data, he found that the NAO phase tends to be negative over the 21st-century period. The EA phase also is found to have a tendency to be positive. This projected phase of the NAO and EA appears to account for gradual warming over Greenland in a changing climate. However, it seems that most of the general circulation models involved in CMIP5 do not reliably produce any downward trend in surface mass balance. In the coming year, Dr. Lim will continue this investigation to better identify the role of the NAO and EA teleconnections in resolving climate variability over Greenland in a changing climate.

Dr. Lim gave three key presentations this past year related to the research on the GrIS and the comparison of data sets. In October 2015, Dr. Lim was a co-author on a presentation titled “Comparison of OLR data sets from AIRS, CERES, and MERRA2” given at a NASA Sounder Science Team Meeting, held in Greenbelt, MD. In December, he was first author on a presentation given at the 2015 AGU Fall Meeting in San Francisco, CA titled “Atmospheric summer teleconnections and Greenland ice sheet surface mass variations: insights from MERRA-2”. This past January, he was lead author of a presentation titled “Atmospheric summer teleconnections and Greenland ice sheet surface mass variations: insights from MERRA-2”, given at the Program for Arctic Regional Climate Assessment (PARCA) meeting, held in Greenbelt, MD.

Work in the coming year will be an extension of research from this past year. Dr. Lim will continue to work on the 2015-2016 warm ENSO event by primarily analyzing the MERRA-2 data. Specifically, the anomalous atmospheric distribution over the extra-tropical region will be investigated to explain why the anomalous distributions differ from those during the previous strong warm ENSO events. He will continue the study on seasonal predictability of the large-scale climate modes to improve seasonal prediction of the Atlantic tropical cyclone activity by further evaluating the predictability of large-scale climate modes that significantly determine seasonal Atlantic TC activity. He will compare the predictability between old and new version of GEOS5 and address the improvement, strength/weakness of the model in realizing those major climate
factors. Additionally, he plans to conduct various experiments on the GEOS-5 model response to climate change. The model experiments and subsequent analyses will cover 1) the evaluation of the model’s capability in simulating the present climate over the Arctic region and 2) global model response to the Arctic amplification.

Under her task, Dr. Erica McGrath-Spangler (sponsor: S. Pawson) used space-based observations and earth system models to further the understanding of the carbon cycle. Complex global models were run, developed, and evaluated and the output applied to address scientific questions about the carbon cycle. Dr. McGrath-Spangler developed an algorithm to produce infrared data files for input to the GEOS-5 data assimilation system with help from Dr. William McCarty (GMAO) that allowed for variable data density with higher data density surrounding tropical cyclones and reduced data density elsewhere and included the ability to neglect infrared data over land. The assumption behind these experiments is that excessively dense data sampling of meteorologically inactive features negatively impacts the analysis while, on the contrary, meteorologically active features benefit from high data density. This was tested using multiple data thinning configurations.

Also, Dr. McGrath-Spangler’s lead author paper “Impact of planetary boundary layer turbulence on model climate and tracer transport” was published by the peer-review journal Atmospheric Chemistry and Physics. This paper finds that sensitivity of the GEOS-5 model to the planetary boundary layer depth can result in uncertainties of 20 ppb and 10 ppm for surface CO and CO₂ respectively. Note: work on this task was completed as of September 2015.

As PI, Dr. Erica McGrath-Spangler (Program Manager: Dr. Eckman) conducts research under a NASA-funded grant, which involves analyzing climatological PBL depth trends in the GEOS-5 atmospheric model and the CALIPSO satellite record and examining the impact on atmospheric tracer concentration and transport. Work this past year included designing and beginning an analysis of collocated PBL depths estimated from the CALIPSO satellite, radiosondes, and global reanalysis data. This work will contribute to an evaluation of the CALIPSO and MERRA-2 PBL depth estimates. She also developed an estimate of surface temperature forcing associated with anthropogenic climate change consistent with CO₂ observations from the Mauna Loa Observatory in Hawaii. This estimate will be used in her GEOS-5 atmospheric general circulation model experiments to evaluate the effect of temperature increases on PBL depth.

Dr. McGrath-Spangler designed a GEOS-5 AGCM experiment examining the effect of increasing surface temperatures on global planetary boundary layer depth and subsequently on atmospheric aerosols and greenhouse gases. She completed running a control experiment, without increasing surface temperatures and is currently performing a perturbation experiment. These experiments consist of perpetual atmospheric conditions for evaluation of the effect of temperature tendencies on future simulations.

Using her CALIPSO PBL depth retrieval algorithm, Dr. McGrath-Spangler computed PBL depth estimates for the CALIPSO satellite record from 2006-present. She then produced monthly mean-gridded PBL depths that will be used to evaluate the presence of trends and the spatio-temporal variability of trends. She developed the capability to produce daily, gridded estimates of PBL depth from the spaceborne CALIPSO satellite. This product will enable comparisons between this spaceborne estimate of PBL depth and those from other observational and model simulation estimates. Further, Dr. McGrath-Spangler developed techniques to perform non-parametric statistical analyses on the PBL depth estimates produced. These include the median of pairwise slopes techniques that can be used to estimated temporal trends. These techniques are more resistant to outliers than other traditional methods, e.g., linear regression.

Work will continue on her GEOS-5 simulations exploring the impact of increasing surface temperatures on PBL depth and atmospheric greenhouse gases and aerosols. She will collocate PBL depth estimates from the CALIPSO satellite, radiosondes, and global reanalysis, and subsequently compare them to better understand differences and similarities between them. A manuscript will be written that describes results from her comparisons of PBL depth estimates from various observations and global reanalysis.

Dr. Erica McGrath-Spangler (Program Manager: Dr. A. Pszenny) also supports research under another NASA-funded grant (PI: Dr. J. Hegarty) in which she participates in science analysis and provides quality-controlled PBLH retrievals from the CALIPSO satellite, refining these retrievals in light of the science analysis (e.g., experiment with the different horizontal averaging windows), and places regional modeling results in the context of the global modeling efforts at the GMAO. Dr. McGrath-Spangler developed the ability to diagnose planetary boundary layer (PBL) depth from WRF model results that simulated the Baltimore/ Washington DC DISCOVER-AQ field campaign during July 2011 using three different definitions. Following results using the
GMAO’s GEOS-5 model showing the sensitivity of model results to PBL definition, she developed the capability to estimate PBL depth using a bulk Richardson number method, a gradient method, and a parcel method. For the parcel method, she also computes the value of a small perturbation temperature (<0.2K) necessary to overcome a slight surface inversion. She then computed these depths at 10 ground-based LiDAR locations and throughout the domain at the times of airborne High Spectral Resolution Lidar (HSRL) flights for comparison with the observational data.

Dr. McGrath-Spangler applied modifications to the quality control of the CALIPSO PBL depth algorithm to satellite orbits over the Baltimore/Washington region during the July 2011 DISCOVER-AQ field campaign for comparison with output from the high-resolution WRF simulations. These modifications include loosening the restriction on overlying optically thick layers and spatial homogeneity. Previous work showed a 70% increase in the number of retrieved PBL depths due to these modifications. She also evaluated the sensitivity of retrieved CALIPSO PBL depth to the size of the averaging window used to increase the signal-to-noise ratio. She found that the PBL depth variability increased with smaller averaging windows, but the number of retrieved PBL depths did not substantially change.

Dr. McGrath-Spangler contributed to presentations given by Dr. Hegarty at two meetings. The first was the Meteorology and Climate - Modeling for Air Quality (MAC-MAQ) meeting held in September 2015 in Sacramento, CA. The presentation was titled “Evaluating high-resolution WRF simulations of PBL depth using observations from DISCOVER-AQ 2011” led by Dr. Hegarty. The second was the presentation titled “Evaluating WRF simulations of urban boundary layer processes during DISCOVER-AQ” at the 2015 AGU Fall Meeting held in December in San Francisco, CA. She contributes to regular teleconference meetings with the project team, providing feedback and suggestions for future directions. Her research goals are to investigate various PBL depth definitions and their impact on model estimates and to evaluate comparisons of the model and other observations to PBL depth estimates from the CALIPSO satellite.

**Dr. Peter Norris** (sponsor: A. da Silva) uses retrieved cloud data to validate cloud properties within the Goddard Earth Observing System (GEOS) model, to measure the capability of trial cloud representations, and to assimilate cloud measurements directly into the GEOS data assimilation system. Throughout this past year, he and his sponsor have been working on Cloud Data Assimilation (CDA) papers. Recently Dr. Norris has resubmitted revisions for Parts I and II of his and Dr. da Silva’s CDA journal article series. The revisions involved a substantial new section in Part I, analyzing the performance of the Bayesian Monte Carlo CDA algorithm in the single model layer context and an expanded inter-comparison of assimilations of cloud retrievals from the MODIS and SEVIRI satellite instruments in Part II. Also, a third paper (Part III) on the radiative evaluation of the CDA system is nearing submission.

Other work related to CDA involved studying the assimilation of geostationary satellite cloud data and its effect on the land surface radiation balance. Using Dr. Norris and da Silva’s Bayesian Monte Carlo cloud data assimilation (CDA) system, researchers conducted a study to assimilate high-resolution GEOS-East full-disk cloud retrievals from Pat Minnis’ NASA Langley group and to provide the CDA-updated surface radiation fluxes to Dr. Clara Draper for testing. Preliminary results look promising, with strong bias reduction in both assimilated fields (cloud optical thickness and brightness temperature) and non-assimilated fields (e.g., cloud fraction and cloud top pressure). A radiative evaluation is in progress. The goal is to see if CDA will improve the land surface energy balance in the GEOS-5 GCM. A preliminary assessment is that land surface radiative flux changes due to CDA seem to have a magnitude large enough to affect the land surface energy balance.

Dr. Norris presented his validation of cloud radiative forcing (CRF) for GMAO’s GEOS-5 Modern Era MERRA-2 reanalysis product at the GMAO MERRA-2 Kickoff Science Theme Meeting in June 2015. The MERRA-2 CRF for thermal and solar bands was compared with the CERES EBAF satellite data product, and also with the earlier MERRA-1 reanalysis. Dr. Norris also finished a chapter on cloud radiative forcing, which he contributed to GMAO’s preliminary report on MERRA-2.

Following previous MODIS cloud simulator work, Dr. Norris produced a high-resolution cloud simulator for the SEVIRI instrument onboard the MSG satellite for Gala Wind and for the future TEMPO instrument onboard another geostationary satellite, to be used by Drs. Arlindo da Silva and Patricia Castellanos to derive radiative transfer calculations for aerosol studies.

Additionally, Dr. Norris performed some theoretical work on adding horizontal correlation to the subgrid-column statistical model that is fundamental to his and Dr. da Silva’s cloud data assimilation strategy. Horizontal correlation will allow for a proper treatment of: (1) horizontal non-independence of assimilated
Dr. Tomohiro Oda (sponsor: S. Pawson) develops and maintains a global fossil fuel carbon dioxide (CO2) emission model (Open-source Data Inventory for Anthropogenic CO2, ODIAC) that produces a global CO2 emission fields at a very high spatial resolution (1x1km). Dr. Oda has produced an updated version (ODIAC2015a) of his ODIAC fossil fuel CO2 emission dataset and delivered this to the international user community. The 2015a version of the ODIAC data has been used for the updated inversion analysis implemented by NOAA Earth System Research Laboratory’s CarbonTracker (http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/). He also examined the use of new nighttime light (NTL) data retrieved from data collected by the Visible Infrared Imaging Radiometer Suite (VIIRS) on Suomi-National Polar-orbiting Partnership (NPP) satellite in his emission model. Using the new NTL data developed by Dr. Miguel Román and his group at Goddard, he developed the first Suomi-NPP NTL-based map of fossil fuel CO2 emissions over CONUS US. The preliminary result was presented at the 2015 AGU Fall Meeting.

As a part of NASA Carbon Monitoring System-funded GEOS-CARB2 project (PI: Dr. Lesley Ott), Dr. Tom Oda also developed an uncertainty map for fossil fuel CO2 emission using differences among four major gridded emission inventories. Drs. Oda and Ott further expanded the uncertainty analysis via atmospheric transport simulations using GEOS-5 to produce the uncertainty estimate that inversion modelers should use in their analysis. Dr. Oda and his European colleagues have attempted to estimate uncertainties associated with the high-resolution emission field in ODIAC. Those results were presented at the 4th International Conference on Uncertainties in Atmospheric Emissions in Krakow, Poland.

Under a NASA Orbiting Carbon Observatory 2 (OCO-2)-funded project (PI: Prof. Eric Kort), Dr. Tom Oda contributed to analyses of OCO2-observed CO2 concentration variability. Using his model and high-resolution WRF system developed and maintained by Dr. Thomas Lauvaux and his group at Pennsylvania State University, some of the observed CO2 peaks were successfully replicated in the simulation. Dr. Oda and the Lauvaux team also have examined LandSat-derived 30m surface impervious data for emission mapping and obtained an inversion analysis for Indianapolis, IN using the 30m emission field as a prior emission field. The inversion analysis yielded a comparable result to the case with a fine-grained emission inventory. The results were presented at the GEIA 2015 conference in Beijing, China. Based on the concept, Drs. Oda and Lauvaux submitted a proposal in response to ROSES2016 CMS.

Dr. Joanna Pelc (sponsor: R. Todling) works along with her sponsor and Dr. Jing Guo on the development of a high-resolution observer within the GEOS-5 data assimilation system (DAS). Atmospheric data assimilation combines model forecasts and observations in order to obtain the best possible weather forecast. Data assimilation procedures involve the minimization of a function that describes the distance between the model and the observations. In the operational weather forecasting system, the model currently is run on a high resolution, while the minimization procedures need to be performed on a low resolution in order to keep the computational cost affordable. The calculated distance between the model and the observations is part of the minimization procedure; however, its computational cost is relatively minor. Over this past year, Dr. Pelc designed and ran experiments to examine the potential for improving the performance of the GEOS-5 DAS by calculating the distance between observations and the model on a higher resolution. This was done while keeping the rest of the minimization procedure at a lower resolution, hence keeping the computational cost feasible for the potential operational applications in the future. She performed tests using the first version of the high resolution observer code and obtained encouraging results. These initial tests demonstrated that increasing the resolution of the observer shows an overall improvement to the performance of the GEOS-5 data assimilation system. Dr. Pelc participated in a series of meetings with the GSI development collaborators at NCEP, where she presented her results.

Additionally, Dr. Pelc spent part of the past year on researching the localization and hybridization strategies to evaluate their potential for improving the background error covariance representation in the GEOS-5 data assimilation system. She will continue this work in the coming year.
Performance of the atmospheric data assimilation is highly dependent on accurate representation of the statistical properties of the errors in the prior model values (background). These play an important role in creating a background error covariance matrix, which provides a mechanism of linking the model information together, and essentially provides a blueprint of how the model variables interact with each other. This is a crucial tool in order to obtain coherent and complete model state estimates, where assimilated data is limited in time and space. Dr. Privé’s upcoming work will focus on the development of novel strategies for optimal specification of the statistical properties of the model error covariances. This work is part of a NASA MAP proposal currently in preparation, where her role as Co-Investigator would be to investigate localization and hybridization strategies for ensemble-based covariances in GEOS-5 data assimilation system.

Dr. Nikki Privé (sponsor: R. Gelaro) supports projects in atmospheric data assimilation, especially regarding the use of current and future space-based observations. This includes diagnostic studies to evaluate and improve the use of observational data as well as running and interpreting observing system simulation experiments. This past year, the transfer of the OSSE system to the new DISCOVR compute nodes was completed, including a model update. Calibration of the synthetic observations and observation errors on the new system was completed. A control case using the G5 Nature Run observations also was completed, including daily forecasts, along with an accompanying validation case using real data. The GMAO OSSE was calibrated and validated for two three-month periods, including 10-day forecasts. Both a control case using real data and the synthetic OSSE case were run. Dr. Privé ran experiments with the GMAO OSSE to test new synthetic observations for SSMIS, ATMS, CRIS, and GMI, as well as observations on METOP-B. Experiments were run with the GMAO OSSE to compare the performance of the synthetic observations developed at GMAO with a similar set of synthetic observations developed at the National Centers for Environmental Prediction.

Some anomalous behavior of the GMAO OSSE was investigated to improve performance. Ingestion of observations was found to be causing a degradation of the analysis quality. This problem was approached using a combination of observation impact studies with the GEOS-5 adjoint, a series of data denial experiments, and manipulations of the synthetic observation errors and their correlations in the OSSE. Dr. Privé determined that the background error covariances may be the source of the poor performance, and these are currently being evaluated for possible improvement. Experiments were run with the new background error covariance matrices to improve performance of the Gridpoint Statistical Interpolation system. Additionally, experiments to investigate the behavior of the adjoint of the GEOS-5 model were begun. The adjoint tool is used to estimate the impact of individual observation types on the forecast skill of the model. The true impact can be calculated explicitly in the OSSE and compared with the estimated observation impact calculated in operational practice to determine the robustness of the tool. Four months of baseline adjoint estimations were calculated using self-verification.

Interpolation errors were explored using the GMAO OSSE framework. The relative errors due to spatial and temporal interpolation were calculated using a 1.5-km global run of the GEOS-5 forecast model. This work resulted in a publication in the Journal of Atmospheric and Oceanic Technology titled “Temporal and spatial interpolation errors of high-resolution modeled atmospheric fields”, co-authored with Dr. Ronald Errico.

Dr. Privé gave invited talks at the Workshop on Sensitivity Analysis and Data Assimilation in Meteorology and Oceanography in Roanoke, WV in June 2015; the JCSDA Summer Colloquium in Fort Collins, CO, in July 2015; and the Department of Atmospheric and Oceanic Science at the University of Maryland, College Park, in March 2016. She also presented at the AMS Annual Meeting held in New Orleans, LA in January 2016. In June 2015, Dr. Privé was Co-organizer of the 10th Workshop on Sensitivity Analysis and Data Assimilation in Meteorology and Oceanography, held in Roanoke, WV. She also co-chaired the Observing System Simulation Experiments (OSSEs) II session of the 20th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS) at the AMS meeting.

In the coming year, she will continue to perform calibration and validation experiments for an updated dataset of synthetic observations for the GMAO OSSE framework. Dr. Privé will perform OSSEs in support of the MISTIC Winds project. She also will contribute to the NOAA Satellite Observing System Architecture effort to develop a value model for the potential future global observational network.

Under this task, Dr. Oreste Reale (sponsor: S. Pawson) studies the impact of Climate Variability on Tropical Storm Characteristics. The original goal of this task was to support scientific research on climate variability and tropical storms using high-resolution versions of the GEOS-5 atmospheric
model developed by the Global Modeling and Assimilation Office (GMAO). In addition, Dr. Reale is also involved in the GMAO monitoring effort, contributing to the ongoing evaluation and assessment of the GMAO modeling suite and other GMAO products. As such, as part of the GMAO Monitoring Group activity Dr. Reale is actively involved in evaluation work, often in collaboration with Dr. Marangelly Fuentes (SSAI/GMAO) and other scientists. Recent work has been focused on hurricanes representation in a set of downscaling experiments produced by Dr. Putman (NASA/GMAO), and targeting Hurricane Katrina. A poster, of which Dr. Reale is co-author, was presented by Dr. Putman at the AMS meeting in New Orleans, LA in January 2016.

As first author, Dr. Reale has completed a draft article on the new 7-km NASA Nature Run. The article is currently being reviewed by the co-authors and should be submitted before the summer. The GMAO Nature Run is a product created by the GMAO in 2015 for use in Observing System Simulation Experiments (OSSEs). Dr. Reale’s work investigates the NR’s realism in representing tropical cyclones and therefore its possibility to serve as a tool to assess the potential impact of future instruments targeting tropical cyclones.

Dr. Reale has been investigating the representation of “historical hurricanes”, those which occurred more than 30 years ago (when global analyses and models did not have the ability to capture features), with the state-of-the-art reanalysis project by the GMAO, the MERRA-2, in collaboration with Dr. Fuentes (SSAI/GMAO). Their findings suggest that MERRA-2 has a unique ability to revisit these devastating systems and shed some light on the potential for predictability. As lead author, Dr. Reale gave an invited talk on this subject at the SED Director’s seminar on April 1, 2016 and co-authored another talk with Dr. Fuentes (GMAO/SSAI) presented at the AMS meeting in April 2016 in Puerto Rico.

Another article, with Dr. Reale as a co-author, describes the large-scale controls on Atlantic tropical cyclone activity, which are much more complex than the current misperceived relationship between El Niño and hurricanes, since several modes of variability other than El Niño are involved. This article is led by Dr. Young-Kwon Lim and co-authored by Dr. Schubert, Dr. Reale, Dr. Molod and Dr. Suarez. At the time of this report, the article has been conditionally accepted by the Journal of Climate, pending minor revisions.

As the PI, Dr. Oreste Reale performs research under a three-year NASA-funded grant (Program Manager: R. Kakar) in which the goal is to investigate the representation of tropical cyclone structure, the changes in structure, and TC forecasting ability, consequent to the assimilation of AIRS data. The work is focused on assimilation of radiances affected by clouds and it includes the investigation of the effects of AIRS data assimilation on precipitation forecast. The research also utilizes the Hilbert-Huang transform to evaluate the spectral properties of analyses obtained by different assimilation strategies. Dr. Erica McGrath-Spangler, Dr. Radina Soebiyanto, and Dr. Yaping Zhou are or have been partly supported by this grant.

Throughout this past year, Dr. Reale coordinated the production and assessment of a very large set of experiments, now completed, to study the effect of variable AIRS radiances data density and distribution in the GEOS-5 Data assimilation and forecast system. The basic idea was to change the current approach towards “thinning” from a homogenous procedure to an event-based one. The results are very convincing, in terms of improvement of global skill and forecast track, and are being organized into two comprehensive articles, in collaboration with Dr. McGrath-Spangler.

He also coordinated the production and completion of a new set of experiments focused on the assimilation of cloud-cleared radiances with variable density. The experiments also were conducted by Dr. McGrath-Spangler. Preliminary results are very encouraging, particularly with respect to improved hurricane intensity forecast, but they need to be analyzed in greater depth and complemented by the addition of bounding experiments.

Dr. Reale has been coordinating the implementation and extensive testing of Hilbert-Huang Transform (HHT) software within the GEOS-5 diagnostics framework, with the aid of Dr. Soebiyanto. Aside from her personal research, she is an expert on mathematical and statistical analysis. She has been working in close collaboration with Dr. McGrath-Spangler and successfully applied the HHT to the output of the AIRS-observing system experiments. Her most recent task is the optimization and parallelization of the HHT algorithm on NASA HEC computing resources, in collaboration with NCCS personnel.

As a member of the AIRS Science Team, Dr. Reale attended the NASA Sounder Team Meeting, held in October 2015 in Greenbelt, MD, in which three talks resulting from work performed under his guidance and supported by this grant were presented: “Adaptive clear-sky AIRS radiance thinning to improve global forecast skill and tropical cyclone representation in the NASA GEOS-5”, authored by Drs. Reale, McGrath-Spangler, McCarty, and Zhou; “Assimilation of AIRS cloud-cleared radiances to improve tropical
cyclone intensity forecast in the NASA GEOS-5", authored by Drs. Reale, McGrath-Spangler, and Rosenberg; and “Sensitivity of a North Indian tropical cyclone analysis to AIRS data assimilation strategy”, authored by Drs. McGrath-Spangler and Reale.

Work will continue on this three-year grant, and two manuscripts on AIRS clear-sky radiances variable thinning will be submitted. Dr. Reale will continue studying the experiments with cloud-cleared radiances and exploring the HHT method as an evaluation methodology for data assimilation purposes, in collaboration with Dr. Soebiyanto. A successor proposal will be submitted when the call is released.

**Dr. Erica McGrath-Spangler** performs research under Dr. Reale’s three-year NASA-funded grant (Program Manager: R. Kakar) in which the goal is to investigate the representation of tropical cyclone structure. In particular, Dr. McGrath-Spangler contributes to the design, carrying out, and analysis of numerical experiments focused on the impact of different AIRS data types and assimilation strategies on the analysis and forecast of TCs in the NASA GEOS-5 system. Dr. McGrath-Spangler performed nine experiments using clear-sky infrared radiances that tested the effect of data density on global and tropical cyclone forecast and tropical cyclone analysis skill and the sensitivity of these to data over land. She worked collaboratively with Dr. Reale on two manuscripts detailing the results of this work. The first manuscript, led by Dr. Reale, discusses the variable thinning approach and general results. The second manuscript is a follow on to the first and focuses on the effect of variable thinning on tropical cyclones in the North Indian Ocean. Dr. McGrath-Spangler presented a talk entitled “Sensitivity of a North Indian tropical cyclone analysis to AIRS data assimilation strategy” by McGrath-Spangler and Reale at the NASA Sounder Science Team meeting in October 2015 in Greenbelt, MD. She also co-authored two talks by Dr. Reale at the meeting.

Dr. McGrath-Spangler conducted three experiments focused on the assimilation of cloud-cleared AIRS radiance data using variable density. These experiments test the sensitivity of TC and global forecast skill to data assimilation strategy. They were conducted following promising results from previous experiments performed by Dr. McGrath-Spangler that showed an improved representation of TC intensity and global forecast skill when increased data density is present in the vicinity of tropical cyclones with reduced data density elsewhere. More recently, she has begun two additional experiments assimilating increased and decreased AIRS data density globally as extreme experiments to bind the variable thinning experiments. These five two-month-long experiments are in addition to the nine two-month-long experiments she performed using clear-sky AIRS radiances. Additionally, Dr. McGrath-Spangler is performing an analysis of historical North Indian Ocean tropical cyclones during the modern era but before operational models could adequately represent tropical cyclones.

Dr. McGrath-Spangler worked closely with Drs. Soebiyanto and Zhou, in addition to working directly with Dr. Reale. She facilitates their analyses by providing model output, explaining current results, and consulting on forward progress. She worked particularly closely with Dr. Soebiyanto applying the Hilbert-Huang Transform (HHT) to GEOS-5 experimental results and has become proficient at using the HHT and frequency analysis tools.

In the coming months, Dr. McGrath-Spangler will test the impact of the variable thinning approach, going from the version used in their current experiments (GEOS-5 using 3DVAR) to the more recent GEOS-5 hybrid system. She will actively work with Dr. Reale to publish results from their work on the variable thinning approach. They are expecting at least two manuscripts. Also, she will complete her latest experiments, investigating the impact of AIRS cloud-cleared radiance data density, computing forecast statistics, and evaluating the representation of tropical cyclones.

**Dr. Radina Soebiyanto** conducts research under Dr. Reale’s three-year NASA-funded grant (Program Manager: R. Kakar) in which the goal is to investigate the representation of tropical cyclone structure. Dr. Soebiyanto is specifically responsible for providing guidance on the use of the Hilbert-Huang Transform (HHT) for applications in data assimilation and global forecast, and she worked with Dr. McGrath-Spangler to transfer the HHT analysis knowledge.

Dr. Soebiyanto had been working on implementing the Hilbert Huang Transform (HHT) - specifically the Empirical Mode Decomposition that decomposes a signal into its intrinsic oscillatory modes. She had tested the HHT capability for a 1D signal and had recently extended the capability to 2D inputs. Dr. Soebiyanto tested the algorithm using meridional wind data from AIRS around the location of where African easterly jet occurs. Due to the intensive computation in performing the 2D HHT, Dr. Soebiyanto is currently working with the NASA High-End Computing (HEC) resources at NCCS to parallelize the 2D decomposition. Work will continue regarding the development and testing of the framework.
Dr. Yaping Zhou also contributed to Dr. Reale’s three-year NASA-funded grant (Program Manager: R. Kakar) by providing tropical cyclone-related precipitation statistics for sets of AIRS assimilations with various sampling strategies from the September - November 2014 period. In addition, Dr. Zhou also analyzed global precipitation statistics, especially the difference of land and ocean in response to changing sampling.

Dr. Cecile Rousseaux (sponsor: W. Gregg) performs research on ocean phytoplankton populations using the GMAO NASA Ocean Biogeochemical Model (NOBM). Her work this past year resulted in numerous papers and presentations. Two papers were accepted for publication (one as first author and one as co-author). Dr. Rousseaux was co-author on one paper submitted to the Bulletin of the American Meteorological Society. She also contributed to three white papers (one to the International Ocean Color Science Group and two to the National Academies RFI request). Dr. Rousseaux’s paper titled “Recent decadal trends in global phytoplankton composition” (Rousseaux and Gregg, 2015) was accepted by Global Biogeochemical Cycles. She worked with the NASA Goddard SVS Team on a media article and video covering this release (see http://www.nasa.gov/feature/goddard/nasa-study-shows-oceanic-phytoplankton-declines-in-northern-hemisphere). Several media, including ~50 websites, commented on this paper. She also co-authored “Climate variability drives plankton community composition changes: The 2010-11 El Niño to La Niña transition around Australia”, which was published in the Journal of Plankton Research, co-authored a paper submitted to the Bulletin of the American Meteorological Society (BAMS), and co-authored the written report of the IOCS meeting to be published on the IOCS website. Dr. Rousseaux was invited to be part of the NASA Ocean Biology and Biogeochemistry Program pre-Decadal report team. She was a co-author on a white paper submitted by this group as well as another white paper submitted by the Carbon Cycle Group in response to the Request For Information (RFI) by the Decadal survey. Finally, Dr. Rousseaux’s work was featured in an article in the magazine ‘Microbes’ (Volume 11, Number 1, 2015, p.3).

Over the last year, Dr. Rousseaux reviewed proposals for five national and international programs. She was invited as a Subject Matter Expert for the Office of Science and Technology Policy Office of the White House. The OSTP invited her to participate in the national Earth Observations Assessment (EOA 2016), which involved participating in meetings and providing feedback on the assessment. This assessment was in response to a congressional request to provide an evaluation of the Nation’s current portfolio of Earth-observing systems.
Equatorial Pacific” and co-author on two other posters. In May 2016, Dr. Rousseaux attended the NASA OCRT Meeting in Silver Spring, MD and presented a poster on “Forecasting the effects of a developing El Nino event on chlorophyll in the Equatorial Pacific”.

Currently Dr. Rousseaux receives funding as PI for one project (PACE) and funding as Co-I from three other proposals (IDS, CMS and NPP-VIIRS). She also leads the GSFC Ocean Focus Group and is a deputy leader for USRA. In January 2016, at the PACE Science Team Meeting in Pasadena, CA, she presented on her project “Phytoplankton composition algorithms for PACE” and gave a progress report of the subgroup that she leads on developing the database for algorithms development for the PACE mission. In March 2016, Dr. Rousseaux attended the three-day-long PACE Mission Concept Review (MCR) at NASA GSFC. She also provided the NASA Ocean Color Group (Code 616) with the 1nm resolution absorption and scattering data generated using the model as part of her PACE work. As part of the PACE project, Dr. Rousseaux leads the PACE Science Team Dataset group, which includes organizing teleconferences and developing the first version of the PACE hyperspectral database. Dr. Rousseaux advertised in the International Ocean Color Group Newsletter the need for additional optical data for the in situ database generated in support of the PACE mission. The first version of the PACE Database has been provided to the rest of the Science Team. As the leader of this subgroup, she (along with Kimberly Casey) managed the input of the different team members.

As part of the IDS funding, Dr. Rousseaux developed the code in GEOS-5 to include the effects of nutrient addition through runoff on the biology in the GEOS-5-NOBM and the new configuration was tested and a stable tag was generated. This tag was merged with the most recent GEOS-5 version available for the oceans running with data atmosphere. A 100-year run was done to test the stability of the model and this run will be used for future data analysis. In January 2016, Dr. Rousseaux presented a poster at the PARCA meeting titled “Interannual variability in the biogeochemistry of the waters surrounding Greenland”. Also, as part of the Carbon Monitoring Program (CMS), Dr. Rousseaux gave a presentation at a GMAO Research Theme Meeting in October 2015. She also provided some slides of her results to Dr. Lesley Ott (PI, NASA) for presentation at NASA HQ.

As part of the NPP-VIIRS funding that she received, Dr. Rousseaux created a new database of in situ chlorophyll that includes several new cruises. While this was done in an effort to validate the latest VIIRS chlorophyll data, it also will be of use to validate all the model runs as well as the continuous satellite record (ESRID). As part of this effort, she conducted a sweep of all the latest CZCS, SeaWiFS and MODIS Aqua reprocessing R2014 including Particulate Inorganic Carbon, reflectance and chlorophyll. She downloaded/formatted these satellite data and the forcing (MERRA/MODIS/GOCART) data for 2015 that are needed to run the NASA Ocean Biogeochemical Model.

Dr. Rousseaux is helming the NASA Goddard Ocean Focus Group, which aims to define the next 2-3 missions that NASA GSFC should be at the forefront to lead in the mid-2020’s. As the group leader, she is responsible for creating a team that represents the various oceanographic disciplines and organizing meetings to define the requirements and deliverables. The group has begun meeting and is defining the requirements, and a white paper will be delivered to Code 600 - and ultimately at the Center level - by April 2016. Several new collaborations have developed and new members added as the missions are being defined. As part of this effort, Dr. Rousseaux has met individually with Lisa Callahan to update her on the progress and discuss future directions of the focus group.

Upcoming plans include the submission of a paper on the effects of the warming in the North Pacific Ocean on the ocean biogeochemistry in this region. Dr. Rousseaux will investigate the changes in water leaving radiances with variable phytoplankton composition and report the results in a peer-reviewed publication. She also will co-author a paper on “Simulating PACE Ocean Observing Capabilities” submitted by her sponsor. Dr. Rousseaux also will submit a proposal as PI to the MAP Call, and will be a Co-I on two other MAP proposals as well as a Co-I on an IDS Proposal. Dr. Rousseaux will attend and/or present at the MODIS/VIIRS Science Team Meeting in June 2016, the Ocean Optics conference in Victoria, Canada in October 2016, and the ASLO meeting and the IOCCG Working Group meeting in February 2017 in Hawaii. She will continue to serve in her various group lead capacities.

Dr. Yury Vikhliaev (sponsor: W. Putman) works toward developing the GEOS-5 Atmosphere-Ocean General Circulation Model (GEOS-5 AOGCM) and conducting research in climate variability and predictability on interannual-to-decadal time scales. The GEOS-5 AOGCM, a coupled climate model developed at the NASA GMAO, is designed to simulate climate variability on a wide range of time scales, from synoptic time scales to multi-century climate change. The main components of the GEOS-5 AOGCM are the atmospheric model, the catchment land surface model, both developed by the GMAO, MOM5, the ocean model developed
by the Geophysical Fluid Dynamics Laboratory and CICE4, the sea ice model developed at Los Alamos National Laboratory. The model is used at the GMAO for assimilation of climate data, climate predictions and for basic climate research. Over the course of the past year, 13 multi-decadal climate simulations with high-resolution atmosphere and ocean components were conducted in order to assess the model performance, address model biases and study climate variability in the GEOS-5 AOGCM. The atmosphere component of the AOGCM was updated to version Heracles-4.3. This version of AGCM has improved the formulation of skin interface between atmosphere and ocean with advanced sea ice thermodynamics. This version of the model is currently being tested.

A 35-year-long integration with 0.5-degree atmosphere and 0.25-degree ocean was completed and analyzed. This version of the AOGCM resolves mesoscale ocean eddies and will be used in future ocean data assimilation and seasonal forecast systems. Although this version of the model showed significant improvements in simulating many aspects of ocean circulation compared to a coarser resolution model, some biases still need to be addressed.

The goal of GMAO is to use a high-resolution mesoscale eddy-resolving ocean model in future ODAS and SI systems; however, this requires a modification of the data assimilation algorithm to enable it to constrain small-scale eddies to observations. While this research is in progress, the intermediate solution is to change the resolution of the atmosphere model from 1-degree to 0.5-degree, creating a higher resolution, and to keep the coarse resolution ocean model, which does not resolve mesoscale eddies. During the past year, Dr. Vikhliaev prepared the model configuration with 0.5-degree atmosphere and 0.5-degree ocean, and tested it in both a free coupled run and replay run with atmosphere constrained to MERRA-2 reanalysis.

In the coming months, the atmosphere component of GEOS-5 AOGCM will be updated to version Heracles 5.2. This version of AGCM includes two-moment cloud microphysics and is currently being tested in uncoupled mode. Dr. Vikhliaev will address model biases which were introduced with the new formulation of the skin layer interface which couples atmosphere, ocean and sea ice. Finally, he plans to assist ocean data assimilation and seasonal-to-interannual forecast groups with model updates and with incorporating the intermediate resolution (0.5-degree atmosphere, 0.5-degree ocean) and high resolution (0.5-degree atmosphere, 0.25-degree ocean) models into their systems.

Dr. Brad Weir (sponsor: S. Pawson) worked on developing trace gas assimilation. During this past year, he extended the trace gas assimilation routine to handle retrievals of the average carbon dioxide in a vertical column from the Orbiting Carbon Observatory 2 (OCO-2) satellite, and refined the horizontal-grid resolution from 2-degrees to 0.5-degree. He also began an analysis of the difference in the results of the GEOS-Chem ozone assimilation between 1) a run that assimilates Microwave Limb Sounder (MLS) v2 retrievals of ozone at different atmospheric levels and 2) a run that assimilates MLS v4.

Dr. Weir also analyzed aerosol type uncertainty on OCO-2 retrievals of carbon dioxide. He investigated the effect that uncertainty about the dominant aerosol types has on the OCO-2 retrievals of carbon dioxide. Research results were presented at the Science Jamboree (July 2015), a 610 Town Hall Meeting (July 2015), a GMAO All Hands Meeting (July 2015), and during an OCO-2 Uncertainty Quantification telecom (August 2015).

Dr. Weir developed near-real time surface fluxes for carbon dioxide based on the observed atmospheric growth rate; these fluxes were necessary for the assimilation of OCO-2 retrievals, which began September 2014 and are ongoing, at present. He analyzed the effect of different precipitation inputs on the net ecosystem exchange (NEE) fluxes from the Catchment-CN and CASA-GFED terrestrial biosphere models. Results of the assimilation of carbon dioxide were presented at the 11th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-11), at two OCO-2 Science Team Meetings, and at the 2015 AGU Fall Meeting.

In the coming year, goals include publication of the results of the assimilation of GOSAT/ACOS and OCO-2 retrievals of the average carbon dioxide in a vertical column. He plans to increase the resolution of the carbon dioxide assimilation to 25 kilometers. Also, Dr. Weir will submit a MAP proposal on the assimilation of level 1 radiances measured from OCO-2 into 3D fields of carbon dioxide mixing ratios. Further, he will include measurements of carbon monoxide, nitrogen oxides, and other trace gases in the GEOS-Chem ozone assimilation and analyze its effect on the analyzed ozone in the troposphere.

Dr. Radina Soebiyanto (sponsor: R. Kiang) utilizes remote sensing technology to monitor, predict and facilitate the control of infectious disease transmission as warranted by the environmental and meteorological conditions. She also worked...
toward developing empirical and theoretical models that can be used by public health organizations for disease surveillance and control. Work on this task was completed in fall 2015, and culminated in a publication that appeared in PLoS ONE in 2015. This paper, which was led by Dr. Soebiyanto, was the result of work in collaboration with the World Health Organization Regional Office for Europe and the US Centers for Disease Control in which she and her sponsor had assessed the relationships between meteorological conditions and influenza dynamics in Spain, Slovenia, Germany and Israel. In addition, Dr. Soebiyanto also had been working with the US CDC in the Central American region to assess how temperature, rainfall and humidity affect influenza in Costa Rica, Honduras and Nicaragua. Results from this work resulted in a 2015 publication in Geospatial Health. Dr. Soebiyanto will continue her research on influenza in collaboration with the US Naval Medical Research Unit - No. 6 (NAMRU-6) in Peru and her sponsor as an advisor to the project. She will assess the role of meteorological conditions on influenza transmission in several locations in Peru, and she also plans to provide training to Peruvian public health officials on using remote sensing data to model influenza transmission.

Dr. Sushel Unninayar (sponsor: S. Wharton) supports NASA HQ in a variety of NASA/SMD-ESE’s internal, interagency, and international programs and activities, such as: The Global Change Research Program (GCWP), the Group on Earth Observations (GEO) that coordinates the Global Observing System of Systems (GEOSS), the GEOSS Integrated Global Water Cycle Observations (IGWCO) Community of Practice (CoP), GEO Global Water Sustainability GEO-GloWS), UN Sustainable Development Goals (SDGs), UNEP-Live, Future Earth, Committee on Earth Observations Satellites (CEOS) among others.

Having served as lead author of several major sections of the GEOSS Water Strategy for the Next Decade — Observations to Decisions, Dr. Unninayar continued working on several themes such as the definition and further development of “Essential Water Variables (EWVs),” and “Water Cycle Extremes.” The global water cycle (see Fig. 1) is characterized by the transport of water and energy between the land, the oceans, and the atmosphere. Time scales of dynamic processes vary from seconds to days to years, decades, and longer. Spatial scales and gradients vary from the microscopic (e.g., cloud processes) to local (meters to 10 km), to regional (~ 500 km – 1000 km) to continental and global. An extensively updated (December 2015) second edition overview of the remote sensing of the global Earth system was published by Elsevier: Unninayar S., and L. M. Olsen (2015), Monitoring, Observations and Remote Sensing—Global Dimensions, Reference Module in Earth Systems and Environmental Sciences, Elsevier. Further, Dr. Unninayar was instrumental in defining “Essential Water Variables” for the IGWCO: precipitation, evapotranspiration (ET), soil moisture, surface waters, ground water, terrestrial snow/ice, and ancillary variables such as surface meteorology, and radiation budget.

As an expert member of IGWCO he participated at the 11th International IGWCO Annual Meeting, held in late June 2015 at the UMD-ESSIC Center, College Park, MD. He made two key presentations: 1) A report on the international WHO-HABITAT-UNEP project on the relevance of Earth Observations for the monitoring of “UN Sustainable Development Goals”, and 2) IGWCO progress on the “Water Cycle Extremes” activity. In parallel, he was invited to present (via Webex) an overview of the protocol developed by the IGWCO for defining “Essential Water Variables—EWVs” to the “Joint ConnectinGEO and GEO Workshop on Essential Variables for GEO,” in mid-June in Bari, Italy.

As part of an ongoing activity, he continued to coordinate with the Earth Observations (EO) Task Team established by the WHO-HABITAT-UNESCO project on “Monitoring Indicators for Sustainable Development Goals (SDGs) and their Targets,” as established by the United Nations. In particular, his expertise was called on to highlight the benefits of the use of remote sensing technology to develop, establish, and maintain a credible, cost-effective global monitoring mechanism for a range of water-related issues, such as the management of waste water, water quality, and water resources, as well as water security, water sustainability, and water use efficiency. He contributed to various UN concept papers on “Matrix Indicators” for the application of EO for Monitoring SDG-Water. As part of this activity, he was invited to and participated in 1) the International Conference on the UN Sustainable Development Goals (SDGs)—A Water Perspective, in August 2015 in Bonn, Germany, organized by the Global Water Systems Project (GSP) and Future Earth, where he presented “The use/benefits of Remote Sensing Earth Observations (EO) for the monitoring SDG indicators” and 2) the first Strategic Meeting on the Sustainable Water Future Program (SWFP) also in August in Bonn, Germany.

Dr. Unninayar continued assisting NASA-HQ in the development of US-GEO-Water (GEOGloWS—GEO Global Water Sustainability), as a part of the implementation of the GEO GEOSS Water Strategy for 2015-2025. This activity, initially led by NASA, will be opened to all other US agencies for a more coordinated effort. GEOGloWS was to be presented to the international GEO Plenary following its further development within the context of
US-GEO. He also proposed the development of a focus on Water Cycle Variability and Extremes—WCEs as a cross-cutting theme for the IGWCO and US-GEO-Water (GEOGLoWS). WCEs would also serve as a central pillar in the Water-Energy-Food nexus. Toward this end, he organized and chaired two sessions (one oral, one poster) at the 2015 AGU Fall Meeting on “Integrated Observations/Modeling of Water Cycle Extremes” and “Attribution of Changes in the Components of the Hydrological Cycle to Human Influences”.

In Spring 2016, he organized meetings between NASA-HQ and the Millennium Challenge Corporation (MCC) in Washington, DC to explore opportunities for collaboration between NASA-ESE’s international projects that use NASA satellite data for a variety of research applied science projects and those of MCC. A US Government program that manages an alternate model for international development assistance, MCC is focused on poverty reduction and economic development. Their projects range in size from $60 million (considered small) to $700 million.

He also initiated a collaboration between NASA and the United Nations Environment Programme (UNEP) based in Nairobi, Kenya, called UNEP-Live. He has established a dialogue with experts in UNEP to build a segment on the Global Water Cycle. Several NASA satellite-based global monitoring examples were submitted in April 2016. The objective of this collaboration is to provide concise “state-of-environment” reports from NASA-based observing and data assimilation modeling technology to the international community. UNEP-Live is a cutting edge, dynamic new platform launched in Geneva, Switzerland in January 2014 to collect, process and share the world’s best environmental science and research. Through the platform’s apps, multimedia content and digital publishing tools, users will have access to data from UNEP. Other activities included exploring the possibilities for collaboration between NASA and Future Earth. Future Earth is an international program with major participation by agencies such as the National Science Foundation.

For the UN “Water” Sustainable Development Goals (SDGs), upcoming work will include exploring and promoting the use of Remote Sensing Earth Observations (EO) for monitoring the UN Sustainable Development Goals. Work also will continue regarding GEOSS-IGWCO and GEO-GLoWS by moving forward with developing the strategic framework for the role of global water cycle observations, assimilation models, and early warning/prediction models in the “Water-Energy-Food” Nexus.

He will continue with further development of the GEOSS Water Strategy activity on addressing WCEs. To this end, he has proposed a session to AGU-2016 on droughts and floods and associated component water cycle variables and parameters such as: Precipitation; Evapotranspiration; Soil Moisture; Surface Waters (Run-Off, River Discharge, Lakes and Reservoirs); Snow/Ice; Ground Water Storages. Dr. Unninayar intends to continue the discussion to evolve products for NASA’s contribution to UNEP-Live, in particular, he plans to explore the processing of data and production of global monitoring information and graphics on a regular basis for delivery to UNEP-Live’s international distribution and access portal. Also, coordination will continue with NASA-HQ regarding the implementation of the GEOSS Water Strategy and the promotion of the use of remote sensing and data assimilation model data in research and applications that serve the end user community.

CODE 612: MESOSCALE ATMOSPHERIC PROCESSES LABORATORY

Dr. Mei Han (sponsor: S. Braun) applies satellite-based observations from NASA satellites (GPM, TRMM, and Aqua) and numerical models (WRF) to study precipitation associated with extratropical cyclones over ocean and land, and to evaluate the performances of cloud and precipitation models and retrieval algorithms in the middle latitudes. During this past year, in order to examine the characteristics of precipitation systems in a large scale and study the climatological feature of precipitation along the oceanic storm tracks, Dr. Han has been conducting an analysis of monthly and seasonally mean precipitation rate with all the available IMERG (nearly two years) and TMPA (since 1998) datasets. This is an effort to understand how precipitation intensity and radiative properties will vary in a climate perspective. This work will be examined in connection with the GPM and TRMM Precipitation Feature (PF) dataset, which will provide a detailed 3-dimensional reflectivity structure, multi-
channel emission/scattering signatures, hydrometeor properties, and precipitation intensity using a statistical method.

Working with the co-authors, she revised and submitted the manuscript “A bin and bulk microphysics based comparative analysis for simulating radar and radiometer measurements” to the Journal of Atmospheric Sciences in February 2016. Dr. Han worked with Dr. Matsui to incorporate the Thompson microphysics scheme into Version 3.5.1 of the Goddard-Satellite Date Simulator Unit (G-SDSU). It adopts the advanced T-matrix method in the radiative transfer calculation and provides consistent physical assumptions for hydrometeors in Thompson scheme in the radiative transfer model and the WRF mesoscale model. This calculation largely improves the accuracy of the simulated brightness temperature for Thompson scheme.

Dr. Han has carried out additional analyses for the microphysics properties of hydrometeors and new G-SDSU simulations. In this paper, two types of microphysics schemes (bin and bulk) are compared to address biases often found in simulated brightness temperature and radar reflectivity. The predicted hydrometeor particle size distributions (PSDs) in HUCM bin scheme and prescribed PSDs in Thompson bulk scheme were utilized in advanced radiative transfer calculations. Results show that the simulated scattering from both bin and bulk simulations in the current study largely reduced the bias of excessive scattering found in other bulk schemes. High biases of simulated radar reflectivity in the control bin run exist due to a peak in snow mass spectrum with large particle sizes. Also, two bin sensitivity runs were conducted to test the enhancement of the snow particles’ breakup (EnBr) and the influence of high ice nuclei (IN) concentration (EnBrIN). Mass spectrum vertical profiles, water path, and snow PSDs and effective radius were analyzed. Enhanced breakup shifted snow mass to smaller sizes and is effective for improving reflectivity simulations. A one order-of-magnitude increase in IN concentration caused a shift in pristine cloud ice crystals toward smaller sizes. More small snow particles were produced at the expense of cloud water, which leads to a large (18%) increase of total snow at the smallest side of the mass spectrum. However, it did not result in changes in the simulated scattering nor reflectivity. A small decrease of graupel mass with a reduction of scattering was found on smaller scales.

Launched in February 2014, the Global Precipitation Measurement (GPM) core observatory is designed to better quantify precipitation characteristics at middle and high latitudes. With the 13-channel GPM Microwave Imager (GMI) and the Dual-frequency Precipitation Radar (DPR), the GPM core satellite provides high-accuracy three-dimensional observations with high spatial resolution. As PI, Dr. Han has proposed a project named “Precipitation Characteristics along Northern Hemisphere Oceanic Storm Tracks”. Utilizing GPM observations, she proposed to advance the understanding of precipitation characteristics of the Northern Hemisphere oceanic storm tracks from cloud to regional scales. While this proposal was not funded, the related data analyses and research investigation have provided initial research results regarding methodologies and scientific merits to conduct a systematic investigation of the relationship between precipitation characteristics and evolving cyclones across different regions of the ocean basins.

Dr. Han also presented a poster at the PMM Science Team meeting in Baltimore in July 2015 titled “A preliminary survey of cold season precipitation from planetary scale to mesoscale”. Using data obtained during the first year of the GPM mission, a survey of the precipitation in the cold season was conducted. With half-hourly IMERG and MERRA data, precipitation systems were identified with their associated cyclones and fronts along the northern oceanic storm tracks in the Pacific and Atlantic and over the CONUS. Precipitation sampled by the GPM core satellite over the open oceans can be classified to different categories of bands/clusters in a way similar to their coastal and land counter parts documented in early literatures. Four types of precipitation features (cold-frontal band, comma-head band, post-frontal cellular convection, and spiral band) have been surveyed over the Pacific Ocean. It is found that the height of precipitating cloud top, the morphology of precipitation features and hydrometeors’ scattering and reflectivity signatures are closely associated with the dynamic and thermodynamic environment of the frontal cyclone. Also, the GPM observations and current algorithms only have limited capabilities on detecting snowfall for two snowstorm cases over land. This survey will contribute to a comprehensive study of precipitation characteristics and hydrometeor properties associated with different types of precipitation bands/clusters.

Dr. Hyokyung Kim (sponsor: R. Meneghini) has contributed to NASA's Global Precipitation Measurement mission and helped the radar algorithm developers to test and evaluate their algorithms using synthetic data. Over the past year, work was focused on improving the GPM radar retrieval algorithm. Dr. Kim analyzed the measurement of the normalized surface cross section (sigma₀) from the dual-frequency precipitation radar (DPR) aboard the GPM satellite. sigma₀ in the presence and absence of precipitation has long been used to estimate the precipitation-induced path attenuation (PIA) for air- or space-borne high-frequency radars. The GPM operational radar retrieval
algorithm requires seasonal look-up tables (LUT) that consist of the statistics rain-free sigma 0 (mean, variance and observation count) over a 0.5 deg x 0.5 deg latitude-longitude fixed grid using each 3-month set of input data for each incidence angle and at each frequency. This past year, she has supported the GPM radar algorithm team by means of providing and updating seasonal LUTs using the DPR data set (JJA 2014, SON 2014, DJF 2014-2015 and MAM 2015).

A problem with this LUT is an insufficient number of samples in many grid points, so Dr. Kim began exploring possible solutions. An alternative table was constructed by a stepwise procedure that begins with the statistics over a 0.25 deg x 0.25 deg grid. If the number of samples at cell is too few, the area is expanded, cell by cell, choosing that cell that minimizes the variance of the data. The question arises, however, as to whether the selected region corresponds to the smallest variance. To address this question, a second type of variable-averaging grid was constructed using all possible spatial configurations and computing the variance of the data within each region. Comparisons of the standard deviations for the fixed and variable-averaged grids are given as a function of incidence angle and surface type using a 3-month set of data. The advantage of variable spatial averaging is that the average standard deviation can be reduced relative to the fixed grid while satisfying the minimum sample requirement. She investigated the impact of alternative LUTs in lowering the variance of the PIA estimates. As expected, the reduced variance by the variable-averaging schemes enhances the fraction of reliable PIA estimates for ocean and land at both frequencies.

Dr. Kim gave presentations related to her research in July 2015 at the NASA Precipitation Measurement Meeting (PMM) and in September 2015 at the AMS 37th Conference on Radar Meteorology, and she co-authored two journal papers as second author. In the coming year, she will continue studies to see if the use of the variable-averaging scheme is expected to reduce the error in estimates of path attenuation that use the sigma 0.

**Dr. Xiaowen Li** (sponsor: W.-K. Tao) uses the Goddard Cloud Ensemble (GCE) model and satellite and field campaign observations to study cloud microphysics and dynamics, aerosol-cloud-precipitation interactions, as well as their implications in global climate. She also works toward developing, testing, and improving cloud-resolving model(s). This past year, for the GCE 2D version, Dr. Li has modified and debugged the option of using cyclic boundary condition with the spectral bin microphysical scheme. This is for the purpose of ultra-high resolution (100 m ~ 250 m) 2D simulations for the DYNAMO cases. For the GCE 3D version, Dr. Li has successfully ported, debugged, and run the gigabyte GCE 3D cloud-resolving model simulations on the NASA NCCS discover cluster. The 250m-resolution is the finest grid spacing in Dr. Li’s simulations of organized tropical convection. It is also the first time the parallel output implemented in the GCE model in the previous year was tested in production runs. The large dataset generated by this run will be used to test data management on Hadoop cluster at NASA NCCS. Going forward, she plans to improve 3D animation and statistical analyses for the super cloud library.

In other scientific research activities, Dr. Li conducted 2D simulations with the spectral bin microphysical scheme. Sensitivity runs were performed for a DYNAMO field campaign case by varying the vertical spacing of the model, and it was found that the vertical grid spacing is very important: a high vertical resolution (100m~200m) produced shallow clouds and congestus much better compared with the default ~500m vertical grids. These results were used in a NASA PMM proposal. For another study of aerosol-cloud-precipitation interactions, the GCE model with the spectral bin microphysical scheme was used to simulate how aerosol concentrations affect the convective core strengths and updraft velocity during the TWP-ICE field campaign. These results were presented at the AMS annual meeting in January. For data conversion and visualization on Hadoop clusters, Dr. Li has tested the animation and 3D plotting using IDL on these clusters. She also converted the original GCE output to CSV format for Hadoop reading, and found the performance of the Hadoop reading satisfactory. Finally, she continued to use the coupled COAWST model to study the air-sea interactions during the DYNAMO period. She conducted further sensitivity tests to identify Sea Surface Temperature (SST) as the dominant factor that produced differences in the coupled and uncoupled simulations. The TRMM-observed surface rainfall data, the RMSS SST data, as well as the RV Revelle ship-borne data also were used to corroborate the model simulations. Dr. Li plans to continue coupled COAWST model simulations and use the wave output in the CYGNSS end-to-end simulator.

**Dr. Liang Liao** (sponsor: R. Meneghini) conducts research on a variety of topics associated with airborne and spaceborne weather radar analysis generally and the TRMM Precipitation Radar (PR) and GPM Dual-Wavelength Precipitation Radar specifically. Part of Dr. Liao’s work involved an approach to check the accuracy of Ku- and Ka-band dual-frequency radar techniques for retrieval of rain rate and rain drop size distribution (DSD), which was studied by using measured DSD data. The
Numerical computations are time-consuming, the scattering generated by use of ice crystal growth model. Because the scattering parameters of the aggregates that are models. Numerical approaches were used for computations of single snowflakes were formed by combining the scattering parameters of various types of aggregates with simple snow models. Numerical approaches were used for computations of the scattering parameters of the aggregates that are generated by use of ice crystal growth model. Because the numerical computations are time-consuming, the scattering results are available only for small to moderate particle sizes. To cover the full range of snow particle sizes found in nature, simple particle models were used for obtaining the scattering parameters for large particle sizes. A full set of the scattering tables will be tested in the dual-wavelength algorithms. Next, one of the major goals of the GPM Ku- and Ka-band dual-wavelength precipitation radar (DPR) is to estimate snow water content and snowfall rate. Because of variability of shapes and structures of snowflakes, it has been a challenging task to accurately measure snow size distribution and mass spectra. The DPR utilizes measurements of Ku-band radar reflectivity and DFR (differential frequency ratio, defined as difference of the radar reflectivities between Ku- and Ka-bands) to estimate snow. The look-up tables, linking measured radar reflectivities to snow bulk parameters, have been formed, and their sensitivity to scattering models and particle size distribution models have been investigated. These look-up tables need to be further tested with the aid of measured particle size spectra.

Another study of the dual-frequency technique for hydrometeor phase identification is aimed at investigating the feasibility of a Ku- and Ka-band space/air-borne dual-wavelength radar algorithm to discriminate various phase states of precipitating hydrometeors. A phase-state classification algorithm was developed from the radar measurements of snow, mixed-phase and rain obtained from stratiform storms. The algorithm, presented in the form of a LUT that links the Ku-band radar reflectivities and dual-frequency ratio (DFR) directly to the phase states of hydrometeors, is examined by applying it to the measurements of the NASA JPL Airborne Second Generation Precipitation Radar (APR-2). In creating a statistically-based phase look-up table, the attenuation-corrected (or true) radar reflectivity factors are employed, which, as a result, leads to better accuracy in determining the hydrometeor phases if true radar reflectivities are used. In practice, however, true radar reflectivities are not always available before the phase states of the hydrometeors are determined. Therefore, it is practical to use the measured radar reflectivities in classifying the phase states. In the latter part of the paper, a procedure is proposed in an attempt to improve the accuracy of the phase identification when the measured radar reflectivities are used. The procedure is then tested using APR-2 data. An analysis of the classification results indicates that the regions of snow, mixed-phase and rain derived from the phase algorithm coincide reasonably well with those determined from the measured radar reflectivities and linear depolarization ratio (LDR) for the stratiform events.

Dr. Liao worked on developing and evaluating dual-wavelength radar snow retrieval. First, for development of the DPR Ku- and Ka-band dual-wavelength retrieval algorithms for estimates of snowfall rate and snow water content, the scattering tables of single snowflakes were formed by combining the scattering database that consists of radar and radiometer scattering parameters of various types of aggregates with simple snow models. Numerical approaches were used for computations of the scattering parameters of the aggregates that are generated by use of ice crystal growth model. Because the numerical computations are time-consuming, the scattering...
were turned on in the NU-WRF; and 3) dust-radiation interaction amplified the diurnal variation of cloud hydrometeors (see Figure 1). These results were orally presented at the 2015 WRF Users’ Workshop in June 2015, the 2015 AGU Fall Meeting in December 2015, and the AMS 32nd Conference on Hurricanes and Tropical Meteorology in April 2016.

On a second task, Dr. Jiaong (Roger) Shi (sponsor: S. Braun) works with NU-WRF simulations of the structure of Saharan Air Layer. The Hurricane and Severe Storm Sentinel (HS3) mission is designed to address the question through substantial measurements over three hurricane seasons using two Global Hawks, unmanned aircrafts that are equipped with a set of instruments geared toward environmental measurements and understandings of storm inner-core structure and processes. The NASA-unified WRF (NU-WRF) is an observational-driven regional modeling system that represents chemistry, aerosol, cloud, precipitation and land processes at satellite-resolved spatial scales (1-10 km). A series of NU-WRF simulations were conducted to simulate a Saharan Air Layer (SAL) event during the HS3 campaign period (Aug 24 and 25, 2013) to probe the role of SAL, characterized by an extremely hot, dry and often dust-laden layer of the atmosphere, in affecting African Easterly Waves. Results show that 1) NU-WRF simulations generally captured the major features of the Aug 24-25 SAL event during the HS3 campaign; 2) 3D structures of the dust layer, relative humidity (RH), wind and temperature compare well to the Global Hawks’ measurements; 3) temperature and RH impacts associated with the lowering of PBL cloud deck, warming of dust layer, and subsidence aloft; and 4) dust decreases the strength of meridional circulation and enhances AEJ near the southern edge of the SAL front. Results from this study were orally presented at the 2015 AGU Fall Meeting in December and at the AMS 32nd Conference on Hurricanes and Tropical Meteorology in April 2016. A peer-reviewed publication from this study is underway.

Dr. Shi also examined the results from the 30-member ensemble simulations of Hurricane Nadine (2012) with and without Saharan dust. In this study, Dr. Shi used the NU-WRF model with interactive aerosol-cloud-radiation physics to identify the role of Saharan dust using 30-member ensemble simulations of Nadine with and without aerosol. Perturbations were added to NCEP GFS analysis/forecast to create initial/boundary conditions for 30-member ensemble in order to study how Nadine would respond to different atmospheric environments. At present, all 30-member ensemble simulations without aerosol and 17-member (out of 30) simulations with aerosol have been completed. Results show that 1) the Saharan dust (temperature, RH, and dust) has a generally negative

![Figure 1. Time-series of the difference in area-mean cloud hydrometeors between (a) Exp. AM1, (b) Exp. AR, (c) Exp. AMR1 and Exp. CTRL (no dust aerosol). Orange contours are for cloud plus rain, purple contours ice, and shading snow plus graupel; solid and dashed lines indicate positive and negative respectively. (d) Time series of area-mean cloud hydrometeor profiles from Exp. CTRL (no dust aerosol). Image provided by J. J. Shi.](image)
impact on Nadine’s intensity; 2) dust impact ranges from slight strengthening to large weakening of Nadine; and 3) upper-level outflow enhancement associated with interaction of Nadine with an upper low may have positive impact on intensity. Results from this study were orally presented at the AMS 32nd Conference on Hurricanes and Tropical Meteorology in April, 2016. A peer-reviewed publication from this study also is under preparation.

**Dr. Tian** (sponsor: G. Heymsfield) conducts research to improve satellite rain retrieval algorithms. Global rain measurements are important for advancing the understanding of Earth’s water and energy cycle and improving forecasting of extreme events that cause natural hazards and disasters. Dr. Tian’s efforts have been directed toward improving microphysical assumptions, such as particle size, phase, and distributions, for GPM rain retrieval algorithms, through airborne radar and radiometer, aircraft in situ microphysics, and ground-based measurements. Over the past year, Dr. Tian took the lead on analyzing multi-ground-based polarimetric radars and airborne radar measurements to understand multi-frequency (X, Ku/ Ka, and W) observations in deep convective storm. The efforts have resulted in a peer-reviewed journal paper to be submitted. Another effort of Dr. Tian toward the same goal is to evaluate the particle models to be used for radar-radiometer combined algorithm. In collaboration with Dr. Olson, Dr. Grecu, and scientists from other institutions, Dr. Tian has analyzed airborne radar-radiometer, aircraft microphysics data from GPM field camping to derive the particle size parameters which were used to validate theoretical model. Two peer-review journal papers have been published.

Dr. Tian also has focused on developing wind retrieval algorithms in hurricanes from observations of HIWRAP (a downward conical-scanning Doppler radar flown on a NASA Global Hawk) during the NASA GRIP field campaign. This is of great interest because, for the first time, HIWRAP provided 3-dimensional wind observations in the inner core of a major hurricane, which could improve hurricane forecasting. This effort has resulted in the publication of two peer-reviewed journal papers. Going forward, she will continue to work on data analysis of GPM ground validation field campaigns (MCE, IPHEX, Olympac) for improving numerical models and GPM retrieval algorithms.

**Code 613: Climate and Radiation Laboratory**

**Dr. Nayeong Cho** (sponsor: L. Oreopoulos) works toward understanding cloud-aerosol relationships through links between MODIS aerosol loading changes and cloud regime variations. She also studies cloud structure and cloud interaction with their environment by using the concept of “cloud regimes” as a basis for performing comparison and compositing analysis on a suite of spatiotemporally matching observational datasets. During this past year, Dr. Cho evaluated cloud regimes from MODIS collection 6. Using 12 years of joint cloud optical thickness and cloud top pressure histogram, she established that 12 distinct MODIS cloud regimes tend to form in distinct dynamical and thermodynamical environments and have global diverse cloud characteristics. MODIS cloud products consist of cloud properties, especially including partly cloudy pixels.

Dr. Cho co-authored an article titled “Radiative effects of global MODIS cloud regimes” that was accepted for publication in J. Geophys. Res. Atmos. The paper shows that the cloud regimes are radiatively distinct in terms of shortwave, longwave, and their combined (total) cloud radiative effect. She and her co-authors show that cloud regimes can be clearly distinguished based on whether they radiatively cool or warm the atmosphere, and, thanks to radiative heating profiles, to discern the vertical distribution of this cooling and warming. She also co-authored a poster titled “Longwave AIRS Cloud Radiative Effect decomposed by MODIS Cloud Regime” that she presented at the AIRS Science Team Meeting in October, and co-authored an oral presentation titled “Insights from a regime decomposition of CERES and CloudSat-inferred Cloud Radiative Effects” given at the 2015 AGU Fall Meeting.

**Dr. Manisha Ganeshan** (sponsor: D. Wu) works on developing an algorithm to retrieve boundary layer properties over the data sparse region of the Arctic Ocean using GPS radio occultation measurements. Ground-truth (radiosonde observations) will be used to aid the development and validation of the algorithm. She also compares GPS-derived refractivity measurements to models, reanalyses and other satellite products with an aim to improve boundary layer and cloud parameterizations over the Arctic region. Dr. Ganeshan was invited to present her research titled “Investigation of Arctic boundary layer processes using ship-based and COSMIC RO observations” at the Climate and Radiation Laboratory Seminar Series at Goddard last May. She also presented a talk titled “An investigation of the Arctic inversion using COSMIC RO observations” at the Third Annual Young Scientist Forum, held at NASA GSFC, last July. And, in December, she presented a poster at the 2015 AGU Fall Meeting titled “Using GPS Radio occultation to study polar boundary layer properties”. To gain hands-on experience using the earth engine tool, Dr. Ganeshan participated in the Google Earth
Engine workshop held at NASA GSFC in September. Additionally, in February 2016, the monthly science highlight in the Climate and Radiation Science Research portal featured her work on the Arctic boundary layer. The societal impacts of her research, via monitoring of the polar boundary layer using GPS RO, were emphasized.

Three papers led by Dr. Ganeshan were published in this past year. “An investigation of the Arctic inversion using COSMIC RO observations” was published in Journal of Geophysical Research-Atmospheres and describes an advanced retrieval algorithm developed using COSMIC RO to study polar boundary layer inversion characteristics and its spatiotemporal variability. Also, “The open ocean sensible heat flux and its significance for Arctic boundary layer mixing during early fall” was published online as a discussion paper for Atmospheric Chemistry and Physics Discussions. Multi-year surface and upper-air meteorological measurements from the Japanese cruise ship R/V Mirai are used in this study to quantify the surface contribution to atmospheric boundary layer (BL) mixing in the region that has witnessed recent sea ice decline. Overall, it was found that the open ocean sensible heat flux (SSHF) can explain ~10% of the BL height variability, but there is strong interannual variability in the strength of the ocean-atmosphere coupling. Third, a paper titled “Nocturnal propagating thunderstorms may favor urban “hot-spots”: A model-based study over Minneapolis” was published in Urban Climate; this work is based on Dr. Gassó’s thesis work. Additionally, she is a Co-Investigator on two submitted proposals.

Work will continue into investigating boundary layer inversion characteristics using COSMIC RO and dropsonde observations over Antarctica. She will compile her findings in a manuscript draft. Dr. Ganeshan also plans to write and submit a proposal to the ROSES 2016 solicitation “Modeling, Analysis, and Prediction” as a principal investigator.

Dr. Santiago Gassó (sponsor: O. Torres) works toward obtaining a continuous record of aerosol optical depth over land using past and present satellite observations in the UV through a multi-satellite approach. This past year, collocated comparisons of aerosol optical depth (AOD) and single scattering albedo (SSA) retrievals by OMI (2-channel algorithm OMAERUV) and AERONET were carried out. One year of observations over the AERONET sites in Alta Floresta, Xiang-He and GSFC were collocated and compared with MODIS Cloud Fraction (CF) information from the MODIS products MYD06 (cloud product) and MYD04 (aerosol product), collection 6. The quality of the CF from both MODIS products (OMMYDCLD and OMMYDAGEO) was evaluated in detail and bugs were found in the CF product from OMMYDAGEO. Bugs were reported to production and will be incorporated in future runs. Of the two CF products available, OMMYDAGEO was found to provide a more realistic detection of clouds inside the OMI pixel. OMI pixels with high AOD with respect to AERONET had consistently higher CF, according to OMMYDAGEO, but not necessarily with OMMYDCLD. Thus, all additional comparisons used the product OMMYDAGEO (i.e., cloud fraction as reported by the MODIS aerosol product and collocated with OMI) for assessment of cloud contamination in the OMI pixel. The comparison of OMI and AERONET AOD revealed that indeed OMI AODs are cloud-contaminated in instances when OMI is higher than AERONET. The contamination is more apparent in pixels with low aerosol loadings. While largely suspected, this analysis proves with actual data that due to its large pixel size, OMI AOD retrievals are, in many instances, cloud contaminated. When the same analysis is carried out with OMI and AERONET SSAs, there is no clear impact of cloud contamination in OMI retrievals. Specifically, there was no clear impact in the AERONET-OMI comparison, when screening out those cloud-contaminated OMI pixels according to MODIS. Additional analyses will be conducted to evaluate the role of cloud contamination in the AOD and SSA retrieval by OMI. In particular, a more quantitative evaluation will be carried out to decide if there is a specific CF that can be used to set a threshold (or another type of rule) using OMI radiances that can be incorporated into the OMAERUV algorithm.

Computations of LERs (lambertian equivalent reflectances) in CAI Bands 2 (382nm) were carried out and compared with the same parameters derived by OMI (388nm channel) over a region that both instruments observed almost simultaneously (within 5-min. of each other). The computation of this parameter required the development of a new approach to derive LER in CAI since the approach used with OMI is valid in a hyperspectral instrument, whereas CAI is a broad-band instrument and OMI’s LER formulae cannot be applied directly. Thus, a new method was devised to compute LER in CAI (including a correction for surface topography), and CAI’s LERs were computed and compared against OMI. The comparison was reasonable in the sense that both instruments derived similar LERs at the same pixels.

Progress has been achieved by the development of an approach to select and determine what pair of OMI pixels and corresponding CAI pixels are suitable for comparison. Up until now, one of the main difficulties has been the search of cases where there is good OMI and CAI data coincident in time and space over homogenous surfaces; finding these cases is rather time-consuming. The developed approach will speed up the
data selection. In addition, this analysis demonstrated that the use of the ratio of standard deviation to the mean of the CAI radiances inside the respective OMI pixel provides a good measure of variability inside the OMI pixel and permits the selection of scenes according to cloudiness as seen by CAI. Similar comparisons were carried out for other case studies of collocated CAI and OMI pixels over diverse surfaces. A scatter plot of CAI vs. OMI LER was created, including the LER from all pixels (i.e., surface types). The data did not line up to the 1-to-1 line, indicating there is probably calibration drift in CAI; this can be adjusted by using an appropriate correction factor and forcing the CAI LERs to match the OMI LERs. A calibration constant was determined for the year 2014.

Dr. Gassó operated the standard aerosol retrieval used by the OMI group (called OMAERUV) and computed the standard operational parameters for input radiances generated by the outputs of the aerosol transport model MERRAer. The output aerosol index (AI) was compared with the same AI computation carried out by MERRAer. The objective is to establish if there are any differences in the way AI is computed by both approaches. The comparison suggested that there is a bias between OMAERUV and MERRAer AI, and this was traced to the way each approach used surface pressure. The comparison was first carried out for one orbit and subsequently with a full day of data (15 orbits). The main result is that it appears OMAERUV anomalous AIs frequently found (and of unknown origin) were mostly removed in the MERRAer computation, and, by applying appropriate correction to the surface pressure treatment in OMAERUV algorithm, most (but not all) of the anomalous AI disappeared. The main finding of this analysis is an improvement in the AI retrieval by OMAERUV.

These computations carried out with the OAMERUV code version 1.5.3 were reported. Since the OMI aerosol group added significant modifications to their retrieval scheme, a new research version was required, and during October – December 2015, a new version (OMAERUVx version 1.6.2.) was created. With this new version, a new comparison of Aerosol Indexes was needed. The same comparison was carried out and the main result of the previous analysis remains, i.e., the role of surface pressure in the AI retrieval is still very important in the new version 1.6.2. This implies that the surface pressure impacts are an important factor that needs to be accounted for in the future versions of the algorithm.

**Dr. Charles Gatebe** (sponsor: C. Ichoku) is focused on advancing the knowledge of clouds, aerosols, ecosystem structure and function, snow and ice, albedo, and feedbacks to climate. He and his colleagues conduct elaborate experiments and develop new methods to define important surface and atmosphere radiative transfer functions, and improve remote sensing retrievals of aerosols and clouds using laboratory, ground-based, airborne and satellite remote sensing. Instruments and technologies are developed for new measurements in support of future missions, including those defined in the U.S. National Research Council Decadal Survey. Another goal is to inspire future scientists through education and outreach. This past year, efforts were dedicated to organizing the SnowEx field campaign, which is designed to test new approaches for mapping snow water equivalent in forested areas. This campaign is led by NASA Goddard and is sponsored by NASA HQ/Terrestrial Hydrology Program, Jared Entin. For details on the campaign, visit [http://neptune.gsfc.nasa.gov/hsb/index.php?section=322](http://neptune.gsfc.nasa.gov/hsb/index.php?section=322).

Dr. Gatebe will be involved in planning and coordinating the campaign. He also will oversee repair and maintenance work on CAR (Cloud Absorption Radiometer) in preparation for the SnowEx campaign.

Dr. Gatebe presented in several conferences and meetings this past year, including the presentation of five abstracts at the 2015 AGU Fall Meeting in December, three abstracts at the 2016 Ocean Sciences Meeting in February, and three abstracts at the 2016 International Radiation Symposium in April (Auckland, New Zealand). He also attended the NASA Snow Meeting at the University of Washington Seattle in late March.

Dr. Gatebe is part of a funded proposal, “GEO-CAPE KORUS-OC” (Korean Ocean Color field campaign in coastal Korean waters). This campaign is planned for May to early June 2016. He and others will collaborate with Prof. Knut Stamnes (Stevens Institute of Technology) to address questions related to large solar zenith angles and Bidirectional Reflectance-Distribution Function (BRDF) effects, which are important for characterizing a geostationary coastal ocean-color sensor and risk reduction of the GEO-CAPE mission.

**Dr. Jie Gong** (sponsor: D. Wu) works on developing retrieval techniques and delivering retrieval products (such as cloud ice water path, cloud top height, ice particle size) of AMSUB/MHS onboard NOAA satellite series. She also compares correlative datasets to evaluate retrieval performances and uncertainties. Dr. Gong’s research has resulted in three papers, two as lead author and one as co-author. The first, published online in J. Geophys. Res. Atmos, is titled “Global survey of concentric gravity waves in AIRS images and ECMWF analysis” and introduces a
Dr. Daeho Jin (sponsor: L. Oreopoulos) is tasked with developing a set of advanced diagnostic frames for evaluating cloud simulation performance of GEOS-5 AGCM and other AGCMs. The advanced diagnostic frame is based on the concept of “cloud regimes,” and is now expanded to joint variability between cloud and precipitation. Previously, Dr. Jin had planned to build a diagnostic frame to evaluate various climate models in the Coupled Model Intercomparison Project Phase 5 (CMIP5). The idea was that the ISCCP simulator output of each model is evaluated against ISCCP observation using the “cloud regime” frame. Dr. Jin actually was able to evaluate CMIP5 models with two different diagnostic frames; one is based on 42 bins joint histogram of cloud top pressure (Pc; 7 levels) and optical thickness (tau; 6 levels), and the other is with three components (Pc, tau, and cloud fraction). The 3-component evaluation frame is a simplified version and is more forgiving to models; however, even this 3-component method is strict enough to reveal the weakness of model performance. Both evaluation results were presented during the Cloud Feedback Model Intercomparison Project (CFMIP) Meeting on Cloud Processes and Climate Feedbacks in June 2015. Results also were compiled into journal papers, which are both in press.

Dr. Jin initiated a new study of the cloud-precipitation relationship. With the benefit of high-resolution satellite data, Dr. Jin built a precipitation dataset that exactly matched the MODIS cloud data in terms of location and time. The grid-matched dataset of cloud and precipitation enables various analyses (e.g., from simple composite analysis to maximum (co)variance analysis and association analysis). Findings showed noticeably different relationships of cloud and precipitation on tropical land and ocean, and further investigation is necessary. Going forward, Dr. Jin will continue to analyze the cloud-precipitation relationship, first focusing on deep tropical warm-pool regions, and later expand the focus to all of the tropics.

Dr. Sergey Korkin (sponsor: A. Lyapustin) works toward developing a numerical algorithm for the retrieval of atmospheric and surface properties using the effect of polarization of light. Using his RT code IPOL, Dr. Korkin generated look-up tables (LUTs) for a variety of aerosol properties. These LUTs provide intensities computed with consideration of the effect of polarization of light. The LUTs are used for polarization correction of Dr. Alexei Lyapustin’s algorithm MAIAC. In order to generate the LUTs, Dr. Korkin enhanced his vector RT code, IPOL, with two features: 1) Scattering by mixture of spheres and spheroids were integrated in the RT code; 2) Dependence of certain microphysical parameters, such as concentrations of fine and coarse fractions, on total aerosol optical thickness was made available. These improvements allow for (almost) global polarization correction of the algorithm MAIAC as applied to MODIS Terr/Aqua and DSCOVR EPIC instruments. The effect of polarization correction, among other topics, was presented by Dr. Lyapustin during a DSCOVR science team meeting in February.

Additionally, Dr. Korkin presented a poster “New accuracy benchmarks for 1D vector radiative transfer models in aerosol remote sensing, with an intercomparison of eight codes” (led by Dr. Anthony Davis, JPL) at the SPIE Polarization: Measurement, Analysis, and Remote Sensing XII conference in April. A full-length paper with the same title has been accepted for publication in conference proceedings. Results of Dr. Korkin’s research also were reported in a poster titled “Discrete Ordinates vs Successive Orders: what method to choose?” presented by Dr. Lyapustin at the 15th Electromagnetic and Light Scattering Conference in Leipzig, Germany.

In the coming months, Dr. Korkin plans to further develop his vector RT code IPOL. In particular, the 4th component of the Stokes vector, the ellipticity V, should be removed from the code for acceleration. As known, V is not important for passive
atmospheric remote sensing and is currently not measured by any remote sensing system. Other work will involve developing and validating a reliable procedure to account for the sphericity of the Earth’s atmosphere.

**Dr. Sergey Korkin** also conducts work under a NASA-funded grant of which he is the PI (Program Manager: Dr. L. Tsaoussi) to develop a fast polarized (vector) radiative transfer (RT) code for Version 3 (V3) AERONET reprocessing. Over the past year, Dr. Korkin has developed a new polarized radiative transfer (RT) code: SORD (Successive ORDers of Scattering). The code has been thoroughly validated. Results of the validation were announced during a talk at the SPIE Conference in Baltimore, MD in April 2016. He also submitted a related lead author manuscript titled “A new code SORD for simulation of polarized light scattering in the Earth atmosphere”. The code has been submitted to NASA GSFC AERONET team for further validation and integration with their retrieval algorithm. Dr. Korkin collaborates with the AERONET team, which includes support of SORD and analyses (run time, accuracy) of results of forward modelling. Occasionally, Dr. Korkin provides updates regarding code development at weekly AERONET science team meetings.

Dr. Korkin has submitted one abstract to each of the following meetings: SPIE Remote Sensing of Clouds and Aerosols, SPIE High Performance Computing, and the 10th Anniversary Y. Kaufman Memorial Symposium. Additionally, he is planning to participate in the following conferences: the 2016 AGU Fall Meeting (Dec 2016) and the American Meteorological Society 2017 Annual Meeting (Jan 2017).

**Dr. Benjamin Marchant** (sponsor: S. Platnick) works on the development of new algorithms to continue improving the cloud optical products of passive instruments such as MODIS, VIIRS, eMAS, etc. Over this past year, he started to develop a machine-learning framework based on Gaussian processes for satellite remote sensing classification. His preliminary results were presented, “A probabilistic MODIS Cloud Thermodynamic Phase Classification based on Gaussian processes and CALIOP data”, during the CALIPSO/CloudSat science team meeting in March 2016. He also is working on a Bayesian inference framework for the inverse problem based on MCMC algorithms and recursive Bayes estimation. In parallel, he works on the validation of MODIS multilayer cloud classification using CALIOP products and the impact of multilayer clouds on MODIS cloud optical products.

Dr. Marchant’s previous work on MODIS Collection 6 Cloud Phase classification was published this year in the first-author paper titled “MODIS Collection 6 shortwave-derived cloud phase classification algorithm and comparisons with CALIOP” published in Atmos. Meas. Tech. Future work will focus on the impact of multi-layer clouds on the cloud optical products, especially the cloud phase. He will continue to investigate the benefits of using machine learning and image processing tools to improve the cloud optical products.

**Dr. Kerry Meyer** (sponsor: S. Platnick) aims to improve current MODIS cloud retrieval capabilities for thin cirrus optical property retrievals using the 1.38 micron channel, and to provide scientific and analytical support for the GSFC cloud retrieval efforts for MODIS (MOD06), VIIRS (MODAWG), PACE, SEVIRI (SEV06), and airborne eMAS (MAS06). This past year, Dr. Meyer provided scientific and analytical support for the NASA MODIS cloud optical and microphysical property product (MOD06). Efforts included writing and editorial support for the MOD06 Collection 6 (C6) User Guide and FAQs, as well as for a manuscript detailing the significant changes and updated for C6 (submitted for publication to IEEE Transactions on Geoscience and Remote Sensing). Other efforts involved ongoing product analysis as necessitated by instrument operating status and user inquiries.

One particular user-instigated analysis involved investigating the causes behind observed differences in cloud property retrievals between C6 and the previous Collection 5.1 (C5.1), specifically the retrievals of liquid phase cloud optical thickness (COT) and effective particle radius (CER). The C6 vs C5.1 COT and CER retrieval differences are found to be quite large, and are the result of numerous changes to the algorithm (e.g., forward radiative transfer assumptions, handling of above-cloud atmospheric effects, etc.) and upstream products (e.g., cloud top pressure). The investigation resulted in a thorough document detailing the differences that will be posted to the public MODIS Atmosphere website. He also provided support for the extension of the MOD06 products to VIIRS (MODAWG) and other satellite and airborne sensors via the CHIMAERA shared-core retrieval suite. VIIRS MODAWG efforts have focused on characterizing the radiometric differences between VIIRS and MODIS such that cloud product continuity between the two can be achieved. In collaboration with colleagues at the University of Wisconsin - Madison, as well as with colleagues in the Dark Target and Deep Blue aerosol retrieval teams, a set of MODIS-VIIRS radiometric match files have been created that contain MODIS and VIIRS pixels having common observation angles and times. An analysis of these files is expected to provide the cloud and aerosol retrieval groups with correction factors that will bring the two instruments into better radiometric consistency, a key foundation
for producing a continuous cloud and aerosol data record. Airborne efforts include collaboration with colleagues at JPL and the Desert Research Laboratory to implement the CHIMAERA suite on hyperspectral observations from AVIRIS.

Dr. Meyer completed a detailed analysis of the expected errors and sensitivities of the NASA EPIC cloud optical property retrievals. The Earth Polychromatic Imaging Camera (EPIC), onboard the Lagrange-point Deep Space Climate Observatory (DSCOVR) platform, observes the entire sunlit half of the Earth, measuring reflected solar radiation at 10 spectral channels, from the ultraviolet to the near-infrared. Observations from the polar-orbiting MODIS Aqua instrument were used as a proxy for EPIC observations to investigate the sensitivities of a single-channel cloud opacity retrieval and a cloud temperature-based thermodynamic phase retrieval to various retrieval assumptions, such as fixed cloud particle size and data spatial resolution. Results show that a single-channel COT retrieval is feasible for EPIC. For ice clouds, single-channel retrieval errors are minimal (<2%) due to the particle size insensitivity of the assumed ice crystal (i.e., severely roughened aggregate of hexagonal columns) scattering properties at visible wavelengths, while for liquid clouds the error is mostly limited to within 10%, although for thin clouds (COT<2) the error can be higher. The details and results of this investigation have been summarized in a paper recently accepted for publication in Atmospheric Measurement Techniques.

Also, Dr. Meyer provided support for ongoing field campaign remote sensing efforts involving the Enhanced MODIS Airborne Simulator (eMAS), as well as the Pushbroom Imager for Cloud and Aerosol Research and Development (PICARD) currently in development. Specific efforts have been focused on the upcoming ORACLES field campaign deployment to Walvis Bay, Namibia (August-September 2016).

Other efforts have involved the continuing development of a new thin cirrus cloud optical and microphysical property retrieval technique using spectral reflectance observations within the 1.88 micron water vapor absorption band. A manuscript detailing this algorithm and early results from the SEAC4RS field campaign has been accepted for publication in AMT.

Dr. Kerry Meyer also performs work under a three-year NASA-funded grant (Program Manager: D. Considine) to develop a technique to simultaneously retrieve marine boundary layer liquid phase cloud optical and microphysical properties, as well as the optical properties of an above-cloud absorbing aerosol layer, using multiple MODIS spectral reflectance measurements, evaluating the retrieval with collocated CALIOP aerosol retrievals, and investigating the direct radiative effects of above-cloud absorbing aerosols. This past year, the multispectral cloud and above-cloud aerosol retrieval algorithm, previously only run on Aqua MODIS, was extended to Terra MODIS. An analysis of the results does not imply the existence of a strong diurnal cycle of the absorbing aerosols over the southeast Atlantic Ocean. This is an important result with regards to coupling Aqua and Terra retrievals to better characterize the regional aerosol radiative effects.

An investigation was initiated to characterize the cloud diurnal cycle over the southeast Atlantic Ocean using observations from the EUMETSAT’s geostationary SEVIRI imager. The direct radiative effect (DRE) of above-cloud absorbing aerosols is controlled in part by the properties of the underlying clouds. Understanding the cloud properties in this region, and their diurnal cycle, is a key component of accurately estimating aerosol DRE, i.e., the warming or cooling effect of aerosols.

In response to a need for above-cloud aerosol retrieval products in support of the upcoming ORACLES field campaign, efforts are underway to implement the multispectral cloud-aerosol retrieval algorithm within the MODIS LANCE near-real time processing stream. The algorithm has been successfully implemented within the multi-sensor algorithm suite (CHIMAERA) used for the operational MODIS cloud products (MOD06), with satisfactory unit test results. Implementation within LANCE is expected to occur before the ORACLES deployment, with data available to the public.

Finally, efforts have begun for performing forward radiative transfer (RT) calculations to create pre-computed cloud/above-cloud aerosol retrieval look-up tables (LUTs). These forward RT calculations, at high spectral resolution, are intended to be flexible such that LUTs can be quickly derived to account for the different spectral channel locations of present and future remote sensing imager instruments, both satellite and airborne. Such efforts are important for implementing the multispectral retrievals on VIIRS and airborne eMAS (important for the ORACLES field campaign).

Dr. Meyer will continue to work on implementing the retrieval on VIIRS as well as airborne imagers, such as eMAS, etc. He also will continue the process of finalizing the LANCE near-real time retrievals, including obtaining permission for implementation. The investigation into the cloud diurnal cycle over the southeast...
Atlantic Ocean will continue, with a specific goal of providing a better estimate of the regional aerosol direct radiative effect. Also efforts will continue toward reconciling above-cloud and clear sky aerosol optical thickness retrievals; efforts will include collaboration with the Dark Target aerosol retrieval group.

As in previous years, much of Dr. Andrew Sayer’s efforts have been related to the ‘Deep Blue’ aerosol project, led by his NASA sponsor (Dr. N. C. Hsu), which uses satellite measurements to determine aerosol loading (from e.g. mineral dust, sea spray, wildfire smoke) globally. Dr. Sayer has continued validation efforts of the current versions of the Deep Blue data set by examining the long-term stability of the Deep Blue data set derived from MODIS Terra data, through comparison to both the ground-based AERONET network and the instrument’s sister onboard MODIS Aqua. This work resulted in a peer-reviewed paper in the Journal of Geophysical Research. He has also been involved in expanding and improving the Deep Blue products. The main focus has been the continued development and evaluation of over-land and over-water aerosol data sets from the S-NPP VIIRS instrument, which are expected to be released to the public soon. However, he also has researched ways of mitigating the MODIS ‘bow-tie distortion’ to improve future versions of MODIS aerosol data products, as well as the development of techniques to monitor absorbing aerosols above clouds from MODIS-like instruments. In addition to these efforts, he has worked toward assisting data users with their analyses of Deep Blue products, and making presentations about Deep Blue at national and international meetings. In the coming year, the main goal is the release of the VIIRS Deep Blue data set, as well as the publication of papers and oral/poster presentation related to it.

Dr. Sayer gave numerous invited presentations at national and international meetings, mostly related to his work on the Deep Blue aerosol project. Specifically, he delivered oral and poster presentations at the annual MODIS/VIIRS Science Team meeting, an oral presentation (remotely via WebEx) at the International Cooperative for Aerosol Prediction (ICAP) 2015 meeting (Barcelona, Spain), attended and presented a poster at the 2015 AEROCOM/AEROSAT joint meeting (Rome, Italy), and was an invited oral speaker at the 2015 AGU Fall Meeting. Recently, he also presented work on MODIS Terra calibration and aerosol retrievals as part of the NASA SED seminar series.

As part of the Seven South-East Asian Studies (7-SEAS) project, the Biomass-burning Aerosols & Stratocumulus Environment: Lifecycles and Interactions Experiment (BASELInE) was carried out in spring 2015 to improve our understanding of physicochemical processes, interactions, and feedbacks related to biomass burning aerosols and clouds in southeast Asia. Dr. Sayer has been involved in the analysis of ground-based and remotely-sensed data collected during this campaign, and various analyses are being published in a special issue of the journal Aerosol and Air Quality Research dedicated to this experiment. He is lead author of one study in press in this special issue, and a co-author on two others in press, as well as others under review.

Dr. Sayer has continued to collaborate widely on studies concerning the effects of atmospheric aerosols on the Earth system. He is a co-author on a study (led by Dr. J. Lee, NASA GSFC/UMD) about a method to determine aerosol single-scattering albedo and height from satellite observations published in the Journal of Geophysical Research. He is also a co-author on two studies examining particulate matter levels from a combination of satellite and ground-based observations: one focused on China from a combination of satellite and ground-based observations (led by Assoc. Prof. Y. Liu, Emory University), published in Environmental Health Perspectives, and a global perspective on this topic in Environmental Science & Technology (led by Dr. A. van Donkelaar, Dalhousie University). He was also a co-author on a study published in Atmospheric Environment (led by Dr. C. Li, NASA GSFC/UMD) about observations of gas flaring emissions at northern high latitudes, and one in press in the Journal of Atmospheric and Oceanic Technology (led by Dr. R. A. Kahn, NASA GSFC) on the influence of atmospheric correction errors on derived ocean surface properties.

Dr. Yingxi Shi (sponsor: R. Levy) has worked on understanding the coverage issue of MODIS Dark Target (DT) Aerosol retrievals over Beijing. The comparisons between MODIS DT aerosol optical depth (AOD) and the AERONET sun photometer aerosol data shows that from late November 2015 to early April 2016, MODIS DT reports very little AOD when compared with AERONET. To understand the cause of this lack of data coverage, all cases of missing aerosol retrievals were selected from winter 2009, 2012, and 2013; then, core cases were chosen and all potential data quality masks were tested to discover what led to the prevention of the retrievals for the DT algorithm. Tests showed that over Beijing, the inland-water mask is the main cause for the lack of DT retrievals over both low and high AOD loadings. Sensitivity tests were conducted to find a suitable threshold of inland-water test that would recover retrievals over this region while eliminating potential melting snow contaminations over high latitude northern continents. In addition to the inland-water NDVI-like test, a brightness temperature test at 2.1 micron was
added. The validation shows that the effect was an increase of the MODIS DT retrieval coverage over Beijing during winter. Over the snow-melting region, where a change of inland-water test is mostly affected, little change is found before and after the inland-water mask adjustment. However, some “hot spots” of AOD were found surrounding the tropical islands. Thus, a change of the QA flag was made to mask these coastal retrievals as low quality. This snow mask flag also introduces false classification of aerosol plumes as snow. Other adjustments to reduce this misclassification are still under investigation.

Dr. Shi also worked on extending the MODIS DT retrievals to bright surfaces. The MODIS DT algorithm is designed to retrieve only over dark surfaces, which leaves data gaps over arid and semi-arid areas. Dr. Shi collaborated with the VIIRS aerosol group to investigate a new method that can be implemented to MODIS DT method to increase the DT coverage to bright surfaces. This method is based on the MODIS DT algorithm.

Other work involved comparisons of the surface reflectance ratio over one AERONET desert site using three different methods: Radiative Transfer Model (RTM) calculated, MODIS DT Look Up Table (LUT) estimated and MODIS albedo products calculated. For the RTM calculated surface reflectance, the Second Simulation of a Satellite Signal in the Solar Spectrum vector (6SV) RTM is chosen to perform the atmospheric correction procedures. Due to the AERONET site (Solar Village) location near desert, where most of the aerosol observed is dust, a non-spherical dust model is needed to better represent this aerosol type. The spheroid dust model from Dubovik (2002) is implemented into the 6SV model. Observations from MODIS top of atmosphere (TOA) reflectance are collocated with the AERONET-measured AOD as well as its inversion products for low aerosol loading conditions only. The 6SV produced the estimated wavelength dependent surface reflectance.

For the method of reverse LUT estimated surface reflectance, the MODIS LUT uses measured TOA reflectance, surface reflectance, and prior knowledge of aerosol properties to estimate the aerosol loading. It also can be used in reverse to estimate the surface reflectance when given the column total AOD. Thus, as in the first step, dust properties were calculated using AERONET measured and inverted products. After the dust aerosol model is built, it is used to generate MODIS LUT tables for the wavelengths to be investigated. Reversed LUT calculation is made using the collocated low aerosol loading datasets to retrieve surface reflectance. At present, the use of MODIS albedo products calculated requires further examination. This research will continue in the coming year.

**Dr. Guoyong Wen** (sponsor: A. Marshak) conducts research related to the radiative transfer of solar radiation in the atmosphere. Two specific areas are the study of the 3D cloud radiative effects on aerosol retrieval in the vicinity of clouds for MODIS aerosol retrievals and research on Sun-Climate relations. Dr. Wen worked with scientists at NASA/GISS to analyze GISS GCMAM results for studying climate response to solar forcing. Results were presented during a Sun-Climate Symposium in Savannah, Georgia, in November. A paper summarizing the results is under review for a peer-viewed journal.

Additionally, Dr. Wen successfully improved a two-layer model to account for cloud-surface radiative interactions and explored the possibility of accounting for cloud-aerosol interactions enhancing clear sky reflectance near clouds. He and colleagues tested the two-layer model using the SHDOM-simulated radiation fields. From this research, one paper was accepted by a peer-reviewed journal and he gave related presentations at national and international conferences.

Dr. Wen also used VIIRS observations to calibrate visible and near-IR radiances for EPIC on DSCOVR. These results were presented in an EPIC Science Meeting.

**Dr. Yuekui Yang** (sponsor: A. Marshak) applies his expertise in radiative transfer to study cloud properties as observed under the DSCOVR sun-view geometry. He develops cloud indices, such as the cloud mask index, the cloud height index, etc., for DSCOVR data analysis, and also will develop an algorithm that is suitable for generating RGB images from data observed by the DSCOVR satellite along with techniques for data quality check for the mission. He accomplished this during the past year when he delivered Version 2 to the DSCOVR Science Operation Center (DSOC) to address issues with the images. The currently available EPIC RGB images at epic.gsfc.nasa.gov are not Rayleigh corrected. To reveal the details of the Earth-atmosphere system and to generate sharper images, Rayleigh correction is needed. Dr. Yang conducted extensive research on atmospheric Rayleigh correction and developed a software package in Fortran for this purpose. Also, ozone corrections were applied to the model and the quality of RGB images showed improvement.

These images demonstrate the effect of Rayleigh correction. The left panel in Figure 1 represents before Rayleigh correction, and the right panel, after correction.
DSCOVR-EPIC L1B data will be released soon. In the coming year, Dr. Yang will deliver the RGB Rayleigh correction model to the DSCOVR Science Operation Center (DSOC) for integration to the production line, and he will conduct intensive validation of the model with the DSOC-generated results. The final Rayleigh-corrected EPIC RGB images will be released to the public. Before releasing EPIC L1B data to the community, an extensive data quality check is needed. This past year, Dr. Yang developed a series of tools specifically for this purpose. These tools have the ability of 1) mapping the Normalized Difference Vegetation Index (NDVI) over the globe and for any given area; 2) converting EPIC L1B counts to spectral bidirectional reflectance factor (BDRF); 3) generating RGB images directly from EPIC level 0 or level 1 data; 4) calculating reflected solar radiation as a function of solar zenith angle; and 5) conducting operations, such as taking the ratio, with multi-channel data. Since the EPIC data format is evolving, the tools Dr. Yang developed in the past will need to be updated and upgraded. Next year, Dr. Yang will maintain the functionality of the data quality checking tools and continue working on applying them to checking the EPIC L1B data to be released to the community.

Dr. Yang also conducted studies on the daily variability of the reflected sunlight averaged over the sunlit side of the earth using DSCOVR-EPIC data. At the Earth’s L1 Lagrangian point, EPIC makes observations of the entire sunlit side of the Earth. Usually within a day, EPIC has 10-15 sets of observations. The variability of the reflected sunlight represents, in part, the variability of the Earth’s planetary albedo, which is of great interest to the science community. With the preliminary L1B data, Dr. Yang developed a software tool that calculates the mean and daily variation of the reflected sunlight for each EPIC band. Results show that the daily variation of each spectral channel is usually within 10%.

Additionally, Dr. Yang delivered the final set of top of atmosphere (TOA) band-integrated and band-averaged solar spectral irradiances for all the EPIC filters. The TOA band-averaged solar spectral irradiances are critical for converting DSCOVR-EPIC radiances to bidirectional reflectances, which provides the basis for deriving many of the EPIC geophysical products. After studying the effect of differences in solar irradiance datasets on the solar fluxes of each EPIC band, he found that the differences can reach 3% for the blue channel. During this research, Dr. Yang applied the solar irradiance dataset used by MODIS to the study, which generated a new set of EPIC solar fluxes; this new set of fluxes will be released to the EPIC Science Team for generating EPIC Level 2 products.

Dr. Yaping Zhou (sponsor: D. Wu) developed a prototype online extreme precipitation monitoring system from the TRMM TMPA near real-time precipitation product as part of the PMM project. The system utilizes estimated equivalent average recurrence interval (ARI) for up-to-date precipitation accumulations from the past 1, 2, 3, 5, 7, and 10 days to locate locally severe events. The mapping of precipitation accumulations into ARI is based on local statistics fitted into generalized extreme value (GEV) distribution functions. Initial evaluation shows that the system captures historic extreme precipitation events quite well. The system provides additional rarity information for ongoing precipitation events based on local climatology that could be used by the general public and decision-makers for various hazard management applications. Limitations of the TRMM ARI due to short record length and data accuracy are assessed through comparison with long-term high-resolution gauge-based rainfall datasets from the NOAA Climate Prediction Center and the Asian Precipitation–Highly-Resolved Observational Data Integration Toward Evaluation of Water Resources (APHRODITE) project. The work was published in Journal of Applied Meteorology and Climatology. Another co-authored paper using the GEV mapping for cases of severe landslides were published in Geomorphology. Dr. Zhou also investigated large-scale forcing and land-atmospheric interactions on precipitation with NU-WRF simulations during fast transitions of ENSO phases in spring to
early summer of 2010 and 2011. A methodology to account for moisture contributions to individual precipitation events, as well as total precipitation, is designed under the same moisture budget framework. The analysis shows that the relative contributions of local evaporation and large-scale moisture convergence depend on the dry/wet regions and are a function of temporal and spatial scales. The study finds that evaporation provides a major moisture source in the dry region and during light rain events, which leads to greater sensitivity to soil moisture in the dry region and during light rain events. The feedback of land surface processes to large-scale forcing is well simulated as indicated by changes in atmospheric circulation and moisture convergence. The results reveal an asymmetrical response of precipitation events to soil moisture, with sensitivity higher under dry rather than wet conditions. Drier soil moisture tends to suppress further existing below-normal precipitation conditions via a positive soil moisture-land surface flux feedback that could worsen drought conditions in the Southwest US. A manuscript on this work was accepted by Journal of Hydrometeorology.

In another study, Dr. Zhou aimed to identify and provide a better understanding of the relationships between the trends of mean and extreme precipitation in three observed precipitation data sets: the Climate Prediction Center Unified daily precipitation data set, the Global Precipitation Climatology Program (GPCP) pentad data set and Tropical Rainfall Measurement Mission (TRMM) Multi-Satellite Precipitation Analysis (TMPA) daily data set. The study employs three kinds of definitions of extreme precipitation: percentile, standard deviation and Generalized Extreme Value (GEV) distribution analysis for extreme events based on local statistics. Any relationship between trends in the mean and extreme precipitation is identified with a novel metric, i.e., Area Aggregated Matching Ratio (AAMR) computed on regional and global scales. AAMR is able to capture many important features of the relationships between the mean and extreme precipitation, such as changes with respect to extreme thresholds, geographical locations and increasing/decreasing regions of the trends. The study confirms an overall “wet-getting-wetter, dry-getting-drier” assessment of recent climate change. A manuscript on this work was submitted to the International Journal of Climatology.

In a second task (sponsor: R. Levy), Dr. Yaping Zhou’s efforts extend toward investigating the feasibility of composite GPS radio occultation observations to study detailed vertical structure of Atmospheric River (AR). She identified all AR cases in the northeast Pacific regions using SSMI water vapor from 2007-2012 even though GPS samples were later found insufficient for providing detailed lower atmospheric information. Also, she is currently working on dust identification and retrieval. In this work, she will investigate various spectral tests including those used by MODIS cloud mask algorithm to identify the dust flag. Once dust is identified, a better dust model can be used in aerosol retrieval algorithm.

Another aspect of this research involved her joining the Dark Target aerosol group to study the interaction of aerosol precipitation interaction. Dr. Zhou has extracted all precipitation events for the TRMM period. A precipitation event is defined as a continuous raining event. Each event is recorded with start and end date, duration (number of days), total rain amount, maximum intensity, etc. In addition, a no-rain event is defined as continuous no-rain days with start and end date. Seasonal and interannual variability has been computed for precipitation events for different regions over CONUS. An initial investigation of aerosol optical depth surrounding the precipitation events indicates the complex nature of day-to-day aerosol variability. Further work is needed to isolate the effects of sampling.

**CODE 614: ATMOSPHERIC CHEMISTRY AND DYNAMICS LABORATORY**

Among other responsibilities, Dr. Valentina Aquila (sponsor: P. Colarco) develops stratospheric aerosol and chemistry modules in the NASA GEOS CCM modeling system, and conducts and analyzes experiments made with the NASA GEOS CCM modeling system to investigate the various roles of stratospheric aerosols and chemistry in Earth’s climate system. This past year, Dr. Aquila was among the participants in the NASA comparative volcanology task group, a group of NASA civil servants and NASA contractors in the Earth Science and Planetary divisions. The goal of the group is to approach volcanology from different perspectives to perform interdisciplinary research. The group was awarded funding from the NASA Science Innovation Fund.

Dr. Aquila published one paper as first author, which was highlighted on the NASA GSFC Earth Science Division homepage in September 2015, and co-authored another one on changes in stratospheric temperatures. Additionally, she is coauthor of a recently submitted paper on the importance of meteorology on the dispersal of the aerosol from Mt. Pinatubo and of the technical report on the MERRA-2 Aerosol Assimilation.
She participated in four meetings, giving three oral and one poster presentations. Additionally, she gave two invited talks, one at NOAA in Boulder, CO and one at Loyola University in Baltimore, MD. Dr. Aquila also served as guest editor for Atmospheric Chemistry and Physics and Atmospheric Measurement Techniques joint special issue “Ten years of Ozone Monitoring Instrument (OMI) observations”.

Dr. Aquila plans to develop her research in two directions: first, she will focus on the recent period from 2000 to present, combining Aura, OMPS, and OSIRIS observations and model results to understand recent changes in stratospheric aerosol. Second, she will complete her ongoing study to help in planning a field mission in case of a major volcanic eruption.

**Dr. Alexander Cede** (sponsor: K. Pickering) worked on calibrating and analyzing the PANDORA and CLEO spectrometer systems to measure trace gases in the atmosphere (e.g., O₃, SO₂, HCHO, BrO, NO₂, H₂O) that have absorption spectra in the 300 to 525 nm spectral range. He also writes and deploys the necessary automated software needed for Pandora operation and data analysis, and the resulting measured trace gas amounts will be compared with AURA/OMI measurements to determine the validity of the OMI spacecraft retrievals. Various ground campaigns will be conducted at multiple sites in coordination with independently funded aircraft campaigns. It is expected that 12 or more Pandoras will be deployed at multiple sites during individual campaigns. During this past year, Dr. Cede and colleagues discovered the reason for the so-called unwanted spectral signal in the Pandora instruments: an etaloning effect of the entrance window and, to a lesser extent, the non-tilting of the reflective neutral density filters. A strategy was developed to change these optical components and have applied these changes have been applied to most of the Pandoras. Also, new laboratory calibration routines for Pandora were developed, which include the use of the blind pixels for an improved dark correction.

He and his colleagues also performed laboratory and field calibration for the Pandora participating in the KORUS-AQ campaign (spring-summer 2016). They will continue to provide support to this campaign.

**Dr. Melanie Follette-Cook** (sponsor: K. Pickering) supports analyses of DISCOVER-AQ data and participates in DISCOVER-AQ field deployments as part of the forecasting/flight planning team as well as in activities under NASA’s Air Quality Applied Science Team. Dr. Christopher Loughner (PI) has conducted “air quality avoided” sensitivity simulations using the CMAQ model to quantify the benefits of emissions reductions over the Eastern U.S. for air quality in this region. Dr. Follette-Cook is using the EPA software package BenMAP to quantify the benefits of emissions reductions with respect to lives and money saved. A manuscript of this work is in preparation.

Last year, Dr. Follette-Cook and PI Dr. Loughner conducted high resolution WRF/CMAQ simulations of the September 2013 DISCOVER-AQ deployment in Houston, TX. Dr. Follette-Cook used ground- and aircraft-based data to evaluate these simulations as well as a source apportionment WRF/CMAQ simulation designed to quantify the contribution of pollution from Houston, TX to a severe pollution episode observed during DISCOVER-AQ. This work was presented as an invited oral presentation on model evaluation at the Meteorology And Climate - Modeling for Air Quality (MAC-MAQ) conference in September 2015. This work also was the subject of an oral presentation at the Community Modeling and Analysis (CMAS) conference in October 2015. Drs. Loughner and Follette-Cook wrote and submitted a final report to the Texas Air Quality Research Program (http://aqrp.ceer.utexas.edu/projectinfoFY14_15%5C14-004%5C14-004%20Final%20Report.pdf). A manuscript of this work is in preparation.

Dr. Follette-Cook conducted a spatial and temporal structure analysis in support of planning activities for NASA’s GEO-CAPE and TEMPO satellites. Overall, analysis results indicate that the precision requirements developed for the GEO-CAPE and TEMPO science traceability matrices are well-equipped to answer the air-quality relevant science questions they are tasked to address. This work was published in Atmospheric Environment in July 2015. She also is comparing the spatial and temporal variability of trace gases during each deployment of DISCOVER-AQ campaign and how they relate to the future TEMPO satellite. This work was presented by Dr. Pickering at the GEO-CAPE science team meeting in September 2015 and was the focus of her poster presentation at the 2015 AGU Fall Meeting. Dr. Follette-Cook has completed the inter-campaign comparison and has compared the observed variability with that of several different model simulations. She is currently calculating spatial and temporal structure functions for three month-long high resolution model simulations corresponding to the California, Texas, and Colorado DISCOVER-AQ campaigns.

Additionally, Dr. Follette-Cook has been investigating the implementation of prognostic biomass burning emissions in GEOS5 in preparation for a ROSES MAP proposal. The Catchment LSM includes prognostic carbon and phenology elements from...
the NCAR/DOE Community Land Model 4.0 (CLM4) Dynamic Vegetation Model (DVM) as well as a fire parameterization based on Thonicke et al. (2001). She found that this fire model greatly underestimates both the fractional burned area and fire carbon loss with respect to observation-based datasets, such as GFED3 and GFED4.

Within GMAO, efforts are currently underway to upgrade this system with the CLM4.5 DVM. The fire parameterization within CLM4.5 calculates fire occurrence, fire spread, and fire effects (e.g., mortality, adjustment to carbon pools) for four classes of fire: agricultural, deforestation, peat, and non-peat. This parameterization yields a carbon flux for each plant functional type (PFT) within the model, of which there are 15. She and her colleagues will propose to use these PFT-dependent carbon fluxes to calculate trace gas and aerosol emissions due to biomass burning. A “quick chemistry” parameterization for important greenhouse gases and radiative forcers is also being proposed. They will propose to integrate and expand upon computationally-efficient modules that already exist in GEOS-5 to simulate climatically-important trace gases and aerosols (e.g., the CH4-CO-OH cycle, CO2, aerosols, and other GHGs (e.g., N2O, HFCs)) and to make them interactive. They will create and add to the “Quick Chemistry” module new parameterizations of 1) OH, 2) the production and loss terms of O(3), a GHG, and 3) H2O2, which is important for aerosol chemistry.

In the coming year, Dr. Follette-Cook will participate in the following activities for DISCOVER-AQ: complete the multiple-campaign variability analysis and submit a related manuscript; complete an epidemiological analysis of the benefits of emissions reductions and contribute to a manuscript by Dr. Loughner; and contribute to a manuscript describing simulations conducted for TEXAS AQRP (Air Quality Research Program) and DISCOVER-AQ by Dr. Loughner. For the Chemistry Climate Modeling Initiative, Dr. Follette-Cook will work on preparing a ROSES MAP proposal, “Coupled Predictive Fire Emissions and Interactive Aerosol and Greenhouse Gas Chemistry ("Quick Chemistry") in the GEOS5 Earth System Model”.

Under his first task, Dr. Pawan Gupta (sponsor: R. Levy) conducts research on aerosol properties and satellite retrieval of aerosol properties over urban areas, including characterizing uncertainties within current aerosol retrieval algorithms and proposing improved algorithms for urban aerosol retrieval. He presented at the 2nd Atmospheric Composition and Asian Summer Monsoon (ACAM) workshop, held in Bangkok, Thailand last June. ACAM, an emerging international project, is sponsored jointly by IGAC and WCRP-SPARC, with Laura Pan (NCAR) and James Crawford (NASA LaRC) as co-chairs. About 170 scientists from 22 countries attended the workshop. Dr. Gupta gave a talk titled “High Resolution MODIS Aerosols Observations over Indian Subcontinent: Long Term Trends and Air Quality”. He also presented research results at the MODIS-VIIRS Science Team meeting, the AQAST Meeting at the EPA, and the DISCOVER-AQ Meeting. Dr. Levy presented a talk on behalf of Dr. Gupta at the 2015 AGU Fall Meeting.

Dr. Gupta has been involved with three proposals this past year. He submitted a proposal under the KORUS-AQ field campaign call (PI: Dr. Levy) to participate in the US-Korean air quality field campaign to improve satellite aerosol retrieval over the Asian region. However, this proposal was not funded. As PI, he submitted a proposal to the Health and Air Quality Science Team that addressed the need and solution of air quality monitoring in global cities using NASA’s satellite observations along with global modeling capabilities. The proposal also has several end-user partners such as U.S. Department of State, World Resource Institute (WRI), Clean Air Asia (CAA), EPA and Delhi Pollution Control Board; this proposal status is pending. Finally, Dr. Gupta and Dr. Levy submitted a research proposal to the DEVELOP program, which provides internships to students for 10 weeks. The goal of this project would be to map airborne pollutants across the Gulf of Mexico (GOM) to complete an historical analysis of the region, correlating these pollutants to primary emission sources and seeing how they compare with in-situ data. Using NASA Earth-observing satellites, this project would create a methodology for the Bureau of Ocean Energy Management (BOEM) to monitor plumes in the GOM to address future environmental concerns. This proposal was funded and two students worked on this project during spring 2016.

Upcoming plans include continued research on urban aerosols, continued research on aerosol trends, and continued support of the MODIS Dark Target team in various research and operational tasks.

Dr. Pawan Gupta (sponsor: K. Pickering) supports the development of remote sensing trainings for the NASA Applied Sciences Program in the area of air quality applications. The project aims to increase utilization of NASA remote sensing data sets among applied professionals. Specifically, he will develop training materials on using data products relevant to air quality applications from the OMI, MISR and MODIS instruments.
In the past year, Dr. Gupta led and organized several Applied Remote Sensing Program (ARSET) training sessions for both domestic and international end-users. First, he represented the ARSET program at the Atmospheric Composition and the Asian Monsoon (ACAM) Training School on ‘Satellite and Model Data use for Aerosols and Air Quality’ ACAM Training School, where he presented tutorials and hands-on activities on the topic of ‘Application of satellite remote sensing for air quality monitoring’ held in June 2015 at the Asian Institute of Technology, Bangkok, Thailand. Several other international experts provided tutorials covering various topics of the training school. The two-day-long training school had about 30 participants from 13 countries in the Asian region. This training event is organized within the framework of the ACAM initiative, jointly sponsored by IGAC and SPARC. Specific goals of the event include building the capacity and training of early career scientists in Asia for effective utilization of satellite retrievals and model data relevant to studying aerosols and air quality in Asia, particularly in connection with the Asian monsoon.

Dr. Gupta along with ARSET team members conducted a two-and-a-half-day NASA ARSET Program training in Atlanta, GA entitled “NASA Air Quality Remote Sensing Training”. There were 30 participants, primarily from government agencies and universities across the Southern United States. The training was hosted by Georgia Environmental Protection Division (GEPD) and held at the Southeastern Air Pollution Control Agencies (SESARM) training facility. The purpose of the training was to 1) teach NASA aerosols and trace gases data products relevant to air quality monitoring and forecasting applications, and 2) provide guided hands-on instruction on how to access and analyze NASA data products, using several web based tools and visualization of NASA imagery with Python modules. On the final day, participants took what they learned in the first two days and prepared and presented case studies that included the impact of fires on local and regional air quality, long-range smoke transport, satellite view of recent industrial explosion in Tianjin, Chian, and analyzing an Icelandic volcano. In the results of a post-training survey, participants stated that the training improved their ability to access NASA data products (62%: it ‘improved a great deal’), and 95% of participants indicated that the training either met or exceeded their expectations.

In October 2015, the NASA ARSET Program hosted an advanced online training on satellite remote sensing of particulate air quality. The five-week training held weekly one-hour sessions during the month of October. Dr. Gupta and guest speakers Dr. Yang Liu (Emory University) and Dr. Randall Martin (Dalhousie University) provided tutorials to over 230 participants from around 50 countries. Attendees came from various organizations, including the California Air Resources Board, Virginia Department of Environmental Quality, D.C. Dept. of Energy & Environment, Argentina National Space Activities Commission, Environmental Management Bureau (Philippines), and the Indian Institute of Technology. The training covered NASA data, tools, and methods to convert satellite-retrieved aerosol properties into surface-level particulate matter mass concentrations for air quality monitoring. This is the first advanced-level webinar series offered by ARSET, and will conclude in the presentation of mini-projects by webinar participants.

On November 10, 2015, the NASA ARSET Program hosted the first meeting of the Air Quality Working Group (AQWG) at Goddard. The goal of the working group is to facilitate communication among NASA scientists, NASA data product and tool developers, and applied science professionals. The first meeting allowed NASA scientists and data providers to learn about ARSET’s air quality trainings and share information on existing and future NASA air quality products and tools for air quality applications, as well as establish ways ARSET and AQWG members can work together. The first meeting was attended by scientists throughout the Sciences and Exploration Directorate (Code 600); Patricia Castellanos (610), Mian Chin (614), Bryan Duncan (614), John Haynes (HQ-DK000), Shobhana Gupta (HQ-DK000), Sarah Hemmings (HQ-DK000), Charles Ichoku (613), Ralph Kahn (613), Lok Lamsal (614), Robert Levy (613), Can Li (614), Christopher Lynnes (586), Kenneth Pickering (614), Andrew Sayer (613), Jennifer Wei (610) and Judd Welton (612), along with ARSET team members Dr. Gupta (614), Ana Prados (614), and Elizabeth Hook (614). Dr. Gupta leads the AQWG initiative at Goddard.

Dr. Gupta attended and/or presented at several conferences and meetings during the past year, including the MODIS VIIRS Science Team Meeting, Silver Spring, MD in late May 2015; the Google Earth Engine Workshop, held at Goddard in September 2015; the ARSET Retreat at NASA JPL, held in November 2015 (note, this is an annual meeting where the entire ARSET team reviews the past year’s activities and plans for the next year and beyond); the NASA Air Quality Applied Sciences Team (AQAST) 10th Semiannual Meeting, EPA, Research Triangle Park, NC in January 2016; the Remote Sensing Training Best Practices Meeting, held at the US Forest Service Remote Sensing Applications Center (RSAC), Salt Lake City, UT in March 2016. The purpose of this meeting, which was jointly organized by NASA ARSET, RSAC and Conservation International, was to discuss...
training experiences among the three programs and identify key common best practices that can be shared with the wider capacity building and remote sensing communities. Dr. Gupta attended the meeting remotely.

Along with ARSET team members, Dr. Gupta submitted two proposals to NASA HQ for funding. In the first, Dr. Gupta would work on the development of ARSET’s five-year plan, which includes several new ideas that will be implemented in ARSET air quality training led by Dr. Gupta. The status of this proposal is pending. The second involves the ARSET 2015-2016 plan to NASA HQ, in which Dr. Gupta also would implement new ideas in ARSET air quality training that he would lead (note, this proposal has been selected for funding).

In the year ahead, Dr. Gupta will submit a proposal to NASA HQ for ARSET 2016-2017. He will attend/provide training at the BAQ 2016 conference in South Korea during September 2016; the AWMA’s Visibility Conference in Wyoming in September 2016; and the ISS Smoke Symposium in California in November 2016. He will conduct/participate in the first Health Webinar in June 2016 and a Level 1 Air Quality Webinar in July 2016. Dr. Gupta also will collaborate with ISRO on a capacity building program and with the U.S. Department of State on Air Quality Training.

Throughout this past year, Dr. Margaret Hurwitz (PI) continued to lead a NASA ACMAP-funded hydrofluorocarbon (HFC) research project (Program Manager: Dr. R. Eckman) with three co-investigators and collaborators, and held monthly project meetings. Under this project, she investigates the atmospheric impacts of HFCs using two chemistry-climate models: the computationally efficient NASA GSFC 2D model and a fully coupled ocean-atmosphere version of the Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM). In collaboration with Mr. Eric Fleming and Dr. Paul Newman, Dr. Hurwitz analyzed GSFC 2D model sensitivity simulations, which isolated the expected impact of HFCs on the atmosphere in 2050. Five key HFC species were simulated as a group and individually. These simulations show, for the first time in a global chemistry-climate model, that HFCs affect global atmospheric temperature, circulation and stratospheric ozone. These results were featured as the Code 614 ‘science highlight’ in September 2015. A manuscript led by Dr. Hurwitz based on these GSFC 2D model simulations was published in Geophysical Research Letters titled “Ozone Depletion by Hydrofluorocarbons”.

She and Dr. Newman also provided quotes and technical advice in the preparation of a NASA press release and video summarizing the above manuscript (see https://www.nasa.gov/press-release/goddard/nasa-study-shows-that-common-coolants-contribute-to-ozone-depletion).

Based on this research, she attended, contributed to and presented at several meetings and workshops. In November 2015, Dr. Hurwitz attended the Montreal Protocol Meeting of the Parties in Dubai, UAE (see photo). She prepared a fact sheet in advance of the meeting, and gave a presentation for policymakers at an HFC-specific side event. In December 2015, she gave a poster presentation at the 2015 AGU Fall Meeting in California. Dr. Hurwitz networked with colleagues at US EPA and the State Department regarding progress on understanding the ozone and climate impacts of HFCs. Also, she and Mr. Fleming planned additional GSFC 2D simulations 1) using extended HFC scenarios through 2100 and 2) testing limited future HFC emissions scenarios, and discussed preliminary results. She has submitted an abstract for the Quadrennial Ozone Symposium, to be held in Edinburgh in September 2016. Authored by Dr. Hurwitz and co-authors F. Li, E. L. Fleming, P. A. Newman, and Q. Liang, the abstract is titled “Ozone and Climate Impacts of Hydrofluorocarbons”.

Dr. Hurwitz completed five ocean-atmosphere GEOSCCM sensitivity simulations: one perturbing atmospheric CO2 and the others perturbing CFC-11, as compared with a 1950 control simulation (run by Dr. Feng Li). Dr. Hurwitz used the simulations to analyze the near-surface and atmospheric responses to CO2 and CFC-11. The climate response to doubled CO2 was compared with that in the atmosphere-only GEOSCCM. Two simulations tested the linearity of the climate and ozone responses to small CFC-11 perturbations. Two further simulations were used to compare the climate responses to equal radiative forcing...
perturbations by CO2 and CFC-11. Dr. Hurwitz gave work-in-progression presentations at the GEOSCCM group meetings in both October 2015 and March 2016. She also gave a presentation at the 11th International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO) in October 2015 in Santiago, Chile. She has drafted a manuscript based on the GEOSCCM sensitivity simulations titled “Comparison of the Climate Response to CO2 and CFC-11 in the Ocean-Atmosphere GEOSCCM”; her co-authors are F. Li, P. A. Newman, E. L. Fleming, and Y. V. Vikhlaev. She also has submitted a first author abstract to the SPARC DynVar workshop, to be held in Helsinki in June 2016 titled “Do all greenhouse gases have the same effects on climate and atmospheric variability?”; co-authors are F. Li, P. A. Newman, E. L. Fleming, and L. D. Oman.

GEOSCCM development continued toward the full implementation of HFC species into the model’s radiation and chemistry schemes. With Dr. Qing Liang, Dr. Hurwitz worked to add five HFC species into the stratospheric chemistry module and test these changes in the GEOSCCM. She coordinated with Dr. Dongmin Lee (who implemented a version of the RRTMG IR radiation scheme that includes six fluorinated species) and Dr. Feng Li (who tested the GEOSCCM with this new version of RRTMG). Dr. Hurwitz created a surface source gas file with observed and projected HFC mixing ratios, for use in future GEOSCCM simulations with interactive HFCs.

As co-author, Dr. Hurwitz contributed to the revision of two manuscripts about the atmospheric response to sea surface temperatures in the El Niño/Southern Oscillation (ENSO) region: one titled “Northern Hemisphere stratospheric pathway of different ENSO flavors in CMIP5 models”, which has been resubmitted to the Journal of Climate, and another titled “Effect of recent sea surface temperature trends on the Arctic stratospheric vortex”, published in Journal of Geophysical Research. In addition, she contributed to a Code 614 memo on the potential impacts of the 2015-2016 El Niño event on atmospheric composition.

Dr. Hurwitz contributed to an effort to quantify air pollution trends in 195 world cities, using a NASA remote sensing data product (specifically, OMI NO2), and identify the local and regional physical, social, industrial and political changes that caused changes in urban air pollution. She provided policy and geopolitical guidance, especially with respect to air pollution trends in the Middle East region, applying her knowledge of international affairs. Her work contributed to a scientific research paper, a NASA press release and to science ‘highlights’ that informed NASA senior management. This paper titled “A space-based, high-resolution view of notable changes in urban NOx pollution around the world (2005-2014)” was published in Journal of Geophysical Research and was authored by B. Duncan, L. Lamsal, A. Thompson, Y. Yoshida, Z. Lu, D. G. Streets, M. M. Hurwitz, and K. E. Pickering.

In the next year, Dr. Hurwitz will lead the team investigating the NASA ACMAP-funded project studying the climate and stratospheric ozone impacts of HFCs. She and co-investigators will run simulations testing various future climate scenarios with the coupled ocean-atmosphere GEOSCCM. Dr. Hurwitz and collaborators will disseminate the results in the form of peer-reviewed manuscripts and will inform the climate and ozone policy communities as needed. Interim results will be presented at the Quadrennial Ozone Symposium in September 2016. She also plans to submit a manuscript based on the GEOSCCM CO2 and CFC-11 sensitivity simulations; a related presentation will be given at the SPARC DynVar workshop in June 2016. Dr. Hurwitz will lead and/or contribute to proposals to the NASA MAP and ACMAP programs.

Dr. Hiren Jethva (sponsor: O. Torres) works on a variety of research under this task. He studies Aerosols above Cloud, working on developing a global operational algorithm for retrieving optical depth of above-cloud aerosols using OMI’s near-UV observations. This task required integration of all components of the algorithm in order to successfully deliver a novel global product of aerosols above cloud. For the OMI Standard OMAERUV Aerosol Product, he works on several activities related to the maintenance, upkeep, improvement, and validation of the standard OMI/OMAERUV two-channel aerosol algorithm and associated product. Under the MEaSUREs task, Dr. Jethva works on generating a set of aerosol look-up-tables that are required for the retrieval from UV sensors, i.e., Nimbus7/TOMS, EP/TOMS, and Aura/OMI. He also produces monthly maps of the parameters retrieved from the first version of Nimbus7/TOMS processing. Finally, he works on an EPIC aerosol project, which aims at delivering snapshots of UV Aerosol Index (UV-AI) and aerosol retrieval in clear as well as cloudy skies from the EPIC sensor onboard the DSCOVR satellite situated at L1 Lagrange point in space. He conducts radiative transfer calculations and prepares look-up-tables of Rayleigh and cloud atmosphere for the calculation of UV-AI from EPIC observations.

For the OMI Above-cloud Aerosol Project, over the past year Dr. Jethva was charged with delivering the first version of OMI global product of aerosols above cloud. He applied several major
modifications and improvements to the basic code developed by Changwoo Ahn (SSAI), such as inclusion of ‘smoke’ and ‘dust’ aerosol types; use of regional daily values of single-scattering albedo in the algorithm; use of AIRS CO Collection 006 data for the robust aerosol type identification; use of OMI-derived near-UV surface albedo climatology; implementation of wavelength conversion scheme to extend retrieval in the near-UV and visible wavelengths; inclusion of ‘cloud-only’ and ‘apparent cloud optical depth’ retrievals, and improvement in the identification of aerosols above cloud scenes, among others. The upgraded algorithm, formally named OMACA, was applied to OMI observations to produce a ten-year (2005-2014) global record of above-cloud aerosol optical depth (ACAOD) and aerosol-corrected cloud optical depth (COD). He carried out a comprehensive analysis of the derived product which includes case studies, frequency of occurrence of absorbing aerosols above cloud, monthly/seasonal maps of the retrieved product, time-series, and trend analysis. He presented these results to the OMI group meeting as well as at the SPIE Asia-Pacific Remote Sensing Symposium held in New Delhi, India held from April 4-7, 2016. To the best of his knowledge, OMACA is the first-of-its-kind aerosol product aimed at helping the community to better understand the cloud radiative forcing in the presence of absorbing aerosols on a daily
global scale. The product will be soon available freely in the public domain.

Under the OMI Cloud-free Aerosol Product Project, Dr. Jethva performed an in-depth analysis of several research versions of OMAERUV in order to understand and improve the aerosol retrieval associated with different algorithmic changes. An important part of the upgrade of OMAERUV algorithm was to introduce a new look-up-table for ‘dust’ aerosols that account for the non-sphericity of the particles. Using a software package provided by Dr. Oleg Dubovik (Univ. Lille, France), Dr. Jethva carried out calculations of phase function given the optical and microphysical properties assumed in the standard OMAERUV dust aerosol models with assumptions about non-sphericity of dust particles as adopted in the ground-based AERONET inversion algorithm. After thorough testing of the package and its successful implementation in the radiative transfer code, he created the new set of look-up-tables for the OMAERUV operational dust models. The full OMI record was re-processed with the new LUT and with some other algorithm-related important changes.

Dr. Jethva performed additional analyses, including creating monthly and seasonal global maps of aerosol parameters; conducting time-series analysis, and evaluating the aerosol single-scattering albedo against ground-based AERONET inversion database. He conducted a comparative analysis of the UV Aerosol Index derived using three independent approaches, namely, LER, MLER, and Mie, for different regions of the world; the comparison was made for clear- as well as cloudy-skies measurements. He also performed a comparative analysis of the different research versions of the OMAERUV aerosol product was carried out in order to understand the impact of algorithmic changes on the aerosol retrievals; this analysis included comparing aerosol products on monthly and seasonal scales.

Dr. Jethva carried out an OMI-AERONET ‘closure’ retrieval experiment using a synergy of OMI and AERONET observation to infer the spectral dependence aerosol absorption in the near-UV and visible part of the solar spectrum. The idea here was to co-locate the ground-based AERONET sunphotometers with OMI observations and ingest AERONET AOT into the two-channel OMAERUV algorithm for retrieving imaginary refractive index and
its spectral dependence between 354 and 388 nm. This study will help characterize the spectral properties of aerosols over different regions, which ultimately can help in developing the regional aerosol models for the OMI aerosol algorithm.

Dr. Jethva is also involved in two other projects: MEaSUREs and EPIC. MEaSUREs aims to deliver a long-term consistent record of aerosols from 1978 to present using UV sensors, i.e., Nimbus-7/TOMS, EP-TOMS, and Aura/OMI. Dr. Jethva successfully carried out two tasks under this project: 1) he carried out radiative transfer calculations and generated aerosol look-up-tables that are required for the operational retrieval, and 2) he performed an analysis of the first processed version of the N7AERUV algorithm applied to 14-year long Nimbus-7/TOMS record.

The EPIC aerosol project aims to deliver snapshots of UV Aerosol Index (UV-AI) and aerosol retrieval in clear as well as cloudy skies from EPIC sensor onboard DSCOVR satellite situated at L1 Lagrange point in space. He carried out the radiative transfer calculations for the Rayleigh and cloud atmosphere in order to generate the look-up-tables (LUTs). Subsequently, the LUTs were used in the calculation of UV Aerosol Index (Mie) using near-UV observations made by the EPIC instrument.

During the past year, Dr. Jethva was asked to perform the following special tasks involving OMI. During the months of October and November 2015, several fires broke out over the Borneo and Sumatra regions of Indonesia, which resulted in the emission of huge amounts of carbonaceous particles and trace gases over the region. The operational aerosol algorithms applied to NASA’s A-train satellite data, including OMI, MODIS, MISR, and CALIOP, largely failed to capture aerosol loading for these intense fires due to an extreme aerosol reflectance signal, which often is misinterpreted as clouds. Dr. Jethva developed a special aerosol algorithm that uses reflectance measurements from OMI and employs a distinct aerosol look-up-table in order to retrieve aerosol optical depth (AOD) and single-scattering albedo for these events. The retrievals from this special algorithm revealed extremely large and unprecedented values of AOD (~10) at UV and visible wavelengths with SSA in the range 0.93-0.96. A manuscript is being drafted to highlight the new results and capabilities of the OMI observations to capture the extreme aerosol loading. An image showing the retrieval of aerosol optical depth for the selected day of Oct 21, 2015 is presented here.

Dr. Jethva also worked with Dr. Nick Krotkov (Code 614) to develop a stand-alone algorithm for the retrieval of volcanic ash loading above cloud using OMI’s near-UV observations. He applied his indigenous retrieval algorithm to the case of the Iceland volcano Eyjafjallajökull which erupted in April/May 2010. Subsequently, the retrieved optical depth of ash above cloud was converted to ash mass loading for comparison against the same quantity estimated from the infrared technique developed by other researchers. The results looked promising and provided enough motivation to expand the scope of this collaborative work.

This past year, Dr. Jethva was involved in several talks and publications related to his research. He presented a talk titled “A Ten-year Global Record of Aerosol Optical Depth above Cloud from OMI’s near-UV Observations: to the OMI Science Team Meeting held at KNMI, De Bilt in the Netherlands. He also gave an oral presentation titled “Validating Above-cloud Aerosol Optical Depth Retrieved from MODIS-based ‘Color Ratio’ Algorithm Using NASA Ames AATS and 4STAR Direct Measurements” at the Young Scientist Forum in July 2015. Dr. Jethva presented the latest results to the 10-year global record of absorbing aerosols above cloud derived from OMI observations during the OMI group meeting as well as at the SPIE Asia-Pacific Remote Sensing Symposium held in New Delhi, India held in April 2016. He has a paper titled “Validating MODIS Above-cloud Aerosol Optical Depth Retrieved from ‘Color Ratio’ Algorithm using NASA’s Airborne AATS and 4STAR Direct Measurements” that is currently under review with the Journal of IEEE Transaction on Geoscience & Remote Sensing. Another paper has been submitted to SPIE Proceedings titled “A ten-year global record of absorbing aerosols above clouds from OMI’s near-UV observations”. And, in response to the NASA ROSES-2015 call, Dr. Jethva (as PI) along with Drs. Duli Chand (PNNL, Co-PI) and Omar Torres (Co-I) have submitted a proposal entitled “An Algorithm for Retrieving Optical Depth, Single-scattering Albedo, and Radiative Effects of Aerosols above Clouds using CALIOP, MODIS, and OMI Synergy”.

In the year ahead, it is expected that the EPIC team will release more data to the algorithm developers in the near-future to test their algorithms. Dr. Jethva is planning to perform the data analysis of the first version of the EPIC aerosol retrieval. For the MEaSUREs project, he will continue analyzing the Nimbus-7/TOMS dataset processed with the N7AERUS aerosol algorithm. For the OMI Above-cloud Aerosols Project, Dr. Jethva is planning to prepare a manuscript highlighting the global record of above-cloud aerosols derived from OMI/OMACA and submit it to a peer-reviewed journal. Also, he is expecting to perform the radiative forcing analysis using OMI dataset in conjunction with other A-train sensors. With ORACLES and CLARIFY-2016 kicking off this July, he and colleagues are expecting to obtain high-quality airborne measurements of aerosols above cloud...
over the southeastern Atlantic Ocean. Dr. Jethva will use these measurements to validate the space-based retrieval of ACAOD retrieved from OMACA algorithm.

Mr. Matthew Kowalewski (sponsor: S. Janz) provides scientific and engineering support to the Radiometric Calibration and Development Laboratory (RCDL) at GSFC. Programs supported include GeoCAPE, NPP and JPSS OMPS, Pandora, and multiple Earth Venture Suborbital campaigns. The RCDL develops and maintains prototype instrumentation and components for use in solar backscatter research. Mr. Kowalewski has ensured that the technical activities of the lab are performed and meet the goals and direction of the lab’s Principal Investigator. In addition, he conducts safety reviews of the labs and completes quarterly safety assessments to the Division. This past year, Mr. Kowalewski participated in the TEMPO flight diffuser calibrations Technical Interchange Meeting (TIM) at GSFC. During this meeting, facility readiness, test requirements, and logistics were agreed upon by the participants.

Mr. Kowalewski attended the open community GeoCAPE workshop at the EPA facility in Research Triangle Park, NC. While at the meeting he participated in the Geo-TASO working group, reporting on instrument operations during the summer ECOA mission, coordinating data distribution efforts, reporting on instrument modification schedules, and planning for upcoming KORUS-AQ flights in 2016. Integration and operations of the GeoCAPE Airborne Simulator (GCAS) and the Geostationary Trace Gases and Aerosol Sensor Optimization (GeoTASO), capable of measuring scene-reflected radiances from the ultraviolet to near infrared, were successfully completed this summer in conjunction with the East Coast Ocean Acidification (ECOA) experiment. The NASA Langley B200 aircraft conducted overflight observations of the ECOA cruise area of operations with the two instruments in July 2015. Two four-hour flights were performed off the coast of Norfolk, VA and in the Hampton Roads channel. The goals of the mission were to evaluate GeoTASO instrument integration and performance onboard the B200, perform science retrieval intercomparisons from a co-manifested platform, and provide upward-welling spectral radiance data for the ocean color cruise in preparation for the KORUS-AQ EV-S mission in 2016. Both GCAS and GeoTASO instruments operated nominally during all flight segments.

Mr. Kowalewski mentored a Morgan State University student in designing and fabricating a GCAS flight cooling system and conducting vacuum chamber measurements of optical ground support equipment related to JPSS OMPS. The GCAS flight cooling system successfully helped regulate instrument temperatures at lower (warmer) altitudes, and the vacuum chamber study focused on recreating reflectivity behavior of a magnesium fluoride (MgF2) mirror using Goddard test sources. Results of the vacuum tests were found to be similar to the JPSS OMPS measurements validating the theoretical explanation of anomalous flight test results. Furthermore, Mr. Kowalewski led the GCAS instrument team in activities supporting multiple Earth Venture Suborbital (EV-S) field missions, which included the North Atlantic Aerosols and Marine Ecosystems Study (NAAMES), Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ), and the Korean US Air Quality (KORUS-AQ) mission.

In support of the NAAMES mission, Mr. Kowalewski and his instrument team successfully completed integration and pre-deployment activities twice. Integration activities were coordinated for the instrument team and with the mission management team. Aircraft test flights were supported out of WFF and demonstrated nominal instrument performance. NAAMES Instrument flight operations were successfully supported over five science flights in November 2015 and two transit flights. He developed a near real-time ocean color index (OCI) software tool for GCAS flight operations with the goal of providing near real time information to the project scientists as to where future ship and aircraft area of operations should occur. For DISCOVER-AQ, Mr. Kowalewski attended the 2015 Science Team Meeting where he presented slant column ozone retrieval comparisons between the ground-based Pandora sensors and the GCAS instrument for the Houston 2013 and Denver 2014 campaign deployments. In addition to presenting analysis results, Mr. Kowalewski served as the Retrieval Issues breakout group rapporteur. He helped lead group discussions on the topic and presented a summarizing presentation to the science team which he delivered the following day. Similar activities were performed in support of the GeoTASO instrument’s participation in the KORUS-AQ field mission. Pre-deployment integration and test tasks were completed on time at NASA GSFC and Langley. Instrument hardware modifications were completed that included GeoTASO detector cooling refurbishment, support of electronics reconfiguration, and chiller troubleshooting. In addition to hardware work, Mr. Kowalewski performed pre-deployment optical testing and characterization of the two instruments that included full field of view radiometric sensitivity, wavelength calibrations, and broadband stray light.
In this past year, Mr. Kowalewski led a GSFC Internal Research and Development (IRAD) project named Development of an Airborne Dual Axis Optical Airborne Tracking System (OATS) and is lead optical engineer for the Global Aerosol Measurement System (GAMS). Both are first-of-their-kind IRAD projects in that they are non-civil-servant-developed concepts funded through internal IRAD funds. He also is the instrument development lead for OATS under Goddard’s IRAD program. The goal of this project is to develop an optical tracking and pointing system that couples scattered light from a desired target into an instrument inside the aircraft. For this work, he coordinated mechanical and electrical design efforts that produced initial engineering requirements, created a system design, and developed an initial packaging concept. Technical interchange meetings with NASA Langley engineers provided important feedback about the flight conditions and aircraft interface requirements.

Mr. Kowalewski also is providing optical design and test support in the development of the GAMS small/cube-sat system, which also is funded under Goddard’s IRAD program. The goal of this project is to develop a small/cube-sat-sized system capable of performing vertically resolved limb scattering observations for the purpose of retrieving aerosol distributions at multi-view angles relative to the satellite’s orbital inclination.

Mr. Kowalewski has begun concept development for implementing the multi-view angles and coupling the light onto a single detector. An optical model of the system in Zemax was established in order to begin the trade study. He also coordinated with the mechanical design engineer to develop a compact CubeSat-compatible packaging concept. Electro-optical components were finalized and procurement has begun on long-lead items. Final optical prescriptions for custom optics were created and fed into the mechanical design.

In the coming year, Mr. Kowalewski will continue his EV-S field mission support and his IRAD development projects, and will conduct test flights in support of GOES-R validation activities. He also will continue to serve as JPSS OMPS science team representative during ground acceptance tests.

Mr. Tom Kucsera (sponsor: M. Chin) supports global and regional modeling and analysis of atmospheric aerosols and trace gases and support NASA-sponsored observational programs. Among other responsibilities, he compiles observations from satellite, ground-based, and in-situ measurements for model input, evaluation, and improvement; executes and evaluates atmospheric modeling codes; and performs software and hardware management, as well as computer administration duties. Over this past year, Mr. Kucsera generated and processed numerical model output for the HTAP program. HTAP-archived modeling products from other research groups were also ported onto the local cluster system for analysis and data processing.

Mr. Kucsera processed 27 years of satellite-derived ISCCP solar radiation products. Monthly averaged data products were generated from the original 3-hourly data products. The results were gridded into 2.5-degree x 2-degree cells for analysis purposes. Products included shortwave downwelling flux at the surface for all sky, shortwave downwelling flux at the surface for clear sky, shortwave flux at the top of the atmosphere, cloud fraction amount, and cloud optical depth. The 3-hourly satellite data were acquired and generated products were processed from July 1983 through the end of December 2009.

Global monthly averaged satellite data from the OMI instrument and OSIRIS aerosol products were archived by Mr. Kucsera on the local Linux cluster. Access for group members to the data is achieved through the locally available common archived system that was established by Mr. Kucsera.

Mr. Kucsera traveled to Boulder, Colo. to receive advanced training in the regional atmospheric modeling programs. The training lessons covered the regional WRF and WRF-Chem modeling programs. Upon his return, Mr. Kucsera successfully prepared and processed emission data sets for the NU-WRF regional model. For the ACMAP project, emission data products for January 2010 were prepared for the nested MICS-ASIA domains. Both the GOCART background and biomass burning emissions were processed. Preliminary runs for the ACMAP project were made with the NU-WRF regional model. Subsequent reviews and analyses of these initial simulations showed a significant deficiency in the emission of sea salt in the ocean near land regions. It was determined that this was caused by the use of the geopotential height over the ocean to discriminate whether this model grid point was an ocean or a lake point. For an initial correction, the threshold to make this determination was relaxed to improve the overall ocean sea salt emission.

He processed three years of FINN Version 1.5 fire data products for use in GOCART and NUWRF modeling simulations. The global data encompassed in their entirety the years 2007, 2008 and 2009. Gridded daily emission products were generated and gridded into .5-degree x .5-degree cells. Estimates of burnt areas
Dr. Kurylo also continued to serve as an atmospheric observations liaison for the Stratospheric Processes and their Role in Climate (SPARC) project of the WCRP and for the GCOS Upper-Air Reference Network (GRUAN). In this capacity, he contributes to coordinating common organizational and implementation aspects among various international measurement networks. As a participant and rapporteur at the October 2015 SPARC Workshop that focused on addressing uncertainties in the atmospheric burden and lifetime of carbon tetrachloride, he worked with members of the Workshop SC to finalize the associated SPARC Report, identifying the key points and issues discussed at the workshop, summarizing new findings, and describing future research activities that could help reconcile the difference between reported industrial emissions and those derived from atmospheric observations. He attended the SPARC Regional Workshop on Chemical and Physical Processes in the Climate System, which occurred just prior to the 23rd SPARC Scientific Steering Group meeting in Boulder, Colo. At the SPARC SSG Meeting he presented a brief report highlighting on the discussions and decisions from the NDACC SC Meeting of joint interest to SPARC. In April 2016, he attended the 8th Implementation and Coordination Meeting for GRUAN in which he presented a review of NDACC measurement and analysis highlights and on operational aspects that are complementary to those facing GRUAN. In particular, he highlighted the development of an NDACC water vapor measurement strategy and addressed various issues associated with the centralization of data processing within NDACC, focusing on how NDACC and GRUAN might build upon each other’s efforts in this area.

Dr. Kurylo continued his collaborations, particularly with NIST scientist (Dr. Vladimir Orkin), in the evaluation of atmospheric kinetic and photochemical data as a member of the NASA Panel for Data Evaluation. This work included the re-evaluation of kinetic data for hundreds of reactions describing the atmospheric processing of numerous halocarbons and other trace gases, complete structural and content revisions of the corresponding evaluation tables and notes, compilation and citation of all relevant publications from the scientific literature, and creation of graphical representations of all of the data suitable for eventual inclusion in the NASA/JPL on-line publication. Following completion of their assigned task, he and Dr. Orkin assisted in the final review of the entire evaluation document (JPL Report No. 15-10). The document includes comprehensive coverage of approximately 670 bimolecular reactions, 85 three-body reactions, more than 30 equilibrium constants, 225 photochemical species, 575 aqueous and heterogeneous processes, thermodynamic parameters for almost 800 species,
and approximately 4500 literature citations. Dr. Kurylo has subsequently drafted and finalized a report that summarizes the content of JPL 15-10, announces its availability, and provides a history of the NASA Panel for Data Evaluation and its activities. This article will be submitted to several international newsletters and publications. Dr. Kurylo also continued his collaboration with NIST scientists in laboratory studies to determine the atmospheric lifetimes and degradation mechanisms of ozone- and climate-related trace gases. He was a co-author of a poster presentation at the 2015 AGU Fall Meeting titled “The Impact of Current CH4 and N2O Loss Process Uncertainties on Model Calculated Ozone and Global Lifetimes”, which detailed the latest collaborative research on such lifetime determinations. At AGU, he also was co-author of two other posters: “NASA Data Evaluation (2015): Chemical Kinetics and Photochemical Data for Use in Atmospheric Studies” and “Higher Accuracy Measurements of Photochemical Properties of Very Short-Lived Substances”, and he participated in an ad hoc meeting of the NASA/JPL Panel for Data Evaluation at which future web-based capabilities for the report were discussed.

Dr. Kurylo was appointed by the Ozone Secretariat of the United Nations Environment Programme (UNEP) to the Advisory Committee for the Vienna Convention Trust Fund (VCTF) for Research and Systematic Observation administered by the Parties to the Vienna Convention for the Protection of the Ozone Layer. He participated in the first meeting of this committee during which a Committee Chair was elected, the Committee Terms of Reference were reviewed, the status of existing activities under the Trust Fund was presented, and plans for the development of a long-term strategy and implementation objectives were discussed. He completed his assignment for drafting various sections of the report from this meeting, specifically text for inclusion in the Terms of Reference that clarify the collaborative role of the Committee with the Scientific Assessment Panel of the Montreal Protocol’s Ozone Assessment and the Ozone Research Manager Assemblies under the Vienna Convention. He also drafted a preliminary version of a funding and proposal solicitation letter to the Parties for support under the Trust Fund. In the coming year, he will continue to serve as a member of the Advisory Committee for the VCTF and will participate in any meetings called by the Committee Chair or by the UNEP Ozone Secretariat.

In the year ahead, Dr. Kurylo will continue to serve as an Emeritus Member of the international Steering Committee for NDACC, working on the 2016 update of the NDACC M&A Directory based on information provided following the 2015 SC meeting, assisting in revising the NDACC Water Vapor Measurement Strategy document, and addressing various action items assigned by the SC co-Chairs following the recent meeting. He also will continue to serve as an atmospheric observations liaison for SPARC and GRUAN in the coordination of common organizational and implementation aspects among various international measurement networks. Additionally, Dr. Kurylo will continue his responsibilities as a member of the NASA Panel for Data Evaluation subsequent to the release of JPL Report 15-10. He will assist the panel co-chairs with addressing any errata associated with the report and will participate in discussions regarding data evaluation, web site development and possible mobile device applications. In preparation for future data evaluations, he will track new laboratory studies on the kinetics and photochemistry of ozone- and climate-related trace atmospheric chemicals. As opportunities permit, he will continue to collaborate with NIST scientists in laboratory studies to determine the atmospheric lifetimes and degradation mechanisms of ozone- and climate-related trace gases.

**Dr. Leslie Lait** (sponsor: P. Newman) investigates the dynamical context of atmospheric measurements, to aid in their interpretation. Data from a wide variety of sources—satellite, balloon-borne, aircraft, and ground-based instruments—are analyzed with an emphasis on using techniques that assist in combining disparate data sources to yield a unified picture of the whole. For the ATom mission, Dr. Lait constructed a climatology of meteorological fields from 1980 through 2014, using MERRA and the NCEP/NCAR reanalysis data sets. Statistics were calculated at each data grid-point at several pressure levels covering the ATom (Atmospheric Tomography) field experiment’s operational range (geographically and in altitude). The results were plotted as maps and vertical cross-sections, and made available on a web site. In addition, Dr. Lait created ten science flight plans for the first ATom deployment, scheduled for July-August 2016. He also attended the ATom Science Team meeting in Palmdale, CA in July 2015. During discussions there, the flight plans were further refined and characterized in terms of solar zenith angle. Dr. Lait then worked with the DC-8 navigator to revise waypoint locations and set takeoff times. He then created a set of timeline diagrams for these flights and distributed them to mission management as a planning aid. He also participated in several planning teleconferences for the mission.

Dr. Lait provided flight planning support from Greenbelt for the NOAA SHOUT field experiment staged from Wallops Island, VA and NASA Armstrong Flight Research Center in California in September 2015 and February 2016, respectively. As part of
mission planning, he received flight plans from NOAA personnel
and used the Goddard flight planning software to check their
timings and provide advice to NOAA concerning flight operations
in the vicinity of the California coast. He also ran the notional
plans through his model of Global Hawk fuel temperatures,
showing that the flights being considered would probably have
encountered difficulty. During the SHOUT missions, Dr. Lait
tested flight plans supplied by NOAA personnel for timing issues,
devised exploratory plans for tentative hurricane flights, and
ran his model of Global Hawk fuel temperatures to examine
the feasibility of suggested flights. He also participated in daily
teleconferences during the September mission.

For the Virgas field experiment flown in October 2015, Dr. Lait
provided support from GSFC. The purpose of the mission was to
test a suite of instruments on the NASA WB-57 aircraft for use
in rapid-turnaround flights to measure atmospheric effects of
volcanic eruptions. Before the flights began, Dr. Lait obtained
flight data from recent NASA missions involving the WB-57
aircraft and analyzed those data to determine up-to-date flight
performance characteristics. He then adjusted parameters in the
flight planning software to provide realistic performance during
Virgas. During the experiment, he created plans to check flight
timings and prepared plots of forecast trace gas distributions
along proposed flight tracks. He also participated in telecons and
monitored flights in progress.

Dr. Lait began working with other Code 614 members to
examine global chemistry model simulation output with and
without the effects of the April 2015 Calbuco volcanic eruption
in South America. He extracted certain meteorological fields
and computed Eliassen-Palm flux vectors and flux divergence
daily from May through December 2015. He then examined the
resulting series of data plots showing the simulated effects of the
volcanic eruption. He also examined MERRA2 assimilation data
for the same time period.

In preparation for IT security assessments that took place in
January 2016, Dr. Lait finished revising and updating a set
of local auditing scripts for determining the Code 614 Lab’s
Cluster machines’ compliance with required security practices.
He also implemented several small improvements to current
practices in the Lab, including the configuration of the “auditd”
server based on analysis of log files. When the assessment took
place, he participated in the evaluation of two machines, with
favorable results for both. Dr. Lait revised the overall structure
of the branch’s consolidated web server, tested out a new
virtual hosting configuration using secure protocols, and re-
registered the Lab’s web sites. He also participated in a Goddard
committee for examining security controls for Linux computers,
as well as the Standalone Systems Working Group to examine
issues related to the upcoming forced collectivization of Goddard
IT. He wrote a briefing document describing the Code 614 Cluster
for the new Laboratory Chief, and he gave briefings on the Cluster
to members of two IT architecture committees at GSFC.

In the months ahead, Dr. Lait will continue preparing for the ATom
field experiment and will provide support from GSFC for the first
deployment in July-August 2016. He will continue development
of the new web-based version of the flight planning software,
including completion of the GUI description document. Work will
continue on improvements to the current version of the flight
planner software, and he will continue to examine possible
dynamical effects of the Calbuco eruption.

Dr. Lok Lamsal (sponsor: N. Krotkov) works on developing and
improving the retrieval of nitrogen dioxide (NO2) from UV/visible
spectrometers, evaluating the product, and interpreting satellite
data using the model. Throughout this past year, Dr. Lamsal has
been involved in the development and improvement of the NASA
NO2 retrieval algorithm and evaluation of the Ozone Monitoring
Instrument (OMI) NO2 product. Ongoing activities include the
development of a new spectral fitting algorithm and improvement
of air mass factor (AMF) calculation. Processing and testing
of NO2 slant column density data have been completed. He
improved the calculation of AMF by using monthly vertical
concentration profiles, a required algorithm input, from a high-
resolution chemistry and transport model (CTM) simulation with
varying emissions (2005–2013). He examined the impact of
neglecting the time-dependence of the profiles and quantified
the errors in trend estimation, particularly in regions where
emissions have changed substantially. These improvements are
part of an upcoming version (v3.0), which is planned for public
release in the summer of 2016. He and his GSFC colleagues
have examined the effects of surface Bidirectional Reflectance
Distribution Function (BRDF) on the OMI cloud pressure and
NO2 retrievals. OMI operational cloud and NO2 algorithms make
use of climatological surface reflectivities for retrievals of the
effective cloud fraction, cloud pressure, and NO2 vertical column
density data. Traditionally, the surface reflectivity climatology is
taken from OMI reflectivities that have no dependence on the
observation geometry. In reality, the reflection of incoming light
from land or ocean surface does depend on the observational
geometry. This dependence, as described by surface BRDF,
leads to significant differences in surface reflectivities due to
changing sun-satellite geometries of OMI observations. To
account for surface BRDF, he and his colleagues developed a novel approach creating geometry-dependent surface Lambert Equivalent Reflectivity (LER) using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and OMI geometries. Over ocean, LER were calculated with the VLIDORT model using the Cox-Munk slope distribution. They conducted a thorough investigation of the impact of the new LER product on the retrievals of cloud parameters and NO2 column. On average, differences in the NO2 columns are small for unpolluted and cloudy areas, but in highly polluted areas there was a considerable effect on NO2 column retrievals, reaching up to 50%. Furthermore, Dr. Lamsal adapted the OMI NO2 algorithm for the Ozone Mapping Profiler Suites (OMPS) and Global Ozone Monitoring Experiment (GOME-2) satellite instruments.

This work on the OMI NO2 product resulted in three manuscripts: a paper led by Dr. Lamsal titled “U.S. NO2 trends (2005–2013): EPA Air Quality System (AQS) data versus improved observations from the Ozone Monitoring Instrument (OMI)”, published in Atmos. Env.; a paper he co-authored titled “Revising the slant-column density retrieval of nitrogen dioxide observed by the Ozone Monitoring Instrument”, published in J. Geophys. Res.; and another paper he co-authored titled “Accounting for the effects of surface BRDF on satellite cloud and trace-gas retrievals: A new approach based on geometry-dependent Lambertian-equivalent reflectivity applied to OMI algorithms”, submitted to Atmos. Meas. Tech.

The Airborne Compact Atmospheric Mapper (ACAM), flown onboard the NASA UC-12 aircraft during the DISCOVER-AQ Maryland field campaign (July 2011), made hyperspectral remote sensing measurements in the 304-910 nm range allowing observations of several tropospheric pollutants including NO2 at an unprecedented spatial resolution of 1.5x0.75 km. Dr. Lamsal has analyzed ACAM measurements to produce middle and lower tropospheric NO2 column (NO2 below the aircraft) data. The retrieval algorithm includes high-resolution information for surface reflectivity (MODIS bidirectional reflectance distribution function (BRDF)) and vertical distributions of NO2 and aerosols, and information on temporal variation in atmospheric NO2. He evaluated ACAM NO2 observations with measurements from in-situ monitors onboard NASA P3B aircraft, ground-based Pandora, and space-based Ozone Monitoring Instrument (OMI). He also compared ACAM NO2 retrievals with NO2 simulations from the Community Multi-scale Air Quality (CMAQ) and Global Modeling Initiative (GMI) chemical transport models. The high-resolution ACAM measurements offer new insights into our understanding of atmospheric composition and chemistry through observation of sub-sampling variability in typical satellite and model resolutions. The retrieval algorithm developed for ACAM could serve as a prototype for algorithm improvements for upcoming geostationary air quality missions. Work related to this research resulted in two papers: one paper that Dr. Lamsal co-authored titled “Analysis of ACAM Data for Trace Gas Retrievals during the 2011 DISCOVER-AQ Campaign”, published in J. Spec., and another which Dr. Lamsal is first author titled “High resolution spatial and temporal mapping of nitrogen dioxide with Airborne Compact Atmospheric Mapper” (in preparation).

Dr. Lamsal also conducted global NO2 trend studies. He used high-resolution NO2 data from the OMI satellite instrument to analyze changes in urban NO2 levels around the world from 2005 to 2014. The study demonstrates complex heterogeneity in the changes, suggesting the potential of high-resolution satellite data for quantifying NOX emissions in regions with a complex mix of sources. NOX changes were found to show consistently that environmental regulations resulted in large decreases. Large increases in the U.S. occurred over three areas of intensive energy activity. Rapid economic growth elevated NO2 levels over many tropical and subtropical Asian cities. Two of the largest increases occurred over recently expanded petrochemical complexes in Jamnagar (India) and Daesan (Korea). Pollution transport from China influenced the Republic of Korea and Japan, thus diminishing their local emission controls. However, in China, there were large decreases over Beijing, Shanghai, and the Pearl River Delta, associated with local emission control efforts. Civil unrest and its effect on energy usage resulted in lower NO2 levels in Libya, Iraq, and Syria. Spatial heterogeneity within several megacities reflected mixed efforts to cope with air quality degradation.

estimates of power plant NOx emissions from satellite data; in Atmos. Env.; “Trends and variability in surface ozone over the United States”, in J. Geophys. Res.; and “Long-term NOx trends over large cities in the United States during the Great Recession: Intercomparison of satellite retrievals, ground observations, and emission inventories”, in Atmos. Env.

Upcoming work will include conducting an evaluation of version 3 NO2 product and conducting retrieval studies to improve retrievals from LEO and GEO satellites. Dr. Lamsal also will analyze NO2 data from DISCOVER-AQ and KORUS-AQ campaigns.

Using the GEOS-5 model with coupled ocean and interactive stratospheric chemistry as the main tool, Dr. Feng Li (sponsor: P. Newman) investigates chemistry-climate interactions, specifically how atmospheric processes, particularly the stratospheric ozone depletion/recovery, affect the ocean circulation and sea ice, and how oceanic processes influence the atmosphere. Another objective of Dr. Li’s research is to improve our understanding of stratospheric dynamic and transport processes. This past year, Dr. Li conducted more than 1,000 years of GEOS-AOCCM simulations. The GEOS-AOCCM includes the Ganymed version of AGCM, MOM5 ocean model, and a comprehensive stratospheric chemistry package. These simulations included a 350-year fixed 1950 control simulation, a 1951-2009 reference simulation under the RCP 4.5 scenario, two 100-year timeslice simulations under 1960 and 2004 conditions, a 200-year timeslice simulation under 1960 greenhouse gases and 2004 ozone depleting substances, and a 200-year timeslice simulation under 2004 greenhouse gases and 1960 ozone depleting substances. These simulations are being analyzed to study climate variability and change.

Dr. Li’s research culminated in a first author paper this year. This current generation of climate models commonly use prescribed monthly-mean zonal-mean ozone field to represent stratospheric ozone forcing. However, the prescribed ozone has serious deficiencies: it underestimates the ozone hole and lacks zonal asymmetries. Dr. Li’s study investigated the impacts of using interactive stratospheric chemistry, instead of prescribed ozone, on simulations of recent climate change in the Antarctic and Southern Ocean. Two sets of ensemble transient simulations of 1960-2010 were conducted with the coupled ocean GEOS-5: one with interactive stratospheric chemistry and the other with prescribed ozone. Dr. Li and co-authors found, for the first time, significant Southern Ocean responses to the interactive stratospheric chemistry with increased overturning circulation in November-January, year-round warming of the subsurface ocean, and Antarctic sea ice decrease. These ocean responses originate from a larger increase of the surface wind stress, which is due to a stronger lower stratospheric cooling and enhanced stratosphere-troposphere coupling. This study showed that the interactive stratospheric chemistry can increase the ozone hole effects by up to 100% compared to prescribed ozone, highlighting the importance of correctly representing stratospheric ozone forcing in climate models in order to fully capture its effects on climate change. These research results were presented in Dr. Li’s paper titled “Impacts of Interactive Stratospheric Chemistry on Antarctic and Southern Ocean Climate Change in the Goddard Earth Observing System, Version 5 (GEOS-5)”, which was published in the Journal of Climate.

Dr. Li co-authored three other papers. One paper, titled “Ozone Depletion by Hydrofluorocarbons” and published in Geophysical Research Letters, was based on a study led by Dr. Margaret Hurwitz in which they investigate the impact of increasing hydrofluorocarbons (HFCs) on the stratospheric ozone layer. Using a 2-D model, it was found that HFCs increase stratospheric temperature and change the stratospheric circulation, leading to a weak depletion of stratospheric ozone. The two other papers were led by Dr. Clara Orbe (GSFC): “Air-mass Origin in the Arctic. Part 1: Seasonality” and “Air-mass Origin in the Arctic. Part II: Response to Increases in Greenhouse Gases”. In part I, the first climatology of air-mass origin in the Arctic is presented; part II focuses on the future changes in transport from Northern Hemisphere midlatitudes into the Arctic.

At the 2016 AMS Annual Meeting in New Orleans, LA in January, Dr. Li presented a paper titled “Separating the impacts of ozone depletion and GHG increases on Southern Hemisphere climate change”. In this study, Dr. Li conducted three sets of ensemble simulations using the coupled ocean GEOS-5: one control ensemble with changing greenhouse gases (GHGs) and ozone depleting substances (ODSs), and two single forcing ensembles in which GHGs and ODSs are respectively fixed at 1960 levels. The results show that ozone depletion is the major driver of the Southern Hemisphere summer atmosphere and ocean circulation change, and GHG increase causes most of the Southern Ocean warming and Antarctic sea ice loss.

Dr. Li will continue to study the impact of stratospheric ozone recovery on Southern Hemisphere climate change in the 21st century. The focus is to quantify the roles of two competing processes, ozone recovery and greenhouse gas increase, in Southern Hemisphere atmosphere and ocean circulation change in the 21st century.
Collaborations will continue in the coming year. Dr. Li will work with Dr. Judith Perlwitz (CIRES, University of Colorado) to investigate ozone-climate interactions in the late 21st century. Dr. Li will conduct a series of reference and sensitivity simulations of the 21st century using the GEOS-AOCCM, and will use these simulations to analyze Northern Hemisphere (NH) climate change and examine whether interactive chemistry impacts the NH response to climate change. Dr. Li also will work with Dr. Hurwitz to investigate the role of HFCs in climate and stratospheric modification. Dr. Li will finish integrating HFCs into the chemistry and radiation schemes in GEOS-5 and conduct simulations to understand the impact of HFCs on ozone recovery.

Also, Dr. Li plans to submit a MAP proposal to investigate Antarctic sea ice change in a warming climate, the objectives being to improve GEOS-5 simulations of the Antarctic sea ice climatology and decadal variability and to improve the understanding of Antarctic sea ice-ocean-atmosphere coupling.

Under this first task, Dr. Qing Liang (sponsor: A. Douglass) conducts several analyses. Current efforts involve the recent extension of the vertical domain for interactive chemistry to include a combined stratosphere-troposphere chemistry model (the GMI Combo) to investigate issues related to the role of ozone in the upper troposphere and lower stratosphere on climate. During the past year, Dr. Liang has been analyzing observations of CO2, CO, O3, H2O, long-lived Ozone Depleting Substances (ODSs) such as CFCs and CCl4 and short-lived VOCs (C2H6, C2H2, C6H6) to look at the surface to upper troposphere and stratosphere transport efficiency and timescale for air of different source origins (continental pollution vs. marine biogenic emissions) using measurements from multiple aircraft missions, including SEAC4RS (2013 North America), ATTREX (2013, 2014 Pacific) and CONTRAST (2014 Western Pacific), SOLVE (1999-2000, Pacific). She compared these measurements against those calculated in the GEOS-5 model for model validation and transport and photochemistry diagnosis. The results from North America were compared with those from the western Pacific to quantify how convective transport differs in these two key regions in terms of delivering surface pollutants to the upper troposphere and lower stratosphere.

During this past year, Dr. Liang also conducted an analysis using surface observations of CH3CCl3, HFCs and HFCs to derive global OH abundance, and searching for the next optimal reference gas that can replace CH3CCl3 as an OH reference gas. She presented these analysis results at the 2015 AGU Fall Meeting in December and in a first-author manuscript titled “Deriving global OH abundance and atmospheric lifetimes for long-lived gases: A search for the alternative reference gas for CH3CCl3”.

Major effort went toward updating the stratospheric chemistry package in the GEOS-5 CCM model in the Heracles-4.3 version to include all major short-lived and long-lived ozone depleting substances and greenhouse gases that are important for the stratospheric ozone chemistry and transport. Details of this work include the addition of 17 new chemical tracers in the stratospheric chemistry package: 2 Halons (H-1202, H-2402), 2 HCFCs (HCFC-141b, HCFC-142b), 6 HFCs (HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a), 5 bromocarbons (CHBr3, CH2Br2, CH2BrCl, CHBrCl2, CHBr2Cl), CO2 and SF6, with the accompanying surface emissions or boundary conditions, and photochemistry in the atmosphere. Also, new diagnostics were added to track photochemical loss rates and surface loss rates for all major gases in the stratospheric chemistry package. These updates were fully tested to assure all potential model bugs are fixed. A 35-year test run has been finished and fully evaluated.

Dr. Liang was involved in two other publications as a co-author, one published in Atmos. Chem. Phys. and another accepted for publication in J. Geophys. Res. She was lead author of three presentations this past year: one at the CT3LS science meeting, Boulder, CO in July 2015; one at the SPARC CCMI workshop, Rome, Italy in October 2015, and at the 2015 AGU Fall Meeting, San Francisco, CA in December 2015.

She will continue to analyze aircraft campaign data collected during the NASA TC4, INTEX-A, and NSF DC3 campaigns to examine the convective transport of anthropogenic and biogenic compounds from the surface to the upper troposphere/stratosphere. These results will be compared with those from SEAC4RS and ATTREX/CONTRAST to compile a full understanding of how convective transport from the surface to the upper troposphere/stratosphere. These results will be compared with those from SEAC4RS and ATTREX/CONTRAST to compile a full understanding of how convective transport from the surface to the upper troposphere and lower stratosphere differ with regions (western Pacific vs. North and Central America) and seasons (summer vs. fall). Dr. Liang also will conduct model simulations of very-short-lived bromocarbons and their impact on stratospheric bromine and ozone for the current and future atmosphere (2100) and investigate how climate change impacts the contribution of very-short-lived bromocarbons on stratospheric bromine abundance and ozone loss.

Dr. Qing Liang (sponsor: E. Wilson) works on a second task in which she supports permafrost research and conducts...
fingerprinting of carbon source types using suborbital measurements. She will analyze the following for air mass identification, CO₂, CH₄ variability and their correlation: INTEX-A Data, ARCTAS (A&B) Data, and ABLE (3A&3B) Data. She also will create source and seasonal dependent characteristic ratios as “fingerprints” for plumes. Over the past year, Dr. Liang has worked on the summarization of the analysis of CH₄ and CO₂ mixing ratios characteristics and as well as column abundance characteristics in various air masses observed from four aircraft campaigns: INTEX-B, ARCTAS-A, ARCTAS-B, INTEX-A. These results were combined with those from collaborators and presented by Dr. Wilson at the AGU 2015 Fall Meeting in December. The presentation was titled “Characterizing thawing permafrost carbon emissions: An integrated pilot study in support of satellite evaluation/design and earth system modeling capabilities”.

In the year ahead, Dr. Liang will continue the CH₄-CO₂ tracer-tracer correlations analysis. She will extend the same analysis that was performed for the previous three missions to the remaining three missions proposed in the PI’s work: (1) ABLE-3A, (2) ABLE-3B. Information compiled from the campaigns will be compared with the proposed measurements collected in Alaska in summer 2015 for this project.

For her third task, Dr. Qing Liang (sponsor: P. Newman) conducts 3-D Chemistry Climate Model and 2-box model simulations for CCl₄ and performing budget analyses to under sources and sinks of CCl₄. Milestones will include evaluating the modeled stratospheric representation of CCl₄ in these simulations with balloon, aircraft, and satellite observations; exploring the inter-hemispheric gradient vs. emission relationship to derive global emissions and to examine the impact of hemispheric emission distribution and ocean loss; and collaborating with Dr. Newman and other participants on a manuscript using the analysis results.

Dr. Liang has been analyzing the newly implemented CCl₄ tagged tracers to track emissions from 12 different regions, including North America, Asia, Europe. The analysis results were summarized in a first-author presentation titled “Global modeling of CCl₄: Can we use atmospheric measurements to constrain emissions and losses for CCl₄?” that she presented at the SPARC CCl₄ workshop in Zurich, Switzerland in October 2015. Dr. Liang has compiled a new emissions inventory using emissions information obtained from the SPARC 2016 CCl₄ report, and a new CCl₄ model simulation driven with the new emissions for 1995-2015 is currently in progress.

Dr. Liang aims to complete the CCl₄ model simulation using the new emissions and new lifetimes information from the SPARC 2016 report. She will analyze the results from this new model simulation by comparing the model results with the surface observations for a comprehensive evaluation of the new atmospheric budget put together by the SPARC 2016 report. In collaboration with Dr. Newman and Dr. Fleming (GSFC), she will prepare a manuscript summarizing the emissions and atmospheric losses of CCl₄ using model results from the GEOS-5 CCM and the GSFC-2D models.

Dr. Liang has been collaborating with Dr. Newman (GSFC) and Dr. Stefan Reimann (Empa, Switzerland) in coordinating the SPARC CCl₄ workshop (over 40 scientists and industrial experts). Research results presented at the meeting have been formulated into a SPARC report titled “SPARC Report on the Mystery of Carbon Tetrachloride” by Liang, Q., P. A. Newman, S. Reimann, et al. The report was submitted to the SPARC office and is undergoing a peer-reviewed process under SPARC auspices.

Dr. Liang has continued work with Dr. Paul Newman (GSFC) and Prof. Steve Wofsy and Dr. Jasna Pittman (Harvard University) to analyze the model CO₂-ODS correlations to quantify the lifetimes of these substances. The GEOS-5 model results were provided to Dr. Pittman for comparison with observations from the NASA ATTREX (Winters 2013 and 2014) and were presented by Dr. Pittman at the CT3LS science meeting in Boulder, Colo. in July 2015 and at the 2015 AGU Fall Meeting. A new model simulation using the GEOS-5 Heracles tag with all new implemented chemical tracers for 1990-2015 has been conducted. These model results will be provided to Dr. Pittman for further analysis. This work will continue into the coming year.

Dr. Jin Liao (sponsor: T. Hanisco) prepares the instruments (CAFE and ISAF) for the KORUS-AQ and ATom field campaigns to measure in situ HCHO concentrations. Dr. Liao analyzes data from the previous SEAC4RS field campaign to understand the relationship between HCHO and organic aerosols. Dr. Liao joined GESTAR in January 2016, and has been involved with preparations for the international cooperative air quality field study in Korea (KORUS-AQ) occurring April-June 2016 to measure in situ HCHO around Korea. Preparations involved helping to build the CAFÉ instrument onboard the Hanseo King Air; this includes assembly of the instrument power supply box and two calibration boxes, plus the calibration of the flow meters inside.
She has learned how to operate, maintain and troubleshoot this instrument. Dr. Liao also performed laboratory work to calibrate/quantify the concentrations of five formaldehyde cylinders using the Fourier transform infrared spectroscopy (FTIR) technique. These cylinders will be used as formaldehyde standards in the field studies. Dr. Liao will participate in KORUS-AQ in South Korea from May 10 to June 14, 2016.

The HCHO instrument ISAF will be part of the NASA A-Tom field campaigns from 2016 - 2018. Dr. Liao helped to prepare the ISAF instrument by helping to assemble and align tunable fiber laser of this instrument and learning how to operate, maintain and calibrate this instrument. She will be participating in the ATom field campaign in 2017.

In additional to instrument and lab work, Dr. Liao also helps improve the O-D Atmospheric Modeling (F0AM) box model by revising and adding cross sections and quantum yields of photolysis rates j values in the model. Further, Dr. Liao has begun analyzing the previous SEAC4RS field campaign’s data. She is working on understanding the relationship between HCHO and organic aerosols by statistical analysis methods and box modeling.

**Dr. Junhua Liu** (sponsor: B. Duncan) aims to understand the processes affecting atmospheric composition in the troposphere and lower stratosphere, specifically the sources, chemical evolution and transport pathways. Her research focuses on quantifying contributions of the stratospheric intrusion, surface biomass emissions and lightning to the observed interannual variations (IAV) and trends in tropospheric O₃ and precursors during the past 20 years over the tropics and mid-latitude and investigating their interaction with the Earth’s climate. She investigated the interannual variability of upper tropospheric ozone at Réunion Island from SHADOZ sondes and the GMI-CTM simulations. Her analysis, based on a stratospheric ozone tracer simulation, concluded that the dominant contribution originates from the IAV of stratospheric ozone input. The IAV of the large-scale, quasi-horizontal wind patterns also contributes to the IAV of ozone in the upper troposphere. Her work on this project was published in JGR-Atmospheres. Dr. Liu also used the GMI-CTM model and a stratospheric tracer simulation to interpret the processes resulting in the observed Southern Hemisphere (SH) tropospheric ozone maximum. She examined the model sensitivity of tropospheric ozone to different ozone sources (combustion, stratosphere and lightning NOₓ) by correlating the ozone changes from that source to ozone from the standard simulation. In so doing, she quantified the relative contributions of changes in stratospheric input and surface emission in determining the interannual variability of tropospheric O₃ over mid-latitudes, with a particular focus on hemispheric winter season when subtropical jet-related stratosphere troposphere exchange peaks. Her analysis specifically focused on four south ocean basins at interannual time scales. A manuscript on this project is currently underway. Additionally, Dr. Liu is working with colleagues from Code 614 to examine how MJO and biomass burning influenced tropospheric chemistry compositions, including ozone and CO in the year 2015. She helped with evaluating the GMI-CTM simulations designed for this project.

In August 2015, Dr. Liu gave a 2-minute highlight presentation on her research during a Code 610 Town Hall meeting. She also co-authored two abstracts: one titled “The extreme biomass burning events during 2002-2015 in tropical region associated with ENSO: impact on aerosols and the tropospheric concentration of greenhouse gases” submitted for the AOGS meeting to be held in late July/early August in Beijing, and another titled “A Comparison of Ticosonde-SHADOZ Ozone Profiles to Large-Scale Analyses and Satellite Data”, for the Quadrennial Ozone Symposium 2016, to be held in September in Edinburgh, United Kingdom. As mentioned, she has manuscripts in progress: “Source attribution of interannual variability of ozone in the troposphere and lower stratosphere over southern ocean” and “Validation of OMI ozone profiles and global distribution of tropospheric ozone with the GMI chemistry transport model and ozonesonde measurements”.

In the coming year, Dr. Liu will continue work on analyzing the interannual variation and trends of tropospheric ozone based on several GMI CTM hindcast runs, a GMI stratospheric tracer simulation, and satellite and ozonesonde measurements over southern hemisphere. She also plans to work on a NASA ACMAP proposal on global distribution and evolution of STE and its effects on the interannual and long-term trend of UTLS chemistry including ozone, water vapor and CH₄; furthermore, she strives to examine its effects on radiative forcing as well as the interaction with climate change. For the upcoming ATom campaign, Dr. Liu will participate in the model analysis of ATom campaign. Also, she will evaluate the GMI-CTM run driven by MERRA2, especially during the Pinatubo period. By comparing the results with the current CTM run driven by MERRA and CCM runs, she plans to identify the dominant process (chemistry or dynamics) that causes the tropospheric ozone depletion after the Pinatubo eruption as seen in many Northern hemisphere ozonesonde data.
Dr. Edward Nowottnick (sponsor: P. Colarco) evaluates Ozone Monitoring Instrument (OMI) aerosol products in the context of the NASA Goddard Earth Observing System version 5 (GEOS-5) model, and provides Observing System Simulation Support (OSSE) and data analysis for spaceborne and aircraft lidar systems. During this past year, Dr. Nowottnick performed several GEOS-5 simulations of the weakening phase of Hurricane Nadine from the HS-3 field campaign to determine contributions of dust toward its weakening. He found that assumed dust optical properties and cloud microphysical scheme have a great impact on the path and rate of weakening of Nadine. Dr. Nowottnick plans to begin writing a manuscript for publication in the next quarter.

As a CATS science team member, Dr. Nowottnick is responsible for the aerosol typing algorithm as part of level-2 processing. The CATS aerosol typing algorithm 1) determines aerosol type and 2) assigns an appropriate lidar ratio to convert the observed backscatter to an extinction product. After several months of testing, Dr. Nowottnick’s algorithm was implemented for the first CATS level-2 data release and is now available to the public. This work was presented at several conferences in the past year: the International Cooperative for Aerosol Prediction, held in Barcelona, Spain in June 2015; the NASA GSFC Young Scientist Forum, held at NASA GSFC in July 2015; and the CALIPSO/CloudSat science team meeting, held in Newport News, VA in March 2016.

Dr. Nowottnick was lead and co-author on several publications during the past year. His first author paper titled “Use of the CALIOP vertical feature mask for evaluating global aerosol models” was published in Atmos. Meas. Tech., and this research was presented at the NASA Code 610AT Town Hall Meeting in January 2016. He was a co-author on a paper currently in review with JGR titled “An Overview of the CATS Level1 Processing Algorithms and Data Products”, and a NASA Technical Memoranda in progress titled “The MERRA-2 Aerosol Assimilation”. Dr. Nowottnick also had two proposals selected for funding, one as PI and one as Co-I, respectively: NASA ROSES New Investigator Program (NIP), “Investigating Future Spaceborne Lidar Aerosol Typing Capabilities in the NASA GEOS-5 AGCM”, and NASA ROSES CloudSat and CALIPSO Science Team Recompete, “Evaluating the Vertical Variability of Clouds and Aerosols Over Large and Small Horizontal Scales”.

Upcoming plans include the completion of his analysis of his GEOS-5 simulations of Hurricane Nadine’s weakening phase and preparing a manuscript for journal submission. Dr. Nowottnick will present this work at either a Code 614 Laboratory Lunch or the AEROCENTER seminar series. He also will continue to develop GEOS-5 assimilation of CATS data capabilities and use it to improve future versions of the CATS aerosol typing algorithm. Work will begin on the first phase of his NASA NIP grant, which entails using NASA lidar observations to better constrain assumed aerosol optical properties in GEOS-5; this will follow closely with Dr. Nowottnick’s work toward assimilating CATS data. As part of his role in the NASA ROSES CloudSat/CALIPSO proposal, he will begin analyzing special variability of aerosol plumes using CATS mode 1 data.

Dr. Mark Olsen (sponsor: A. Douglass) conducts research on the analysis of stratosphere-troposphere exchange (STE), transport in the lower stratosphere and troposphere, and the coupling of stratosphere and troposphere in both global atmospheric data sets and output from global models. GEOS-5 ozone analyses were used to study the stratospheric influence on tropospheric ozone variability. Results showed that hemispheric values of ozone STE explain the greatest variance of tropospheric column ozone in the middle latitudes, which is consistent with prior studies. The response in the Northern Hemisphere is significantly greater than in the Southern Hemisphere. The hemispheric values of lowermost stratospheric ozone mass generally have a higher correlation with tropospheric ozone than the hemispheric STE estimates.

Dr. Olsen investigated the impact of using averaged model fields in calculating the magnitude of STE. In particular, it was desired to determine how much uncertainty is introduced when using zonally or monthly averaged fields. A model simulation was run where fields required for mass and ozone STE calculations were saved as daily 3D, zonal mean, and monthly mean 3D values. It was found that the mean fields were sufficient to reproduce the seasonal cycles and interannual variability of both mass and ozone STE. In addition, the annual totals were within 2% of the values calculated using daily 3D fields.

A paper using the GEOS-5 ozone analyses to investigate the tropospheric ozone variance explained and sensitivity to ENSO forcing was completed, revised, and has been resubmitted to the Atmospheric Chemistry and Physics journal following the open discussion phase. New work performed throughout this year and included in the manuscript quantitatively examined the ozone tendencies due to convection, dynamics, analysis increments, and turbulence. The ozone response in the tropics is dominated by the resolved advective transport compared to the other terms. In the extratropics, the convective tendency influence can be
nearly as large as the dynamical tendency. This investigation brings insight to several seemingly disparate prior studies of the El Niño influence on tropospheric ozone in the middle latitudes. In addition, these results are valuable as a process-oriented assessment of the tropospheric response in model simulations. Further, the tropospheric ozone response to ENSO simulated by the GEOS-CCM was then evaluated and compared to the results derived from the GEOS-5 analyses. It was found that the explained variance in the tropics is much more spatially variable in the CCM than in the assimilation and GMI-CTM over short time periods. The ozone sensitivity to ENSO in the CCM is similar to the others models, thus additional variability from other sources must impact the explained variance differences. Over longer time periods, this extra “noise” is reduced and the CCM tropical response agrees well with the assimilation and CTM simulation.

The impact of ENSO and the QBO on the variability of ozone around the subtropical jet is currently being studied. The jet coordinates are based on the vertical and meridional distance from the subtropical jet. This coordinate provides a unique perspective of the upper-troposphere/lower-stratosphere that enhances the view and ability to investigate tropopause folding, stratosphere-troposphere exchange, etc. A vertically and horizontally resolved dataset of ozone in the vicinity of the subtropical jet was created from the GEOS-5 ozone assimilation output. Multiple linear regression was then used to determine the ozone variability with respect to ENSO and the QBO. Results show that, during El Niño conditions and the positive phase of the QBO, increased global average stratosphere to troposphere transport occurs equatorward and below the subtropical jet. The magnitude of the transport varies by longitude. Significant correlation of ozone to the QBO and ENSO time series is also found in the lower stratosphere just above the subtropical jet on a global average. The ENSO patterns of ozone sensitivity are similar to the patterns from the first EOF of the QBO. The net response is a generally a linear combination of the individual forcings except in the tropical upper troposphere, where up to 15 percent of the explained variance is confounded between the ENSO and QBO forcing.

Dr. Olsen presented research results at a press conference, scientific meetings, and seminars. The study of the tropospheric ozone response to ENSO was presented in an AGU press conference and as a science talk at the AGU 2015 Fall Meeting. In addition, a presentation was given as part of a Science and Exploration Division Director’s Seminar at Goddard Space Flight Center. Related work was presented for state legislators at the Morgan Innovation Day in Annapolis. A poster presentation of the ENSO-related tropospheric ozone variability was given at the Chemistry Climate Model Initiative workshop in Rome. Invited seminars were given at the physics departments of the New Mexico Institute of Mining and Technology, and Villanova University. Additionally, Dr. Olsen was a contributing author on a paper published in the Journal of Geophysical Research and lead author on a revised paper currently under review with the Atmospheric Chemistry and Dynamics journal.

In the next year, Dr. Olsen plans to complete and submit a paper on the ENSO and QBO influence on ozone from the jet-coordinate perspective. The study of the stratospheric influence on tropospheric ozone variability will be completed and a paper will be prepared for submission. Dr. Olsen also will contribute work on the downward flux of ozone to the chapter of Extratropical Upper Troposphere and Lower Stratosphere in the report by the SPARC Reanalysis Intercomparison Project.

Dr. Henry Selkirk (sponsor: A. Douglass) participates in a variety of research under this first task. Research involves the characterization of the vertical structure and variability of water vapor and ozone in the tropical upper troposphere and lower stratosphere using balloon sondes, analyzing transport and moisture processes in observations and models, and providing scientific support of NASA airborne missions including the
Airborne Tropical Tropopause Experiment (ATTREX) and the Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS). This past July marked ten years since the advent of Ticosonde balloon sounding of water vapor and ozone in Costa Rica. For water vapor, Ticosonde uses the Cryogenic Frostpoint Hygrometer (CFH), an in situ reference instrument in the tropical upper troposphere and lower stratosphere (UT/LS). As of the writing of this report, Ticosonde has assembled a record of 195 CFH water vapor profiles as well as contributed 485 ozone profiles to the Southern Hemisphere Additional Ozonesondes (SHADOZ) network. Indeed, the Ticosonde water vapor data record is the longest-running series of regular measurements of water vapor in the tropical UT/LS. As such, it has been and will remain invaluable to NASA for both validation of satellite measurements of water vapor and monitoring of the radiative impact of UT/LS water vapor on global climate. Dr. Selkirk’s first image is a composite of the ten years of water vapor measurements in altitude versus day of the year. It shows the tropical ascending portion of the Brewer-Dobson circulation in unprecedented vertical detail. Clearly seen is the annual cycle of moistening and drying of the upper troposphere and lower stratosphere, which is driven by the seasonal variation of temperature at the tropopause (shown as a thin black line near 17 km).

In September 2015, a Ticosonde paper was published online in the Journal of Geophysical Research titled “Sources of seasonal variability in tropical upper troposphere and lower stratosphere water vapor and ozone: Inferences from the Ticosonde data set at Costa Rica” and authored by M. Schoeberl, H. Selkirk, H. Vömel and A. Douglass was published online in the Journal of Geophysical Research on September 17, 2015.

Additionally, Dr. Selkirk is a co-author of a paper summarizing the results of the FAA’s ACCRI research program published in the May 2016 issue of the Bulletin of the American Meteorological Society. The lead author is Dr. Guy Brasseur and the title is “Impact of Aviation on Climate: FAA’s Aviation Climate Change Research Initiative (ACCLI) Phase II”. Dr. Selkirk led a team of scientists from NASA Goddard, including GESTAR scientists Qing Liang and Richard Damoah, who performed simulations using the GEOSCCM chemistry climate model in a free-running mode to test its sensitivity to aircraft emissions. It was found that component-specific radiative forcing (RF) in GEOSCCM was in line with the chemistry-transport models (CTMs) used by other groups in ACCRI. The largest magnitude response was the short-term ozone response at 30.5 mW/m², and the response to methane was estimated at -12.3 mW/m².

In the coming months, Dr. Selkirk, together with Dr. Holger Vömel of NCAR, Dr. Jorge Andrés Díaz of the Universidad de Costa Rica and Dr. Anne M. Thompson of NASA Goddard will propose another four years of Ticosonde water vapor and ozonesonde profiling in Costa Rica to the ROSES 2016 Upper Atmospheric Composition Observations call by July 1, 2016. Also, water vapor and ozone soundings will continue at Costa Rica, ozone on a once-weekly basis and water vapor once a month. In addition, the dual ozone launch activities conducted under the following task will be incorporated into this task.

Dr. Henry Selkirk (sponsor: J. Joiner) works on another task and makes dual ozonesonde measurements of SO₂ in Costa Rica in collaboration with Dr. Gary Morris at St. Edwards University and Dr. Jorge Andres Diaz of the Universidad de Costa Rica (UCR): it is supported by the NASA Goddard OMI science team headed by Dr. Joiner. These profiles provide validation for column measurements of SO₂ by the OMI and OMPS instruments on the Aura and Suomi-NPP satellites. In the past twelve months, seven dual ozone sondes were launched, culminating in a total of 36 dual soundings since February 2012 and 35 since the dual sonde program supported by Dr. Joiner commenced in July 2013. Two of the seven yielded detectable plumes of SO₂. Of the 45 total launched for Ticosonde in the past year, there were 19 (or 42%) with SO₂ plumes detected.

Dr. Selkirk presented results of SO₂ profiling to NOAA Global Monitoring Conference at the NOAA Earth Sciences Research Laboratory, Boulder, CO, May 19-20, 2015. Titled “Ticosounding Turrialba – Profiles of volcanic SO₂ in Costa Rica and validation for OMI and OMPS”, Dr. Selkirk’s presentation showed that plumes of SO₂ originating from the volcano Turrialba upstream from the Ticosonde launch site can be detected with the electrochemical concentration (ECC) ozonesonde, and that the increased depth and frequency of the measured plumes have
coincided with major eruptions of the volcano since early 2010. Examples of work to validate SO2 retrievals from the Aura OMI and Suomi-NPP OMPS instruments were provided. Dr. Selkirk’s second image shows the nine-year record of tropospheric column SO2 inferred from notches in Ticosonde profiles of ozone. The arrows show significant eruptions of Turrialba.

In late September/early October, Dr. Selkirk traveled to the Sentinel-5 Precursor Validation Team (SP5VT) workshop at ESA/ESTEC in Noordwijk, The Netherlands, where he presented a poster entitled “Ticosounding Turrialba – Profiles of volcanic SO2 in Costa Rica and validation for Sentinel-5 Precursor”.

The poster begins with a discussion of the notches observed in ozone profiles at Costa Rica and their attribution to plumes emitted from Volcan Turrialba. It provides an overview of the dual ozonesonde launch campaign beginning in July 2013 and an intercomparison between the inferred SO2 method based on the notches derived from single ozonesondes with the dualsonde technique. The presentation concludes with comparisons of the sonde columns to maps of SO2 in Central America from Principal Components Analysis (PCA) retrievals from the OMI/Aura and OMPS/SNPP instruments.

Note: this work will be incorporated into the previous task as GESTAR moves into its next five years.

For his third task, through the analysis of suborbital water vapor and related tracer data, Dr. Henry Selkirk (sponsor: A. Douglass) aims to improve the moist physics components in GEOS-5 and then use these observations to inform improvements to GEOS-5 in collaboration with Dr. Andrea Molod of GMAO. The continued analysis of SCM results points to a relatively low impact of changes in RHcrit on upper tropospheric relative humidity although there are substantial changes in cloudiness. It was proposed to do a more careful analysis of the ice budget, as this is clearly affecting the clouds.

At the 2015 AGU Fall Meeting, Dr. Selkirk presented a poster entitled “An Assessment of Upper Tropospheric Water Vapor in the MERRA-2 Reanalysis: A Fine-grained Comparison with MLS and in situ Water Vapor Measurements over Costa Rica”, which presented 10-year pressure-level time series of upper tropospheric and lower stratospheric water vapor over Costa Rica (10°N, 84°W) derived from MLS/Aura profiles and the GMAO MERRA-2 reanalysis and which were then compared to Ticosonde CFH balloonsonde measurements.

He and his colleagues found noteworthy results. While there was excellent agreement between MLS and CFH at MLS levels in the vicinity of the tropopause (121, 100 and 83 hPa), MLS showed a tendency to underestimate CFH at 146 and 177 hPa. This MLS low bias is more pronounced during the rainy season, suggesting that deep convection may be influencing the MLS retrieval. Also, like the MLS measurements, the MERRA-2 reanalysis shows excellent agreement with the CFH observations at tropopause level (100 hPa). In the lower stratosphere (83 hPa), however, the reanalysis does not capture the full range of the water vapor seasonal cycle in the CFH observations, as the MERRA-2 values in boreal winter in particular are biased higher compared to CFH. At 146 hPa, where (as noted above) the MLS is low-biased relative to CFH, the variability of the reanalysis is more consistent with that in the CFH observations. In addition, while the MERRA-2 average at 147 hPa is higher than the observations by ~25%, the MLS low bias is ~40%. Direct comparison of MERRA-2 at Costa Rica with MLS shows that MERRA-2 is 50-100 % higher than MLS in the upper troposphere. While this is consistent with the comprehensive analysis recently published by Jiang et al., the comparison to in situ observations, albeit restricted to a single tropical location, suggests that the models are not doing as poorly as other results might indicate.

Dr. Selkirk is Co-I on a proposal to be submitted to the ROSES 2016 Modeling, Analysis and Prediction call. The PI is GMAO scientist Dr. Donifan Barahona, and fellow Co-Is are Dr. Mark Schoeberl of the Science and Technology Corporation and Dr. Andrea Molod of GMAO. The overall goal of the proposal is to improve the capability of GEOS-5 and other large-scale models to simulate clouds at the low temperatures found in the tropical tropopause layer.

Mr. Stephen Steenrod (sponsor: L. Oman) supports the Global Modeling Initiative (GMI) investigations of chemical and dynamical aspects of the middle and lower atmosphere. Work includes development, optimization, multiprocessing, execution, and evaluation of atmospheric modeling codes; development of diagnostic software for analysis of model output and satellite data; and development of general user software to allow simple access to large central databases of model output. This year, Mr. Steenrod worked on several issues with the GMI CTM model, including several enhancements to the model’s capabilities. Of high importance was the implementation of a much newer photolysis code. This enhancement not only updated the reaction rates to the latest JPL recommendations, but also greatly enhanced the cloud interactions in the photolysis reactions. A new reaction was also added to all of the full chemistry mechanisms. This new reaction is important to the speed of polar stratospheric spring-time ozone depletion. In his work
Mr. Steenrod developed and ran the GMI full chemistry model to support the upcoming ATom aircraft mission. This involved runs to simulate the data that will be retrieved during the mission and to use the model to fully understand the many different influences on the chemistry that will result in the measured quantities. The GMI model output needed to be post-processed into a standard form; further, the GMI model also needs to be run with prescribed temperature and moisture fields during the mission.

Working along with others, Mr. Steenrod had to adapt the GMI model to run under new mainframe hardware and software on the NCCS’ massively parallel computer system. The computer was modified by adding many new processors and eliminating older ones. During the year, he ran many simulations; one set was used to look at the ozone depletion sensitivity to an additional reaction, \( \text{CH}_3\text{O}_2+\text{ClO} \). Mr. Steenrod also extended the existing long-term simulations into 2016 and ran the tracer suite in conjunction with full chemistry simulations. He also ran the GMI tracer suite in conjunction with several of the full chemistry simulations, and he created many GMI model input files, which are various resolutions for updated boundary conditions and sensitivity tests. Additionally, he developed a new program to create an emission input data set for volcanic eruption tracer studies.

Mr. Steenrod’s administration support included updating and securing the operating systems of the Code 614 computer cluster regularly, as well as updating and maintaining the hardware on this cluster in a timely and unobtrusive manner. This included replacing nine computers, adding many new and replacement hard-drives and diagnosing failed graphics cards and memory chips.

In the coming months, Mr. Steenrod will continue work on improving the GMI model and fixing issues as they are discovered. There are current plans to support the ATom aircraft mission in near real-time. He also needs to implement the latest version of the photolysis routines. Mr. Steenrod plans to submit model results to CCMI. His computer cluster group leader activities will continue, especially with regard to the OS security updates and installation of new and replacement hardware.

Dr. Susan Strahan (sponsor: P. Newman) focuses on analyzing stratospheric observations to improve the understanding of stratospheric transport processes, their variability, and their effects on the chemistry of trace gases, especially ozone. The results of observational analyses are used to evaluate the representation of transport and chemistry in NASA models, including the Global Modeling Initiative (GMI) chemistry transport model (CTM) and GEOS-5 models. Model simulations integrated with reanalyses are used to interpret observations from satellites and ground-based measurements.

This past year, Dr. Strahan worked on quantifying Arctic ozone depletion. While there is no Arctic Ozone Hole, there is ozone depletion in the Arctic each winter. The amount of depletion cannot be determined simply by measuring ozone at the end of winter (March) because natural year-to-year variations in the stratospheric circulation also cause Arctic ozone levels to vary. Dr. Strahan used simulations of the GMI CTM with MERRA meteorology, integrated with and without polar ozone-depleting reactions, to calculate how much ozone depletion occurred each winter from 2005-2015. The results showed a linear relationship between the amount of Arctic column ozone depletion and the number of days each winter with temperatures below the threshold for ozone-depleting reactions to occur. The number of days with low temperatures is related to the occurrence of a stratospheric sudden warming (SSW), a powerful, wave-driven event that rapidly warms the polar stratosphere. Years with a SSW had about one-third the depletion of years without an SSW. And, only one-third of the observed variability in March Arctic ozone was found to be due to ozone depletion while the rest comes from dynamical (natural) variability. Only years without SSWs have enough ozone depletion to enhance midlatitude surface UV radiation in spring, but the impact is only a few percent. Dr. Strahan presented these results at the Annual Meeting of the American Meteorological Society. This work has been submitted to the Journal of Geophysical Research.

Dr. Strahan collaborated with Dr. Paul Newman and a group of Code 614 atmospheric scientists to monitor ozone levels and meteorological conditions in the polar stratosphere. The group monitored the development of the 2015 Antarctic ozone hole with the goals of understanding 1) why it grew so large in spite of declining chlorine levels and 2) whether its size and depth were
consistent with their understanding of the physics and chemistry of ozone depletion. Working with NOAA scientists, this group produced a press release in late October that described this year’s very large hole, explaining the factors that contributed to its size (http://www.nasa.gov/feature/goddard/annual-antarctic-ozone-hole-larger-and-formed-later-in-2015). The group has also submitted an article on the 2015 Antarctic Ozone Hole to the Bulletin of the AMS special issue ‘State of the Climate 2015’.

The Network for Detection of Atmospheric Composition Change (NDACC) consists of hundreds of ground-based instruments that measure trace gases such as O₃, H₂O, NO₂, CH₄, and HCl. The instruments are located at stations throughout the globe and many have operated for two decades or more, offering long-term records of atmospheric composition. Dr. Strahan attended the annual NDACC Steering Committee meeting in San Diego, CA in October, where model support requirements were discussed with instrument PIs. Based on PI input, she has worked to provide output from GMI simulations of the recent past (‘Hindcasts’) that are customized for various NDACC instruments and stations. The GMI output assists NDACC scientists with interpreting their measurements, allowing them to put their data sets in a global perspective. For the first time, global model outputs are available for NDACC scientists on the NDACC data archive.

Dr. Strahan is now the Project Scientist for the GMI chemistry transport modeling effort. She continues to manage new simulations in support of many projects within NASA. For one current project, the goal is to determine the impacts of trace gas and aerosol emissions from massive Indonesian fires associated with the 2015 El Niño event. For another, researchers are investigating the cause of an observed decadal trend in global tropospheric column ozone. GMI is providing specialized simulations in support of the NASA ATom airborne mission of which the goal is to understand how chemical reactivity, particularly of anthropogenic climate forcers O₃ and CH₄, affects the atmosphere on a global scale. GESTAR scientists Dr. Sarah Strode, Dr. Jerry Ziemke, and Dr. Junhua Liu are collaborators in these studies and will perform analyses of observations and GMI simulations. Additionally, Dr. Strahan has directed numerous updates to the GMI model and has evaluated their impacts on constituent simulations. The updates included changes to surface source gas forcing, a new reaction involving in stratospheric chlorine, revised anthropogenic emissions, and new kinetic and photolytic rate constants. Several new model components were evaluated, including a new chemical solver and an updated photolysis solver.

Additionally, Dr. Strahan assisted in evaluating a new chemistry and transport model (CTM) developed by the GMAO, the GEOS-CTM. The goal is to create an offline model, like the GMI CTM, using an updated advection core. Initial experiments revealed problems with trace gas conservation in the troposphere. Additional experiments have continued to reveal problems affecting the model’s stratospheric residual circulation. With many of the initial problems now fixed, Dr. Strahan is collaborating with Dr. Clara Orbe (USRA/610.1) to identify and diagnose remaining transport issues by integrating the GMI tracer suite in GEOS-CTM simulations.

Future plans include an investigation into methods to combine model simulations of the past with the existing long-term NDACC data sets to estimate global budgets and decadal trends for important species such as O₃ and HCl. Also, Dr. Strahan will continue working with Code 614 scientists to monitor ozone depletion in the Arctic and Antarctic. The goals are to understand the roles of chemistry and dynamics in controlling the extent of ozone loss each season, and to communicate this information to the public through press releases and scientific publications.

Dr. Sarah Strode (sponsor: B. Duncan) contributes to three-dimensional modeling efforts, both for Chemical Transport Models (CTM) and Chemistry Climate Models (CCM). She also conducts simulations for the Atmospheric Chemistry-Climate Model Intercomparison (ACMCI), and provides emission scenarios for past and future simulations. This past year, Dr. Strode used a series of CTM and CCM experiments to analyze the trends in carbon monoxide observed by the MOPITT instrument on the Terra satellite. She found that the emission changes assumed in a recent emission inventory are consistent with the satellite trends over the U. S. and Europe, but not over China. She
submitted a paper presenting these results, which is currently in review.

Chemistry climate models (CCMs) often show a low bias in carbon monoxide, which may result from an underestimate of carbon monoxide emissions or a high bias in simulated OH concentrations. Correctly simulating OH is important for simulating the atmospheric lifetime of methane, an important greenhouse gas. Dr. Strode and coauthors published the following paper exploring this issue in Atmospheric Chemistry and Physics: “Implications of carbon monoxide bias for methane lifetime and atmospheric composition in chemistry climate models”.

Additionally, Dr. Strode is analyzing ozone concentrations in the tropical troposphere in cloudy regions compared to clear ones. She gave a talk on this topic at the American Meteorological Society meeting entitled “Analysis of Ozone in Cloudy Versus Clear Sky Conditions”. Also, Dr. Strode is contributing to model simulations and to interpreting chemical forecasts as part of the Atmospheric Tomography Mission (ATom). She gave a presentation on GMI model capabilities at the ATom Science Team meeting.

Under this first task, **Dr. Ghassan Taha** (sponsor: R. Mcpeters) leads Aura Validation Data Center (AVDC) activities by supporting various Aura and NPP calibration and validation activities and maintaining web content and related system hardware management activities. He also serves as an administrator of the center databases. Dr. Taha provides support to AVDC users and responds to various scientific requests of services provided by the center. This past year, three of the AVDC server’s operating system and software packages were updated in compliance with code 600 policy. Dr. Taha also addressed requests from Code 600 to fix webpage vulnerability and maintained the AVDC webpage. He also collects and updates multiple satellites and ground-based datasets needed for AURA and NPP validation studies. He will continue collecting, converting, and hosting various correlative measurements needed for satellite validation studies.

Dr. Taha attended the SAGE III Science Utilization Team meeting in Hampton, VA, and presented a poster titled “The Aura Validation Data Center (AVDC): Current and Future activities”. He also discussed with SAGE team potential AVDC role in aiding the SAGE III validation efforts after launch. In the coming year, he will include SAGE III validation to AVDC activities.

**Dr. Ghassan Taha** (sponsor: G. Jaross) works on a second task investigating SNPP OMPS Limb sensor data quality with the goal of identifying improvements to current and future Limb sensors. The focus is on alternative approaches to data reduction that have potential implications for sensor and algorithm design. Dr. Taha analyzed OMPS, OSIRIS and SCIAMACHY measurements at high altitudes in the tropics and derived QBO aerosol contribution using the Regression analysis technique. He also analyzed three years of records of aerosol scattering index (ASI) global distribution and produced daily global zonal means of climatology and daily ASI maps to study volcanic eruptions and meteor explosions distributions in the stratosphere. He also derived an empirical correction to improve OMPS ASI to account for seasonal variations of the instrument-viewing geometry and its effect on aerosol and Rayleigh phase function.

Dr. Taha examined the distribution of stratospheric aerosol at different altitudes following both the Kelut and Calbuco volcanic eruptions and used MERRA2 wind vectors and potential temperature to correlate the aerosol plume global transport with the dynamical processes in the middle and lower stratosphere. He also performed detailed comparisons with both the OSIRIS and GEOSCCM aerosol models; the agreement with OSIRIS was within 20%. Additionally, he developed a new empirical straylight correction of OMPS LP radiances and tested its effect on ozone and aerosol retrievals. The new corrections were implemented for the next ozone and aerosol products to be released this summer.

Dr. Taha co-authored a paper titled “Ground-based assessment of the bias and long-term stability of fourteen limb and occultation ozone profile data records”, which has been accepted by Atmospheric Measurement Techniques. He also presented a poster titled “Validation of OMPS LP Ozone Profiles with Satellite, Ozonedones and Lidar Measurements at the Advances in Atmospheric Science and Applications conference (ATMOS2015), held in Heraklion, Greece, and gave a talk titled “OMPS LP Global Aerosol Profile measurements” at the International Symposium Atmospheric Radiation and Dynamics (ISARD-2015), held in St. Petersburg, Russia. In December, he attended the 2015 AGU Fall Meeting and presented a poster titled “OMPS LP Characterization of Stratospheric Aerosols”. He also co-authored a presentation titled “How certain are we of the uncertainties in recent ozone profile trend assessments of merged limb/occultation records? Challenges and possible ways forward”.

Going forward, Dr. Taha will validate OMPS LP aerosol new version 1.0 using OSIRIS and CALIPISO aerosol measurements. He also will investigate the use of CALIPSO and CATS polarization
measurements to improve OMPS cloud detection algorithm. He will continue analyzing the OMPS LP measurements of volcanic eruptions and the injection of Calbuco aerosol into the polar vortex. He also plans to validate the Goddard GEOSCCM-modeled aerosol extinction against OMPS, OSIRIS, GOMOS and SCIAMACHY.

Dr. Zhining Tao (sponsor: M. Chin) works on developing the regional chemistry-transport model (NASA Unified WRF (NU-WRF)), examining biosphere-atmosphere interactions, and investigating the role of aerosols and trace gases (e.g., CO$_2$ and ozone) in climate change and air quality through global/regional modeling studies and data analysis. Specific research areas include, but are not limited to, case studies on regional air quality/climate over the North America, Asia, Africa, and other interested areas with NU-WRF, examining interaction between aerosol and cloud/precipitation over the west Africa, and analyzing satellite/ground-based/aircraft measurements, e.g., HS3 and DISCOVER-AQ.

Dr. Tao leads the effort to integrate the CASA-GFED CO$_2$ fluxes and PCTM global model results into the NU-WRF framework and to study the CO$_2$ spatial-temporal variability using the high-resolution regional model. A new approach was adopted to disaggregate the monthly CASA flux into hourly ones using the NU-WRF-simulated meteorology. In this manner, the same meteorology is used to conduct both CO$_2$ flux estimate and transport. These results were presented at the 2015 AGU Fall Meeting. Dr. Tao also leads the effort to perform the regional simulations using NU-WRF to understand the interactions between Asian monsoon and air quality. The year-long baseline simulation and perturbation experiments are underway. The aerosol-cloud-radiation feedback and the trans-boundary impact are anticipated to be quantified. Preliminary results were presented at the 7th MICS-Asia Workshop.

Dr. Tao continued the modeling study and analysis of the impact of dust on the Saharan Air Layer (SAL) structure. He compared and evaluated the model results with the data collected during the HS3 campaign and carried out the sensitivity study to identify the impact through aerosol-cloud-radiation interactions. These results were presented at the 2015 GoldSchimdt Conference and the 96th Annual AMS meeting.

As lead author, Dr. Tao has published two papers: “The Role of Aerosol-Cloud-Radiation Interactions in Regional Air Quality: A NU-WRF Study over the United States” in the journal Atmosphere, and “Impact of transpacific aerosol on air quality over the United States: A perspective from aerosol-cloud-radiation interactions” in Atmospheric Environment.

Dr. Tao will continue work on the currently funded projects from MAP, ACMAP, and HS3 programs. He will start to work on two recently funded projects supported by USEPA and NOAA, respectively. Meanwhile, Dr. Tao will continue to explore funding opportunities and submit proposals to various NASA programs and other agencies.

Dr. James Wang (sponsor: S. R. Kawa) works on this first task examining inverse modeling of atmospheric CO$_2$ using satellite and in situ observations. This past year, Dr. Wang gave a lead author oral presentation titled “A Synthesis Inversion Analysis of Recent Variability in Natural CO$_2$ Fluxes Using GOSAT and In Situ Observations” at the 11th International Workshop on Greenhouse Gas Measurements from Space (IWGMS-11) in Pasadena, CA in June 2015. The co-authors were Stephan R. Kawa (Code 614), George J. Collatz (Code 618), and Lesley Ott (Code 610.1). The group used a unique inverse modeling approach to optimally estimate CO$_2$ emissions and uptake around the world using the satellite and ground-based observations. Their results indicate a significant terrestrial sink for carbon, especially at higher latitudes of the Northern Hemisphere, which may have been smaller in 2010 than in 2009 because of extensive heat waves and drought in 2010. Dr. Wang also chaired a poster session on Future Missions at this conference, and participated in a community workshop at this venue to discuss the NASA ASCENDS CO$_2$ satellite mission and white paper.

As a member of the newly formed Diversity Committee of USRA, Dr. Wang attended the annual meeting of the committee at the USRA Headquarters in Columbia, MD, in July 2015. The goals of the committee are to promote diversity in hiring and promotions, raise awareness of diversity issues throughout USRA, and develop diversity training. The attendees brainstormed and then determined actions to focus on in the near-term.

Dr. Wang gave a poster presentation at the 2015 American Geophysical Union Fall Meeting in December in San Francisco, CA. The presentation, titled “An Inversion Analysis of Recent Variability in Natural CO$_2$ Fluxes Using GOSAT and In Situ Observations”, was part of the Atmospheric Science session “Constraining Biosphere-Atmosphere Exchange Processes using Remote-Sensing and In Situ Networks”. He was also a co-author on a talk (“Evaluation of Diagnostic CO$_2$ Flux and Transport Modeling in NU-WRF and GEOS-5”). Dr. Wang presented his AGU
poster at the 9th Annual Sciences and Exploration Directorate/Code 600 New Year’s Poster Party Blowout at GSFC in January 2016. During the Code 610 Town Hall meeting in October 2015, Dr. Wang gave a 1-minute science presentation on his atmospheric CO2 research. The meeting was attended by the Code 600 leadership as well as many in Code 610.

Dr. Wang is a Co-I on a grant proposal submitted to the NASA Carbon Monitoring System opportunity in March 2016. The proposal, titled “Verification of Intended Nationally Determined Contributions by Satellite and Ground-Based Observing Systems”, is led by PI Clark Weaver and includes another Co-I, S. Randolph Kawa. At present, the status is pending.

In the coming year, Dr. Wang will wrap up his global CO2 inverse modeling project involving different combinations of ground-based and GOSAT satellite CO2 measurements. He will finish several drafts of a paper on his results for publication in a peer-review journal, with a target submission date in summer or fall of 2016. He also will conduct work as part of grant-funded research. As part of a NASA MAP grant (PI: S. Randolph Kawa), Dr. Wang will work on coupling the STILT backwards-run Lagrangian transport model with meteorology from the high resolution NU-WRF regional model, and will begin to carry out STILT simulations in a test year for each of various ground-based CO2 observation sites in North America. As Co-I on a NASA Carbon Monitoring System proposal, he will begin using a more sophisticated inversion technique and incorporating newly released OCO-2 satellite CO2 measurements in the analysis. He also plans to be involved as Co-I with a grant proposal to extend his ongoing CO2 inverse modeling work. The proposal may be submitted to the NASA Interdisciplinary Research in Earth Sciences opportunity.

For his second task, Dr. James Wang (sponsor: B. Duncan) studies the modeling of the interactive atmospheric methane-carbon monoxide-hydroxyl system. He gave an oral presentation on this research at the 2016 American Meteorological Society Annual Meeting in January 2016 in New Orleans, LA titled “Evaluation of a Computationally-Efficient CH4-CO-OH (ECCOH) Module with Climate-Sensitive Wetland CH4 Emissions within the GEOS-5 Climate Model”. The session on greenhouse gas emissions took place within the 18th Conference on Atmospheric Chemistry. Dr. Wang conducted the research in collaboration with fellow NASA GSFC scientists and co-authors Bryan Duncan, Yasin Elshorbany, and Sarah Strode. The talk described their coupling of methane emissions and ECCOH chemistry modules to the NASA GEOS-5 global climate model and analysis of resulting atmospheric methane evolution and chemical feedbacks. That work is part of a larger ongoing effort of developing a more complete Earth system model. Dr. Wang also presented his research at a meeting in May 2015 of the Changes in the Arctic and Boreal System (CABS) task group, which fosters collaboration on this topic across the different departments of GSFC. In addition, Dr. Wang presented his methane research and plans for grant proposals to extend the work at the monthly Chemistry-Climate Model group meeting at GSFC in March 2016.

Dr. Wang co-authored a scientific paper that was published in the journal Geoscientific Model Development in February 2016. He contributed to the development of the model of the atmospheric methane-carbon monoxide-hydroxyl system and to the writing of the paper, which was titled “The description and validation of the computationally Efficient CH4–CO–OH (ECCOHv1.01) chemistry module for 3-D model applications”.

Dr. Wang co-authored a poster presented at the 11th International Workshop on Greenhouse Gas Measurements from Space (IWGMS-11) in Pasadena, CA in June 2015 titled “The Computationally-Efficient CH4-CO-OH (ECCOH) Module for Scientific Studies & Mission Design Support”; the authors were B. Duncan, Y. Elshorbany, J. Wang and S. Strode. He also co-authored a poster presentation given at the 2015 AGU Fall Meeting in December in San Francisco, CA. The presentation title was “Interannual Variability and Trends of CH4, CO and OH using the Computationally-Efficient CH4-CO-OH (ECCOH) Module”.

Dr. Wang organized a scientific seminar, sponsored by the Atmospheric Chemistry and Dynamics Laboratory and GESTAR, which was held on September 3rd at NASA GSFC. The speaker was Professor Qianlai Zhuang from Purdue University, and the title of the seminar was “Quantifying Arctic Carbon Dioxide and Methane Emissions and Their Feedbacks to the Climate System”. The audience included people from all across the Earth Sciences at Goddard and a few people from outside Goddard as well. Dr. Zhuang described the evolution of the ecosystem and biogeochemistry models that he and his group have developed over the past decade to simulate the effects of a changing climate and thawing permafrost on Arctic greenhouse gas emissions, and advocated for additional measurements to help refine our understanding of these processes. During Dr. Zhuang’s visit, he and Dr. Wang and a number of other Goddard researchers discussed details of a possible collaboration on modeling carbon cycle-climate feedbacks.
In April 2016, Dr. Wang was awarded funding from a USRA IRAD grant. The title of his proposal was “Simulations of Natural Methane Fluxes for Improved Prediction of Carbon Cycle-Climate-Atmospheric Chemistry Feedbacks”. He and colleagues at NASA GSFC have been developing a simulation of the atmospheric methane-carbon monoxide-hydroxyl radical (CH₄-CO-OH) chemical system within the NASA GEOS-5 global climate model. He proposed to couple advanced, process-based models of CH₄ emissions from wetlands and lakes to GEOS-5 to improve the ability to simulate and predict changes in the global CH₄ cycle. This work also will contribute to the further development of GEOS-5 into a comprehensive Earth system model. Dr. Wang will collaborate with NASA GSFC and outside colleagues with expertise in hydrology, permafrost dynamics, biogeochemistry, and atmospheric chemistry. This funding will enable Dr. Wang to conduct initial studies and to develop additional grant proposals targeting funding opportunities within and outside of NASA.

This coming year, Dr. Wang will continue to evaluate a parameterization for wetland methane emissions using surface and satellite observations of atmospheric CH₄. He will extend the wetland emission calculations and atmospheric simulations into the future (projections). He also will attempt to implement a version of the parameterization that can be run on-line. He will migrate to a new version of the GEOS-5 climate model that can run on the latest operating system at the NCCS supercomputing center, and will help to fix any bugs in the methane simulation. Finally, he plans to help modify the code so that the methane simulation can be run at higher spatial resolution.

As PI, Dr. Wang will lead the writing of a grant proposal to be submitted to the NASA Modeling, Analysis, and Prediction (MAP) opportunity in June 2016. The grant would support further development of simulations of climate-sensitive methane emissions, in collaboration with an outside expert, Professor Qianlai Zhuang at Purdue University. Specifically, he is planning to obtain Dr. Zhuang’s process-based models of wetland and lake methane emissions for coupling with Goddard’s GEOS-5 climate model. As Co-I, Dr. Wang will participate in a related grant proposal. The response to the NASA Carbon Cycle Science call, due in June 2016 and led by PI Sarah Strode, will describe their plans to develop wetland and lake methane emissions simulations, with a focus on impacts of drought in the Amazon. Dr. Wang also will participate as a PI or Co-I in a NASA Interdisciplinary Research in Earth Sciences proposal due in September 2016. The team will use various trace gas measurements and modeling approaches to constrain the global methane budget and trends over recent decades.

Dr. Jerry Ziemke (sponsor: P. Newman) conducts research to develop a long-record (1979-current) of tropospheric and stratospheric ozone by combining measurements from TOMS and OMI v9; to derive OMI/MLS tropospheric ozone using TOMS/OMI v9 retrieval; to develop a continuous tropospheric ozone product from OMPS nadir mapper and limb profiler and a new tropospheric ozone product from EPIC measurements on the DSCOVR spacecraft; and, to produce a new tropospheric ozone product from combining measurements from the NPP OMPS nadir mapper and limb profiler.

During this past year, the ozone products have undergone many changes in algorithm codes. The related research of the developed products has resulted in several publications. Dr. Ziemke was a lead author on one paper titled “Tropospheric ozone variability in the tropical Pacific from ENSO to MJO and shorter timescales” published in Atmos. Chem. Phys. in July 2015, and another lead author on a paper titled “Tropospheric ozone in State of the Climate in 2015”, which is currently in press with Bull. Amer. Meteorol. Soc. Research also culminated in four papers of which he was a co-author, one published in Atmos. Chem. Phys., one published in BAMS, another in press with BAMS, and a fourth in review with J. Atmos. Sci.

Dr. Ziemke attended the European Geophysical Union (EGU) meeting in Vienna in spring 2016 and presented two papers, one as first author based on global tropospheric ozone variability from trends and ENSO events to the 1- to 2-month MJO and shorter time scales. In the year ahead, Dr. Ziemke will continue producing ozone data products, attending meetings, writing proposals, and publishing science papers. As PI, he plans to write an ACMAP proposal (due this summer).

Dr. Ludovic Brucker (sponsor: S. Nowicki) conducts research to advance and validate satellite-derived properties of snow and ice on Earth using surface-, air-, and space-based microwave radiometers and scatterometers. Specifically, radiometers operating at L-band (~1.4 GHz) are used to retrieve sea surface salinity over ice-free oceans. One hindrance of their use in the high latitudes is the preponderance of mixed scenes, where seawater and sea ice are both present in the sensor’s field of view. Accurately characterizing the scene is crucial for oceanographic and cryospheric applications. To that end, Dr.

**CODE 615: CRYOSPHERIC SCIENCES LABORATORY**
Brucker investigated the sea ice model operationally used to derive the ice fraction affecting the Aquarius observations. He and Dr. Dinnat found that the current model tends to overestimate sea ice fraction in the marginal ice zone where observations may be used for salinity retrievals. Also, they noticed that the current model underestimates ice fraction within the ice pack where observations may be used to derive sea ice properties, such as thickness. These results were presented and a manuscript submitted, and the new methodology will be implemented in a future Aquarius data product reprocessing. As part of the funded Interdisciplinary Science project “Feedbacks, Processes and Impacts of Contemporary Changes in the Arctic”, Dr. Brucker worked in collaboration with NASA GMAO members to enhance sea ice thickness data assimilation in the Northern Hemisphere. This was made possible by combining multiple types of satellite observations including freeboard derived from ESA’s CryoSat-2 radar altimeter. On a different project, Dr. Brucker conducted fieldwork in Cambridge Bay, Nunavut for monitoring snow properties in the watershed surrounding the Canadian High Arctic Research Station. Finally, he also worked on developing a method to extract and map the geolocation data recorded by the prototype airborne wideband instrument for snow measurements (WISM). This allowed for identifying issues in the geolocation data recording stream, a first assessment of the distance between the airborne observations and the in situ measurements he collected in 2015.

Dr. Brucker’s work over the past year has resulted in six journal publications, one book chapter, and over twenty presentations (including invited, oral, and poster presentations). In addition, Dr. Brucker contributed to the organization of the MicroSnow2 workshop that took place at USRA Headquarters, Columbia, MD in July 2015. MicroSnow workshops allow the exchange of the latest results, field measurements, models, and ideas related to understanding the connections between microwave signatures of snow and the detailed internal structure of snow. He also facilitated a session during the first meeting about SnowEx, a forthcoming multi-year airborne snow campaign, to identify the ideal characteristics of potential survey sites. Finally, Dr. Brucker participated in an interview with NASA GSFC Office of Communication and was featured in an online profile. In the coming year, Dr. Brucker will work on publishing new results on the state of the Arctic, which includes work on Arctic ice thickness retrievals, evolution of the Greenland firn aquifer, and likely analysis of the unusually warm 2016 winter at high northern latitudes.

This past year, Dr. Brucker was involved in three proposal submissions. He led the submission of a new NASA ROSES proposal for the solicitation Science Utilization of the Soil Moisture Active-Passive Mission. The proposal aims to utilize the SMAP L-band data for retrievals of sea ice properties. For this proposal, he teamed with co-I Dr. Dinnat (NASA GSFC/Chapman Univ.), as well as national and international collaborators: Prof. Johnson (The Ohio Uni.), Prof. Haas (York Uni., Canada), and Prof. Kaleschke (Hamburg Uni., Germany). As Co-I, Dr. Brucker submitted two NASA ROSES proposals, one to the solicitation Physical Oceanography, and the other to the solicitation Precipitation Measurement Mission (PMM). The latter, led by PI Dr. Munchak (NASA GSFC), has been awarded to improve representation of active and passive microwave surface characteristics in the Global Precipitation Measurement algorithm. Specifically, Dr. Brucker will provide expertise on microwave radiative transfer modeling of snow and ice covered areas to study the relationship emissivity/backscatter for refining precipitation property retrievals.

**Dr. Paolo de Matthaes** (sponsor: D. Le Vine) provides support of the Aquarius/SAC-D mission, in which the goal is to provide global sea surface salinity maps from space for studying large-scale ocean processes and climate change. The Aquarius science instruments include an L-band radiometer, whose received signal is sensitive to salinity, and a radar scatterometer that helps correct for the effect of the sea surface roughness. Note, even though Aquarius has ceased operations in June 2015, calibration/validation activities are still taking place to deliver a final version of the data products. Dr. de Matthaes is working on the improvements for this final version of Aquarius data. He co-authored a presentation titled “Comparison of L-Band Radio Frequency Interference Seen by Aquarius and SMOS” (led by Dr. Yan Soldo) for the 2nd SMOS Science Conference held in Madrid in late May 2015. He also attended the International Geoscience and Remote Sensing Symposium 2015 (IGARSS 2015) held in Milan in July, co-organizing and chairing a full technical session titled “RFI in Microwave Remote Sensing: Observations and Management Techniques” and giving a first-author oral presentation titled “The Aquarius Mission: Three and a Half Years of RFI Observations at L-Band”.

Dr. de Matthaes has been working on electromagnetic modeling of sea ice and estimation of sea ice thickness estimation using Aquarius data. Some of the results of his work were recently presented at the 14th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment (MicroRad 2016), held in Helsinki, Finland in April. Work in the coming year...
will involve working on sea ice thickness estimation and possibly collaborating with European research groups.

Dr. de Matthaeis has been re-appointed co-chair of IEEE GRSS Frequency Allocations in Remote Sensing Technical Committee (FARS-TC) for another two-year term. He attended the 35th Meeting of the Space Frequency Coordination Group held in Japan from 28 July to 5 August 2015, presenting the work on the RFI observation database currently under development. He also prepared and filed technical comments with the Federal Communications Commission (FCC) in response to an FCC Notice of Proposed Rulemaking under Docket 14-177.

Dr. Yan Soldo (sponsor: D. Le Vine) supports the Aquarius/SAC-D and the SMAP missions to map ocean salinity and soil moisture worldwide. His research aims to improve the quality of salinity retrievals from raw satellite data. Part of Dr. Soldo’s work has been selected by the Aquarius team to improve the quality of the future release of the Aquarius data. His contributions over the past year include an improved strategy to detect Radio-Frequency Interference (RFI) in Aquarius data, and a significantly improved model of the emissivity of land surfaces; in particular, this second aspect has required Dr. Soldo to lead an effort involving several team members and to interact with different teams at Goddard, JPL and USDA. He made three oral presentations at the Aquarius meeting in March; one oral presentation at the SMOS conference in May, and he attended the SMAP workshop in September. On behalf of the Aquarius team, he presented the main accomplishments/highlights of the Aquarius mission to Earth Science management. He co-authored a paper that was published in RSE and is currently working on another paper. He designed and submitted a proposal involving RFI investigations using SMOS, Aquarius and SMAP data; his sponsor is the PI, and to date the decision is pending.

Dr. Soldo has led or participated in several other investigations including SMOS, Aquarius and SMAP data. Most notably, he led the comparison of Total Electron Content (TEC) retrievals from Aquarius and SMAP. This work seems to clarify that Aquarius and SMAP are capable of measuring TEC with a better spatial resolution than the current available models. He also led the comparison of RFI in Aquarius and SMOS data, and defined a new metric to compare RFI in these very different instruments. This work led to the improvement of RFI detection in Aquarius. He also examined the differences between salinities retrieved from the three radiometers in Aquarius. This work specifies that the three Aquarius radiometers measure slightly different salinities. The justification of this is unknown; therefore, an investigation is ongoing. He worked to detect Aquarius RFI based on the statistics of measurements, which aims to improve the strategy of detecting RFI. Additionally, he began working on localizing RFI in SMAP data. For this investigation, he has outlined the plan of the work to be conducted. Finally, Dr. Soldo is investigating a possible problem with the orientations (the clocking angles) of the Aquarius horns. This work has the potential to significantly improve the retrievals of Faraday rotation angles.

Dr. Soldo is a member of FARS, a technical committee of IEEE that aims to develop a web-based tool to share information about RFI across the spectrum and in different satellite instruments. In this context, he has managed entirely the inclusion of two of the three instruments currently featured in this tool, from the processing of the satellite data to detecting/characterizing RFI to the actual implementation on the website.

CODE 616: OCEAN ECOLOGY LABORATORY

Dr. Andrea Andrew (sponsor: C. Del Castillo) works on capturing colored dissolved organic matter (CDOM) dynamics in the mangrove forest of Southwest Florida coastline, via the analysis of absorption and fluorescence measurements as well as other parameters including salinity, tidal patterns and location. By developing photodegradation experiments, she aims to determine the photoproduction efficiency of dissolved inorganic carbon (DIC) in this study area. These quantum yields, in conjunction with ocean color remote sensed absorption data, will then be used to estimate the long-term photoproduction of DIC in coastal waters influenced by the Shark River (Florida).

Dr. Andrew has collected and analyzed absorbance, fluorescence and DIC data for over 80 samples, and she presented the results at the 2016 Ocean Sciences Conference in New Orleans in February. Salinity-absorbance data revealed the presence of multiple end members at zero salinity. Along the salinity gradient there was evidence of several CDOM inputs, most likely attributed to the many tributaries clearly visible in the study area. In general, absorbance decreased while the spectral slope increased with offshore distance. This is expected as CDOM undergoes photobleaching or modification as it transits to the ocean, resulting in a loss of absorption and increased spectral slopes (absorbance decreases at a much faster rate with increasing wavelengths).
The method development is almost complete for the photodegradation experiments, which involves the use of a solar simulator to irradiate CDOM samples, followed by the use of a coulometer to measure the CO₂ produced. The solar simulator has been transformed with a sample holder that can accommodate 10cm cylindrical cuvettes and also can facilitate the use of a spectroradiometer and fiber optic cable for the acquisition of spectral irradiance. The CO₂ Coulometer has been reconditioned and now produces data within the error specified by the manufacturer. Instrument parameters for the solar simulator, spectroradiometer and CO₂ Coulometer have been optimized through preliminary experiments. Field work is planned for summer 2016 to obtain additional CDOM samples for photodegradation experiments.

Dr. Andrew will be working on a project that will focus on Black Carbon Analysis (Solid Phase extraction, Microwave Digestion and HPLC) and Lignin Analysis (Microwave Digestion and GC-MS) of aquatic samples in the lab (CDOM). She is working on a report highlighting the required chemicals and reagents, determining instrumental requirements, updating protocols and suggesting changes in previous protocols based on the current literature.

CODE 617: HYDROLOGICAL SCIENCES LABORATORY

Ms. Debbie Belvedere (sponsor: J. Santanello) engages the integration of NASA’s global water and energy cycle research that addresses cross-cutting water-cycle research initiatives introduced by inter-agency and government-administrative science panels. This past year, she was involved in forming the NEWS (NASA Energy and Water Cycle Studies) Team. The NEWS project created new working groups that identify integration needs and make connections to partner and coordinate with water and energy cycle research and application activities occurring at other organizations within NASA, nationally, and internationally. The new working groups are: 1) Uncertainties of Vertically Integrated Water and Energy Budget Components, 2) NEWS Synthesis: Water and Energy Cycle Variability, 3) NEWS Indicator Project, and 4) Energy and Water Cycle Budgets. This working group structure reflects the scientific priorities of the investigators, while still adhering to the basic objectives and goals of the NEWS program.

In 2015, a NEWS Matrix was created for the current NEWS team. Discussions and experiences have revealed that, within working groups, the most progress is made when there are specific science questions to address and strong leadership is provided from a few to corral inputs from group members. Ms. Belvedere’s role was to encourage team members to participate, bring the team together with regular telecoms, and answer NEWS programmatic questions.

Each year, for the Annual GPRA Report, Ms. Belvedere seeks publications and highlights that support NASA’s contribution of scientific advancement against the goal: to demonstrate progress in quantifying the key reservoirs and fluxes in the global water cycle and in improving models of water cycle change and fresh water availability. Documentation is required to review and evaluate progress. This annual report includes an overall summary, key accomplishments and high-impact research results that appear in peer-review literature.

In August 2015, an article was published in GEWEX News titled “The First Decade of Integrated NASA Energy and Water Cycle Studies (NEWS)”, which provided an overview of how NEWS began and how it has progressed, as well as what is planned for the future. This article was written by Dr. Robert Schiffer, Dr. Paul Houser, Ms. Belvedere, and Dr. Jared Entin, and is available at http://www.gewex.org/gewex-content/files-mf/1438893730Aug2015.pdf.

Mr. Richard Lawford (sponsor: J. Bolten) develops and coordinates water resource applications and water cycle activities within Group on Earth Observations (GEO), US GEO. He maintains the coordination, reporting and synergies needed to advance NASA data products and water activities in both international GEO and in US GEO. He also enhances the coordination of GEO water cycle activities in areas of interest to NASA (e.g., drought, precipitation, soil moisture, groundwater, capacity building, evapotranspiration, user engagement, the Water-Energy-Food Nexus, the Sustainable Development Goals, etc.).

**Water Cycle Activities**

Engaging the scientific community in supporting the GEO water task requires substantial coordination and nurturing both within and outside the U.S. He has initiated activities, reported on progress, and explored synergies needed to advance NASA data products and water activities for both international GEO and US GEO. As coordinator for water task-related activities, he reviewed the submission of descriptions of initiatives and activities from NASA and other sources from the 2016 GEO Transitional Work Plan, and consolidated inputs for the GEO Secretariat to use...
in preparing documents for the GEO Plenary in Mexico City in November 2015. He recommended GEO Water activities be placed in the new Work Plan. He worked with Adrian Strauch and Dr. Rifat Hossain to develop a new Community Activity on water and cross-Societal Benefit Area (SBA) activities, which address the Water-Energy-Food (W-E-F) Nexus, Wetlands, and the Water Sustainable Development Goals (SDG). As co-chair of the Societal Benefits Implementation Board (SBIB), he prepared SBIB’s inputs to the GEO Plenary.

A critical mechanism for the coordination of GEO water activities is the Integrated Global Water Cycle Observation (IGWCO) Community of Practice (CoP), which Mr. Lawford chairs. The major issues addressed by the IGWCO COP included engaging stakeholders in response to the GEOSS Water Strategy; clarifying inputs to the 2016 GEO Transitional Work Plan in terms of Community Activities or Initiatives; adjusting work flows to accommodate the new GEO Implementation strategy, and launching and enhancing cross-SBA activities. He helped with planning the 11th annual GEO IGWCO COP meeting in College Park, MD, which attracted international experts as well as program managers and scientists from NASA, NOAA and USGS. Based on these discussions, Mr. Lawford prepared a list of action items, a workshop statement and a comprehensive set of minutes. He led IGWCO CoP teleconferences dealing with follow-up to the GEO Summit and the 2016 GEO Transitional Work Plan, and plans for the 12th annual IGWCO COP meeting held in Koblenz, Germany. A major achievement for the IGWCO COP and Mr. Lawford personally in 2015 was the development of an initial set of actions to address the recommendations in the GEOSS Water Strategy Report (that he previously edited). The Committee on Earth Observation Satellites (CEOS) formed a Water Strategy Implementation Study Team (WSIST) to assess its response to the recommendations. As liaison between the WSIST and GEO Water, he clarified the context for the recommendations and provided feedback on the WSIST proposed actions. In particular, he consulted with the IGWCO COP and provided an assessment of preliminary needs for a study of a “Water Train” (or constellation of water satellites) and proposed ways to advance this assessment.

Mr. Lawford continued to document other (non-CEOS) contributions for the GEOSS Water Strategy Implementation Plan from the Global Terrestrial Network – Hydrology, from IGWCO members (on Extremes) and flagged recommendations for which no action was being taken. He is discussing how GEOGloWS may assist in addressing these gaps. At the November 2015 GEO Plenary in Mexico City, Mr. Lawford organized and chaired a side event on the Implementation of the GEOSS Water Strategy that featured updates from CEOS, GTN-H and GEOGloWS, among others. Actions are planned for more than 60% of the 58 recommendations and more will be forthcoming through GEOGloWS. He presented an overview of the role of Earth Observations in monitoring wetlands in a special session on Global Wetlands Observing System at the GEO Plenary. Further, Mr. Lawford completed a multi-authored article, of which he was first author and involved 11 co-authors, titled “Implementation of the GEOSS Water Strategy: From Observations to Decisions” for the Bulletin of the American Meteorological Society. This article has undergone revision and will be resubmitted.

In September, at the 8th annual Asian-Pacific GEOSS Symposium in Beijing, China, Mr. Lawford co-chaired the Asian Water Cycle Initiative (AWCI) breakout session, including a session on the Water-Energy-Food Nexus, and gave a presentation of the GEOSS Water Strategy. AWCI will include Disaster Risk Reduction and the W-E-F Nexus in its new plans. He gave an AWCI session summary presentation and served on the closing workshop panel in the final plenary. He also gave a seminar on the GEOSS Water Strategy at the Chinese Academy of Sciences. In October, Mr. Lawford gave a presentation for the International Astronautical Congress held in Jerusalem. His paper in the Congress Proceedings outlined ten trends and developments that are likely to affect the role of Earth observations and their applications in water resource management.

**GEOGloWS**

Through USGEO, the U.S. is developing a stronger coordination role for its GEO activities and its inputs to the international GEO program. Strengthening the US GEO Water activity is an important part of this strategy. During the year, several challenges needed to be addressed, including the internationalizing of the GEOGloWS initiative beyond US GEO and merging it with the new GEO structure being implemented for the 2016-2025 time period. Mr. Lawford worked with several U.S. government colleagues to update the GEO Global Water Sustainability (GEOGloWS) strategy with U.S. agency and international inputs.

Regarding the advancement of GEOGloWS, Mr. Lawford made substantive edits to the GEOGloWS document to address comments from USGS regarding water quality and water use; subsequently, the paper was circulated to a broader agency audience for comment. As a result of a NASA/NOAA meeting, the US GEO GEOGloWS initiative will be made more international and a GEOGloWS initiative proposal will be produced for the GEO 2016 Transitional work plan. Mr. Lawford iterated
As the Future Earth lead organizer for the first workshop, Mr. Lawford collaborated with the Texas A&M University and their W-E-F programs. The TAMUS (Texas A&M System)/Future Earth workshop, “Research gaps in the integrated observations and improved governance for the W-E-F Nexus”, was held in Washington, DC in June 2015. Approximately 75 people from four continents participated in the meeting, which attracted program managers from seven agencies plus scientists from universities and government labs, and promoted discussions on agency plans to support future W-E-F research. Mr. Lawford made two presentations on W-E-F issues, chaired several sessions, and served as a rapporteur to a breakout group on Earth Observations and the W-E-F. One critical recommendation was a call for a Nexus CoP; subsequently, he provided comments on the TAMUS proposal for this CoP. This workshop report was prepared by Mr. Lawford and Rabi Mohtar. They also collaborated on an article titled “The present and future Water-Energy-Food Nexus and the role of the Community of Practice” published in the Journal of Earth Studies and Science, which outlines an approach for managing W-E-F research and applications activities by implementing a broad Nexus CoP. The second Future Earth WEF workshop was held in November 2015 at the Fraunhofer Institute in Karlsruhe, Germany. Approximately 40 experts, mainly from Europe, attended the meeting. Mr. Lawford gave two papers, one that summarized some major science issues associated with the W-E-F, and one that discussed NASA assets that could support the implementation of the W-E-F Nexus. He contributed to an introductory presentation and chaired a breakout group on Earth observations and the W-E-F Nexus. He is currently assisting the University of Osnabrueck in preparing the workshop report. For the third Future Earth W-E-F workshop, held at the Research Institute for Humanities and Nature (RIHN) in Kyoto, Japan in April 2016, Mr. Lawford solicited participants and developed the agenda. The workshop focused on filling in some of the gaps in the information gathered to date, including information on the role of land and aquaculture in the W-E-F. Future Earth experts also participated in the meeting and discussed how this study would support the WEF Knowledge Action Network (KAN). The workshop featured sessions on complexity and scaling where observation and modeling issues were explored. The breakout group on Observations and follow-on discussion led to an initiative to address the geospatial mapping of stresses that are affecting the productivity of the W-E-F. Mr. Lawford is working with the staff at RIHN to produce a workshop report.

Note, planning is underway for the fourth and final workshop on WEF and the SDGs, which will be held in November 2016.

Earth Observations and the Water-Energy-Food Nexus

Water, energy, and food are interconnected in many ways and are critical for sustainable development. For example, it is estimated that food production uses 70% of the water that is consumed by human activities while approximately one-third of the world’s energy is used in operations for producing and providing food including farm operations, fertilizers for crops, crop planting and harvesting, food processing, and transportation. Managing the Nexus more efficiently on national and regional scales could result in higher productivity and reduced input requirements. Future Earth has launched a number of short-term fast-track projects related to interdisciplinary science; one project is the Water-Energy-Food (W-E-F) Security project, which is supported through the Belmont Forum. This project will develop a research plan for using integrated information systems (and Earth observations) and improved governance to strengthen W-E-F sustainability. The knowledge and ideas for implementing this program will be based on four regional workshops. The plan will be used by Future Earth, its Food, Energy, Water Knowledge Action Network, and by the Sustainable Water Futures Programme application and solutions activities. In addition, the development of a Community of Practice (CoP) of experts is being considered.

With Dr. Angelica Gutierrez (NOAA) to prepare and submit an initiative proposal to the GEO Work Planning process. A one-page summary regarding GEOGloWS and its implementation was provided for the GEO Summit, where the U.S. delegation highlighted GEOGloWS as one of the U.S. initiatives. Based on feedback from the GEO Plenary, it was agreed that the description of the strategy’s relationship to SDGs should be strengthened. Mr. Lawford revised the document to centralize this theme, and he provided updates to the GEOGloWS document and the GEOGloWS Initiative in the Transitional GEO Work Plan for 2016.

Based on an invitation from the Chair of the Task Team on User Needs for the Japan Cabinet Committee of Space, Mr. Lawford arranged a meeting in Silver Spring, MD between Japanese Task Team members and project managers in NOAA, NASA and USGS to discuss U.S. interests and priorities for a collaborative framework in the area of water missions and water information. GEOGloWS was an area of common interest. He prepared a summary of this meeting for the participants and other interested parties. In April 2016, Mr. Lawford attended the NASA Water Applications PIs meeting and presented the GEOGloWS summary to encourage NASA investigators to play a larger role in addressing priorities within GEOGloWS.

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**Sustainable Development Goals**

The United Nations (UN) has been formulating the Sustainable Development Goals (SDGs) to direct development activities in the Post-2015 era. In September 2015, this agenda was adopted by all 193 nations of the UN. Since October 2015 efforts have been directed at defining indicators that will allow for monitoring targets associated with the 17 goals. Mr. Lawford joined the Task Force on Costing Water SDG indicator networks and provided comments on this group’s documentation. He also participated in a side session on Earth Observations and the SDGs chaired by Dr. Lawrence Friedl (NASA) at the November GEO Summit. As a result of this meeting, a new GEO initiative is being developed to address the SDGs. Mr. Lawford has participated in follow-on teleconference calls and has provided inputs when appropriate to support this effort. He also obtained feedback on an indicators workshop proposal that is being finalized for submission to NASA.

Mr. Lawford was invited by workshop organizers to develop a session on Earth observations and global water indicators for post-2015 Development monitoring in the area of water that was held in Bonn, Germany in August 2015. The observations session identified opportunities for the applications of Earth observations, but participants recognized that data must be processed to be made more relevant to the needs of the SDG community. He chaired a plenary session and contributed to the preparation of the final workshop report. He also participated in a 2015 ICSU assessment of the proposed SDGs and provided input on the water SDG and its relationship to other Goals. The assessment is summarized in the report “ICSU, ISSC, 2015: Review of the Sustainable Development Goals: The Science Perspective”, Paris: International Council for Science (ICSU), 92 pp, ISBN: 978-0-930357-97-9. He also prepared and presented a poster at a SDG science session at the 2015 AGU Fall meeting held in December.

**Other Activities**

Mr. Lawford contributed to NASA participation at the World Water Forum in Daegu, South Korea in May 2015 by linking NASA experts with organizers of several scientific sessions and giving a talk in a wastewater session and in a session on the Efficient Water Management in the Post 2015 period. At the NASA Exhibit at the US Pavilion, he staffed the NASA booth, explained NASA services and products, and gave two talks related to Applications of NASA Observational Capabilities to Address Integrated Water Resources Management and NASA Capacity Building in the Water Sector. After the Forum, he provided feedback on visitors’ interests to NASA program managers.

He provided inputs and updates for presentations made by Dr. Bradley Doorn to US GEO and to Dr. Angelica Gutierrez (NOAA). They discussed necessary steps to advance GEOGloWS in international circles, and developed a one-page summary for the GEO Plenary. He also discussed with Dr. Doorn the best way to address drought within the GEOGloWS framework, and they agreed that a risk-based approach that uses global data is the most appropriate and addresses the problem in ways that are different than the ongoing GEO Global Drought Information System. In support of the GEOGloWS initiative, Mr. Lawford began a paper on tracking the evolution of drought risk through the use of satellite data. At the 2015 AGU Fall Meeting, Mr. Lawford organized a Town Hall session on GEOGloWS and its contributions to the overall GEOSS Water Strategy. He collaborated with Dr. Sushel Unninayar in organizing a session on Monitoring Extremes and presented a poster in the session.

At the International Institute for Sustainable Development and the University of Manitoba, Prof. Charles Vorosmarty and Mr. Lawford held meetings to discuss the potential for establishing a node for the Sustainable Water Future Programme in western Canada. Subsequently, a meeting will be held in Saskatoon, Saskatchewan to further explore this possibility. Possible regional node activities include testing a regional concept for a W-E-F Nexus testbed, developing a data platform for the Lake Winnipeg drainage basin and conducting analytical studies to support the Sustainable Water Future Programme and the W-E-F Nexus. He also initiated discussions with the Long Plain First Nation band (Ojibway First Nations) about how they could use satellite data in their management activities and options for building a capability to use these data. These discussions are generating input for an NASA Ames Research Center initiative for an Indigenous Peoples Needs Assessment.

Additional activities involved the publication of a Conference Working Paper as lead author titled “Adapting to Climate Change: The Role of Science and Data in responding to opportunities and challenges in the Water-Soil-Waste Nexus”. He also participated in a one-day symposium held by Texas A&M University on the topic of “2015 TAMUS – Resource Nexus: Water Forum” in November 2015, where he chaired a session on Multi Stakeholders Landscape of the Water Challenge.

In the coming year, Mr. Lawford will continue to represent NASA interests to GEO in the capacities previously presented. He plans to assist in developing the USGEO and international water activities by contributing to the further development and implementation of a GEOGloWS strategy. He will prepare
a discussion paper on the opportunities for drought research and Earth satellite applications within NASA and GEOGloWS to provide advanced information for both risk-based and deterministic information frameworks. Mr. Lawford will further develop the theme of Earth Observations linkages to the W-E-F Nexus as part of a Future Earth W-E-F project and the SWFP, will be involved in the fourth regional Future Earth W-E-F workshop, and will participate in the SWFP Executive Meeting in summer 2016. Also, he will contribute to the development of NASA application priorities including drought, and evapotranspiration, support international capacity building activities for non-conventional communities, and support efforts and initiatives related to monitoring SDGs. A proposal will be submitted for a workshop on indicators for SDG goals and targets, creating opportunities for NASA and US scientists to participate in SDG monitoring and international capacity building efforts. He also hopes to work on the framework for Earth Observations and water resources decision-making in the Red River of the North international Basin.

**GEWEX**

The Global Energy and Water Exchanges (GEWEX) project of the World Climate Research Programme (WCRP) brings together a significant component of the world climate community in joint initiatives to advance understanding of coupled hydrologic and atmospheric processes from regional to global scales and use observations and models to address the problems of climate and water resources around the world. Scientists from over 45 countries participate in major GEWEX projects aimed at quantifying the hydrologic cycle and energy fluxes by means of global measurements of atmospheric and surface properties; modeling the global water cycle and its role in the climate system; developing the ability to predict variations of global and regional hydrologic processes and water resources and their response to environmental change; and fostering the development of observational techniques, as well as data management and assimilation systems. GEWEX activities involve understanding and modeling land-atmosphere coupling and cloud system processes, global data set development, water resource applications, and the effective use of Earth Observations in climate science.

**Dr. Robert Schiffer** (sponsor: J. Santanello) leads the NASA grant covering the operation of the IGPO. The International GEWEX Project Office (IGPO) facilitates and coordinates GEWEX research, activities, and products. IGPO oversees the implementation of recommendations given by the GEWEX Scientific Steering Group (SSG) and plays a central role in the outreach of GEWEX through its website, quarterly newsletter, and through the organization of science conferences and workshops. IGPO also provides an interface between GEWEX and other WCRP activities, as well as other global environmental science programs and the space sciences programs. During this past year, the Science and Technology Corporation (STC) provided support for activities required to meet the obligations and responsibilities of IGPO and its Director, **Dr. Peter van Oevelen** (sponsor: J. Santanello). This included supporting the GEWEX SSG and its Co-Chairs; assisting with the coordination and implementation of the Third Phase of GEWEX (post-2013) through GEWEX Panels, Working Groups, and the SSG; coordinating the formation of new working groups, panels, and related activities in areas of GEWEX requiring further support; reporting on GEWEX activities to international bodies and government agencies; providing support to WCRP on all aspects of GEWEX and its implementation; implementing an outreach program for GEWEX; representing GEWEX at scientific conferences and other international forums; facilitating the development of cross-cutting issues and the linkages of GEWEX with other programs; preparing/publishing reports and documents relevant to GEWEX; managing requests from scientists for travel financial assistance to attend GEWEX meetings and meetings where GEWEX attendance is required; reviewing plans from WCRP and other environmental programs, providing input and responding to RFIs; and, representing WCRP in International Global Water Cycle Observations Community of Practice (IGWCO-COP) theme and Science Advisory Group through the provision of secretariat services and contributions to the Group on Earth Observations (GEO), where appropriate.

This past year, IGPO supported GEWEX SSG activities. IGPO planned, attended, and supported the SSG meeting on 25-28 January 2016 at ETH in Zürich, Switzerland. Activities included coordinating travel grants with WCRP, developing the agenda in coordination with the SSG Co-Chairs, and implementing and maintaining the meeting website, which contained logistics information, GEWEX Panel status updates, and copies of the presentations. IGPO drafted and is now finalizing the meeting report and action items.

IGPO also supported activities related to WCRP and the WCRP Joint Scientific Committee (JSC). GEWEX is leading two of the six WCRP Grand Challenges, and has links to the other four. IGPO is assisting the GEWEX SSG Co-Chairs in setting up and outlining activities related to these Grand Challenges, as well as working with the GEWEX Panels in aligning their activities to them. IGPO hosted a GEWEX Executive Meeting in Washington, DC in September 2015. The WCRP Joint Planning Staff liaison for
GEWEX participated in the meeting, which also was attended by the SSG and Panel co-chairs. The main purpose of the meeting was to discuss the necessary actions to address the GEWEX Science Questions and the WCRP Grand Challenges. IGPO is assisting the GEWEX SSG co-chairs in selecting candidates for new SSG members to replace those whose term ended in 2015. The list of candidates and their backgrounds were presented for approval at the JSC meeting in late April in Geneva, Switzerland. In February 2016, the Director of IGPO attended the Climate and Cryosphere (CiC) SSG Meeting to explore potential joint activities related to the WCRP Water Grand Challenge, and is finalizing the draft implementation plan for the WCRP Grand Challenge on Water Availability (Water Availability for the Bread Baskets of the World) and will present it to the JSC for approval. IGPO is also supporting the development of a new CLIVAR/GEWEX JSC task group on extreme weather and climate.

IGPO is actively seeking a new Global Atmospheric System Studies Panel (GASS) Chair. For the GEWEX Data Assessments Panel, IGPO attended and provided support to the GEWEX Data and Assessments Panel (GDAP) annual meeting in October 2015 in Xiamen, China. IGPO is also supporting efforts to maintain the location of the World Radiation Monitoring Center (the central data archive of BSRN) at the Alfred Wegener Institute for Polar and Marine Research. IGPO drafted and sent a letter confirming the new Baseline Surface Radiation Network (BSRN) Project Leader, confirming his appointment. For the GEWEX Hydroclimatology Panel (GHP), IGPO created a meeting website, sent invitations and assisted with logistics and planning for the annual GHP Meeting. In addition, IGPO provided onsite support for the meeting, which was held in November 2015 in Entebbe, Uganda. The Director of IGPO attended the final international science conference, highlighting the results of the Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative (MAHASRI) RHP in March in Tokyo, Japan. Also in March, Dr. van Oevelen attended the WMO/India Meteorological Department Regional Stakeholder Consultation on Climate Services for the Third Pole Region in Jaipur, India in March. This was a part of the program for implementing the Global Framework for Climate Services (GFCS) at Regional and National Scales. The Third Pole Region is associated with high climate variability, extremes and a fragile ecosystem. IGPO is investigating the possibilities for a RHP in this region as well as a RHP located in Latin America. IGPO sent numerous correspondences related to GHP projects and project members.

IGPO manages several types of communication products. The GEWEX Newsletter is distributed on a quarterly basis to approximately 2,000 people. IGPO develops, publishes, and distributes GEWEX News. For every issue, IGPO determines the content, solicits articles, and collects, edits, and formats these for layout in the newsletter. All past issues of the newsletters are available on the GEWEX website. Also, IGPO periodically distributes an electronic newsletter that includes recent news of interest to the GEWEX community that is time sensitive, including calls for papers and research and position announcements. In addition, IGPO hosts (including domain registration), maintains, and continually updates the GEWEX website (http://www.gewex.org), which provides recent GEWEX science results, overviews of the structure and organization of GEWEX and its projects, access to GEWEX reports and publications and GEWEX data sets, updates on recent and planned activities, and a calendar of project meetings and conferences. In May 2015, IGPO launched a newly designed GEWEX website with a responsive layout that is easy to read on tablets and cell phones. IGPO has worked closely with the GEWEX Panel and project leaders to include the latest information on the website. The new website is more user-friendly and easier to navigate, and includes social media integration, a new events calendar, and search engine. IGPO also implemented a new online registration system for meetings. The affiliate GEWEX website, gewexevents.org, is undergoing a redesign that will allow it to better host information for meetings and workshops coordinated by IGPO.

IGPO participated in collaborative Activities with other groups throughout the year. To encourage the involvement of young scientists in GEWEX/WCRP activities, IGPO invited the Young Hydrologic Society and the Young Earth System Scientists Community to contribute one-half page in each issue of GEWEX News to advertise their activities. IGPO is assisting in the planning of cross-collaboration activities of GEWEX and the integrated Land Ecosystem-Airshpere Processes Study (iLEAPS), of which the importance was recently highlighted by the signing of a MOU between WCRP and iLEAPS. The Director of IGPO gave a Skype presentation at the March iLEAPS SSC Meeting. Also, GEWEX and CLIVAR joint activities include the new JSC task group on extreme weather and climate, and the WCRP Monsoon Panel.

Dr. van Oevelen, the IGPO Director, co-chairs the International Soil Moisture Working Group, one of the drivers in establishing the global soil moisture in situ network, and supports the ESA Water Cycle Multi-Mission Observation Strategy (WACMOS) as the Chair of the Advisory Board. He also serves on multiple boards: the Executive Board of the Science Committee for the Integrated Global Water Cycle Observations (IGWCO) CoP of the Group on...
Earth Observations (GEO) (and provides input to the Water Cycle Societal Benefit Area under GEO); the Board of the Helmholtz Alliance as a user group representative; and, the Board of the FP7 Project Earth2Observe Project.

The following is a compilation of meetings and workshops that IGPO staff supported or attended from May 2015 – Apr 2016: for May 2015, GLASS Panel Meeting, Toulouse, France; Joint GLASS/GABLS – DICE Workshop, Toulouse, France; Japan Geosciences Union International session on “Asian Monsoon Hydroclimate”, Chiba, Japan; World Water Congress XV, Edinburgh, Scotland; for June 2015, Chapman Conference on Evolution of the Asian Monsoon and its Impact on Landscape, Environment and Society Hong Kong, China; 1st WCRP Summer School on Climate Model Development: Atmospheric Moist Processes, Hamburg, Germany; 26th IUGG General Assembly 2015, Prague Congress Centre, Czech Republic; International Symposium Retrospective and Perspective in Land Surface Processes and Interactions – from HCMM to Sentinel Missions and Beyond, Enschede, The Netherlands; for July 2015, 4th Session of the WCRP Data Advisory Council, Reading, UK; for Aug 2015, 14th International Swiss Climate Summer School – Extreme Events and Climate, Ascona, Switzerland; for Sept 2015, GEWEX Executive Meeting Washington, DC; 9th HyMeX Workshop, Mykonos, Greece; EGU Outreach Committee, Haarlem, Netherlands; Annual GDAP Meeting, Xiamen, China; for Oct 2015, International Conference on Water Resources Assessment and Seasonal Prediction, Koblenz, Germany; Earth Observation for Water Cycle Science 2015 ESA-ESRIN, Frascati, Italy; Land Modeling “LandMIP” Workshop, Zurich, Switzerland; Land Surface, Snow and Soil Moisture Model Intercomparison Project Workshop, Zurich, Switzerland; for Nov 2015, GEWEX Water Vapor Assessment Workshop, Madison, Wisconsin; PANNEX: GEWEX Workshop on the Climate System of the Pannonia Basin, University of Osijek, Croatia; GHP Annual Meeting, Entebbe, Uganda; for Dec 2015, 2nd Annual OzEWEX Workshop, Queensland, Australia; 2015 AGU Fall Meeting, San Francisco, CA; for Jan 2016, GEWEX SSG-28 Meeting, Zurich, Switzerland; for Feb 2016, CiC SSG Meeting, Copenhagen, Denmark; for Mar 2016, MAHASRI International Science Conference, Tokyo, Japan; Regional Consultation on Climate Services for the Third Pole Region, Jaipur, India; iLEAPS SSC Meeting, India; Austin International Conference on Soil Monitoring, Austin, Texas; for April, WCRP Joint Scientific Committee Meeting, Geneva, Switzerland.

Additionally, IGPO organized the Water Availability Grand Challenge for North America Workshop held on 3-5 May 2016 at USRA Headquarters, Columbia, MD. IGPO created a workshop website with online registration and developed an early career scientist video contest. This workshop explored creating a GEWEX Regional Hydroclimate Project (RHP) that addresses the water challenges facing the central western North American continent, as well as the creation of an RHP that tackles water availability from different vantage points: high-resolution climate modeling, evaluation of climate projections, mountain hydrology, observations, ecosystem science, socioeconomic and political impacts, and the intersection of water, energy, and people. The objectives of the conference were determining program elements and structure; establishing science focus areas and identifying leaders for each area; confirming a planning committee; and, developing an independent plan or path forward for each focus area plus identifying next steps.

Under a second task, Dr. Robert Schiffer (sponsor: J. Santanello) provides technical, administrative and managerial support and assistance to the Earth Science Division at NASA Headquarters on energy and water cycle-related research as part of the NASA Energy and Water Study (NEWS) program. The overarching goal of NEWS investigations is to integrate Earth Science components to make decisive progress towards the NEWS challenge. NEWS investigations integrate and interpret past, current, and future space-based and in situ observations into assimilation and prediction products and models that are global in scope.

Dr. Schiffer assisted the NEWS program in oversight and coordination of the NEWS Science Working Groups established in 2013. The Cloud and Radiation Working Group links clouds, precipitation, and the energy budget with an initial focus on the southeastern Pacific, and stresses the importance of boundary layer clouds to the radiative energy budget, the relationships between clouds and radiative effects, and the impacts of precipitation on cloud and radiative properties. The Extremes Working Group aims to understand severe drought in the United States. The 2012 drought may not have been predictable based upon current schemes employed for such purposes; however, it may have been anticipated due to knowledge of key precursors, such as favorable (remote) sea surface temperature patterns, and reduced regional soil moisture and winter snow packs. This Working Group will examine the extent to which the 2012 drought could have been anticipated and how to put recent severe droughts in perspective. The Climate Shift Working Group analyzes a climate shift in order to gain perspective on future events. During the last 25-30 years of satellite and reanalysis information, global warming of the Earth’s surface and increases in ocean water vapor are evident, primarily in the pre-1998
period, with a leveling off of these increases in the post-1998 period. This “climate shift” is similar to an earlier interdecadal change event in the late 1970s and has been linked to changes in ocean-atmosphere interactions linked to Pacific Decadal Variability (PDV), although other processes (e.g., AMO, aerosols) could also be involved. There is evidence that other components of the water (and energy) cycles show a shift at approximately the 1998-2000 point as well; however, not all the global data sets and reanalyses agree and/or have homogeneity issues. The objective of this working group is to understand and better document the “shift,” and the strengths and weaknesses of global data sets and reanalyses to build a group consensus as to “what happened” and which data sets and reanalyses can be used, and with what level of confidence. This activity will point to possible actions to improve the data sets and reanalyses to enable more confident studies in the future. Finally, the Evaporation and Latent Heating Working Group evaluates latent heating over a selected region for the NEWS time period of 1998-2007 in order to determine mean seasonal flux, interannual variability, and the statistical distribution of events. This will lead to an analysis of extremes and other aspects of the distribution, and how they relate to surface variability and atmospheric transport variability. An analysis of the extremes can then be tied to specific weather events, such as atmospheric rivers or cyclonic events, and to an analysis of trends in the transport over the time period.

Results of this and earlier NEWS research was reported in a summary titled “The First Decade of Integrated NASA Energy and Water Cycle Studies”, published in the August 2015 issue of the GEWEX Newsletter (vol.27 No.3), which was previously referenced in this annual report. More recently, Dr. Schiffer organized and supported a NEWS Science Team meeting in March 2016 at USRA Headquarters, Columbia, MD. The hope is that this meeting will lead to the formulation of new NEWS Science Teams based on investigations approved by NASA in response to the ROSES-2013 solicitation. Several approved investigations were reviewed at the meeting, each led by the following researchers: J. Wang/ Georgia Tech; R. Adler/UMD College Park; L. Stott/US Southern California; P. Houser/GMU; T. L’Ecuyer/U. of Wisc-Madison; A. Behrangi/JPL; B. Olson UMBC/ GSFC; J. Roberts/MSFC; B. Mapes/RSMAS; M. Bosilovich/GSFC; M. Bourassa/Florida State Univ.; J. Famiglietti/JPL; Z. Pu/ Univ. of Utah; D. Waliser/JPL; A. LeGrande/GISS; H. Su/JPL; M. Rodell/ GSFC; S. Margulis /UCLA; and T. Liu/JPL. An update of the NEWS Master Matrix Spreadsheet is underway.

Dr. Schiffer assisted with compiling the 2016 GPRA report, and supported NASA HQ in implementing the peer review process for the Water Cycle ROSES solicitations (subject to NASA regulations). He also assisted the International GEWEX Project Office (IGPO) in organizing a conference on a North American Regional Climate Effort. This workshop, which addresses both NEWS and GEWEX scientific issues, will explore creating a regional hydroclimate project that tackles water availability from different vantage points: high-resolution climate modeling, evaluation of climate projections, mountain hydrology, observations, ecosystem science, socioeconomic and political impacts, and the intersection of water, energy, and people. Conference objectives include determining program elements and structure; establishing science focus areas and identifying leaders for each; confirming a planning committee; and, developing an independent plan or path forward for each focus area and identifying the next steps.

In the year ahead, Dr. Schiffer will continue to support NASA HQ coordination and management of the NEWS Program. He also will organize a session at the 2016 AGU Fall meeting on Energy and Water Cycling: Regional to Global Variability to focus on how understanding and quantifying the effects of water and energy exchanges in the current and changing climate can be improved and how the uncertainties can be conveyed to society. New approaches are being developed to investigate water cycle behavior across various spatial scales (e.g., atmospheric rivers and water isotopes). These new methods have the potential to provide new insight into the complex hydrological cycle. This session will address uncertainty in current data sets, consistency among water and energy budget components, and how these factors relate to our understanding of recent climate variability. Extremes, especially water and energy cycle dynamics behind those extremes, are of particular interest.

Mr. Thomas Stanley (sponsor: D. Kirschbaum) develops tools for landslide hazard assessment. The Landslide Hazard Assessment for Situational Awareness (LHASA), a landslide model calibrated in Central America with TMPA data, was adapted to use the Integrated Multi-satellitE Retrievals for the GPM data product (IMERG) rainfall estimates. The performance of the adapted model was generally good, but an anomaly in IMERG at San Jose, Costa Rica propagated through to LHASA output. This past year, in response to a deadly landslide in suburban Guatemala City, the American embassy requested assistance in assessing landslide hazard. A preliminary landslide susceptibility map with a resolution of 30 meters was prepared for the Guatemala City metropolitan area and sent

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to U.S. officials. The effectiveness of LHASA in this instance was reviewed. Also, in mid-September, the U.S. Army requested assistance in responding to a request for information about El Niño and natural disasters by the Ambassador to Peru. Within one week, a landslide nowcast for Peru was validated against the GLC and made available online.

Mr. Stanley created a global landslide susceptibility map with the heuristic fuzzy logic method previously used in Central America and Nepal. This map incorporates information on the distribution of roads, faults, geological materials, slope, and forest loss. In order to improve predictions in alpine regions, a new SRTM-based terrain map had to be developed. The map was validated with the Global Landslide Catalog. Additionally, a new global landslide model incorporating a 7-day antecedent rainfall index was developed to use TMPA inputs. The model was adjusted to utilize IMERG rainfall estimates, which have several advantages, including spatial resolution, temporal resolution, and additional sensors. This model also was validated with the Global Landslide Catalog.

In the upcoming year, Mr. Stanley will work on documenting the progress made on global landslide hazard assessment in three papers. The first will be on quantile mapping of precipitation data, the second will be on the global landslide susceptibility map, and the third will be on the global landslide nowcast model. He also hopes to develop a landslide forecast model, forced by GEOS-5 weather predictions. Mr. Stanley had submitted a proposal to assess the risk from landslides to roads in Nepal; if funded, this work would last for a three-year period.

Ms. Kristen Weaver (sponsor: D. Kirschbaum) is an Education & Communication Specialist for GPM, which involves managing and supporting multiple projects within the GPM E/PO portfolio. She works with the GPM E/PO team to implement new initiatives that align with GPM’s E/PO plan and lead or supports E/PO projects. Over this past year, Ms. Weaver has run or helped run 20 distinct educator professional development sessions reaching over 600 participants, ranging from K-12 classroom teachers, librarians, and informal/extracurricular educators. Formats ranged from one-hour webinars to a week-long workshop held at Goddard Space Flight Center, and included presentations and posters at conferences of the National AfterSchool Association and the 2015 AGU Fall Meeting. In addition, another ten STEM engagement events, the largest of which was the NASA Classroom at the Odyssey of the Mind World Finals, have reached an additional 1,500 students and 400 adults. She also has supported a series of training webinars aimed at users of GPM data for applications purposes, such as research into flooding, landslides, drought monitoring, etc.

In her communications role, Ms. Weaver has helped organize and staff tables, either just for GPM or as part of a larger NASA effort, at large outreach events such as Weather & Climate Day at the National Aquarium in Baltimore, the Wallops Flight Facility 70th Anniversary Open House, Explore@NASA Goddard, the American Association for the Advancement of Science Family Days, the USA Science and Engineering Festival, Earth Day at Union Station, Rockville Science Day, and Maryland Day. In total, she and the members of the GPM E/PO team have shared information about GPM and precipitation science directly with over 7,000 members of the general public, at events reaching many times that number.

Ms. Weaver was co-author and project lead for GPM’s new educational comic book, “Raindrop Tales: GPM Meets Mizuchan,” which tells the story of the science and technology of the GPM satellite through Japanese-style manga art (the satellite was built in collaboration with JAXA). The comic has been well received by educators, even being tweeted about by the National Ambassador for Young People’s literature in March 2016.

Upcoming outreach activities include helping at a NASA booth and kids’ activity table at Awesome Con in early June, as well as hosting a citizen science panel at this event. She and other
members of the Goddard E/PO community will be returning to host the NASA Classroom at the Odyssey of the Mind World Finals in late May. The GLOBE El Niño Field Campaign will continue through the beginning of 2017.

**CODE 618: BIOSPHERIC SCIENCES LABORATORY**

Dr. Assaf Anyamba (sponsor: C. J. Tucker) conducts research using time series satellite vegetation index measurements from various satellite instruments and associated ground-based rain gauge measurements. Research also focuses on land surface response to interannual climate variability associated with El Niño/Southern Oscillation (ENSO), drought pattern analysis, and long-term trends and dynamics of vegetation patterns, as well as development of long-term data records of the biosphere and links between climate variability and vector-borne disease outbreaks. Dr. Anyamba leads and develops research analysis and applications for global agricultural and drought monitoring for the USDA Foreign Agricultural Service (USDA/FAS), climate variability and vector-borne disease prediction mapping in support of the DoD Global Emerging Infections Surveillance and Response System (DoD/GEIS) and the USDA Center for Medical, Agricultural & Veterinary Entomology (USDA/CMAVE) and in the geospatial risk assessment of plant pathogens in support of the FDA.

Dr. Anyamba’s work focuses heavily on Rift Valley Fever, a mosquito-borne zoonotic emerging infectious viral disease caused by RVF virus (RVFV) (Bunyaviridae: Phlebovirus) that presents significant threats to global public health and agriculture in Africa and the Middle East. Dr. Anyamba co-authored a paper with Drs. Linthicum and Britch (USDA/ARS) titled “Rift Valley Fever: An Emerging Mosquito-Borne Disease” in the prestigious Annual Review of Entomology (ARE): Linthicum, K.J. (USDA-ARS), Britch, S.C. (USDA-ARS), Anyamba, A. (USRA/618) (2016), Rift Valley Fever: An Emerging Mosquito-Borne Disease, Annual Review of Entomology, Vol. 61: 395-415, doi: 10.1146/annurev-ento-010715-023819. RVFV is listed as a select agent with significant concern for international spread and use in bioterrorism. RVFV has caused large, devastating periodic epizootics/epidemics in Africa over the last ~60 years, with severe economic and nutritional impacts on humans from illness and livestock loss. In the last 15 years alone RVFV caused tens of thousands of human cases, hundreds of human deaths, and >100,000 domestic animal deaths. Cattle, sheep, goats, and camels are particularly susceptible to RVF and serve as amplifying hosts for the virus. This review highlights

**Rift Valley Fever in South Africa study region map of the Free State Province showing land cover classification and farm boundaries. Also shown are the mosquito vector sampling and weather station locations. Image provided by A. Anyamba.**
recent research on RVF, focusing on vectors and their ecology, transmission dynamics, and use of environmental and climate data to predict disease. Important directions for future research are also discussed. This manuscript is an analytical review of 40+ years of work on various aspects of Rift Valley fever research and early warning systems.

Dr. Anyamba and Alan Kemp (CEZD-NICD-South Africa) conducted field work in the Free State Province, South Africa at field sites for intensive mosquito sampling, rainfall and NDVI measurements as part of a five-year Rift Valley fever in South Africa project. The fieldwork is a critical component of this project, funded by the Defense Threat Reduction Agency (DTRA), led by EcoHealth Alliance (http://www.ecohealthalliance.org/) in collaboration with South Africa’s Center for Emerging and Zoonotic Disease National Institute for Communicable Diseases (CEZD-NICD) and GESTAR/GIMMS Group. The fieldwork was aimed at assessing the soil and vegetation types suitable for floodwater Rift Valley fever mosquito vectors and geolocating sites for normalized difference vegetation index and rainfall monitoring by satellite. In the coming months, Dr. Anyamba will travel to South Africa to continue to conduct Rift Valley fever fieldwork in support of this EcoHealth Alliance project to georeference various locations for coincident rainfall, vegetation, land surface temperature monitoring and mosquito vector collection.

In June 2015, at the Global Vegetation Science Session of the 36th Canadian Symposium on Remote Sensing, Dr. Anyamba presented on “Global ENSO Teleconnection Patterns derived from NDVI3g: 1981-2013” and Dr. Compton J Tucker (GSFC) presented on “A Non-Stationary 1981 to 2014 AVHRR NDVI Time Series “ in, St John’s Newfoundland and Labrador, Canada. Dr. Tucker organized and chaired the Global Vegetation Science session. These presentations summarize the utility of the 30+ Global Vegetation measurements derived from the Advanced Very High Resolution Radiometer (AVHRR) instrument onboard the NOAA Polar Orbiting Satellite platform since 1981. Both the operational and long-term NDVI data sets are processed by the GIMMS Group and widely used in environmental monitoring, famine early warning systems, agricultural monitoring, global climate models (land surface component) and ecologically coupled vector-borne disease studies.

Dr. Anyamba was invited to join the interagency Pandemic Prediction and Forecasting S&T Working Group (PPFS&T) organized under the Subcommittee on Biological Defense Research and Development (BDRD) Committee on Homeland and National Security, National Science and Technology Council. The goal of the group, which is comprised of experts from across the U.S. Government, is to improve warnings and predictions for infectious disease threats to human and animal health. During this past year, Dr. Anyamba, Dr. Kenneth Linthicum (USDA) and CDR Jean-Paul Chretien (DoD-AFHSC) contributed a brief on “El Niño and Rift Valley fever risk, East Africa: Prediction, Preparedness, Prevention” for consideration. The alert was featured on the Climate.gov website: https://www.climate.gov/news-features/understanding-climate/el-ni%C3%B1o-east-africa-and-rift-valley-fever.
Work in the months ahead will involve work on the manuscripts “Global Teleconnections Mapping using the new AVHRR NDI3g data set” and “Disease Outbreaks Associated with the 2015-2016 Niño event”. Dr. Anyamba will work on proposals focused on 1) Rift Valley fever risk monitoring, mapping and prediction and 2) Global climatic monitoring of conditions associated with Chikungunya and Zika Outbreaks. He also will present and participate in several workshops and meetings, including an invited presentation at the ASM Microbe 2016 meeting in Boston, MA in June 2016.

**Dr. Amanda Armstrong** (sponsor: K. Ranson) works on developing and testing new techniques which combine remote sensing with ecological modeling to measure and predict forest growth and response to changing conditions. She worked on developing the Howland, ME model parameterization. The SIBBORK spatially-explicit individual-based forest growth model was chosen to pilot the Remote Sensing Theory project for two of the three study sites because of the spatially explicit format, ease of tethering with satellite imagery, and because it is a recently developed model, developed by converting code of the ZELIG model (from Fortran to python), with improved light climate characteristics. In order to run SIBBORK for the Howland, ME study site, model parameters need to be developed for the specific forest site, the driver files that direct the code need to be re-written with the new parameters, and the new model parameterization then needs to be tested against forest inventory data from the study site.

Site-specific datasets for forest inventory, soils, weather and weight tables have been gathered and compiled. Relevant environmental variables were converted into .hdf spatial format files, and tree allometric and growth variables are in the process of being calculated. The driver file is in the process of being re-written with the new parameters. In the coming year, the capacity to ingest satellite-derived parameters in a spatial presentation will be developed. The goal will be to directly import .hdf files derived from improved LUTs to initialize the model. Model testing will be verified by forest inventory datasets.

Dr. Armstrong is involved with the Hyperion Libya-4 Cal/Val TOA calculation. The original scope of this work, which is in collaboration with Christopher Neigh and under the direction of Dr. Elizabeth Middleton as part of the EO-1/Hyspiri Working Group, was to calculate TOA reflectance for the Libya-4 PICTs site. Dr. Neigh has been investigating a number of variables with respect to calibration and validation of Hyperion and ALI data at the Libya-4 PICTs site. The TOA reflectance time series was initiated to investigate the effects of satellite precession on TOA. To accomplish this goal, 30 images of Libya-4 from 2004 to 2015 were downloaded, co-registered with WV1/WV2 images of the same site, and subsetted to include the areas that overlapped in all 30 images. Top of atmosphere reflectance was then calculated across all 242 bands. After the initial scoping with the 30 images, the project was expanded to include 395 images from 2004 to present at Libya-4, and in addition, 190 images from 2007 to present for Dome-C (another PICTS site). Due to the depth and breadth of the time series in this new analysis, the calculations will be made on the NCCS ADAPT cloud. The new analyses are as follows, with respect to the effects of satellite precession over time: 1) a Top of Atmosphere (TOA) time series analysis; 2) full smile/frown artifact analysis; 3) overall precision analysis; and 4) slope and aspect analysis. The result of these analyses will be used formulate projections for orbit degradation impacts in 2016.

Further work involved using Hyperion-Derived Vegetation Indices to initialize an individual-based model. Initiated under the direction of Dr. Middleton as part of the future applications of EO-1 data, this research is in conjunction with recent calls by NASA headquarters for more research that focuses on the application of forest models with NASA satellite projects to project the fate of forested ecosystems globally. The investigation was undertaken to assess a number of hyperspectral dataset- derived vegetation indices as inputs into individual-based models.

The SIBBORK-ME model will be used to accomplish this research, which is being conducted in collaboration with Drs. Petya Campbell and Qingyuan Zhang to examine scale leaf-level variables like faPAR and water stress to inform modeled growth output through time in Howland, ME. The SIBBORK parameterization is underway and vegetation indices feasibility is being assessed in a through literature review. Upon completion of the Hyperion Vegetation Indices assessment toward initializing ecological models project, she plans to draft a manuscript of the results.

This past spring, Dr. Armstrong was awarded funding through USRA’s IRAD in support of primarily the Remote Sensing Theory research, and secondarily the EO-1 Hyperion Vegetation Indices and Modeling research. The funds will allow for travel to Leipzig, Germany during the summer of 2016 to code and test a Costa Rican version of the FORMIND model.
Dr. Richard Damoah (sponsor: C. J. Tucker) supports the FDA’s interagency agreement between scientists at FDA’s Center for Food Safety and Applied Nutrition (CSFAN) and NASA Goddard Space Flight Center on designing, building and operating a Geospatial Risk Assessment Model of environmental contamination of produce by enteric pathogens. The model incorporates USDA National Agricultural Statistics Service (NASS) cropland map layer (impact layer), Feedlot, dairy and poultry locations (pathogen sources) and NCEP Rainfall and MODIS Vegetation Index (pathogen likelihood indicators). This will enable CFSAN to communicate to industry specific areas with likelihood, environmental contamination of produce by E. Coli and Salmonella where early surveillance investigations should be conducted. With Dr. Damoah’s expertise in meteorology and climate, his primary role is to investigate the met/climatic variables associated with Pathogen activity. Dr. Damoah also supports CHORI’s (Children’s Hospital and Research Center at Oakland) effort led by Dr. Assaf Anyamba to investigate the burden of Chikungunya virus (CHIKV) and Dengue virus (DENV) transmission, infection and disease in Kenya. His role in CHORI is to extract, process and analyze NOAA’s African Rainfall Climatology rainfall data at the study locations and make the data available to the project members. This past year, as part of the Dengue and Chikungunya vector–borne diseases study in Kenya, he constructed and has updated the rainfall system analysis website. He and Dr. Anyamba presented a poster at the 2015 AGU Fall Meeting on their work on rainfall analysis in Africa.

Dr. Damoah is involved in several collaborations with Morgan State University. He is collaborating with Dr. Nkwanta of the mathematics department on a DHS-funded project to examine the Malaria outbreak in US and climate data. He also is collaborating with Dr. Peters of the education department on a NASA-funded project to provide climate change professional development to pre-service teachers. During the last year, with his ASCEND proposal funds, Dr. Damoah acquired a radiosonde ground system to profile the weather condition over Morgan, and he successfully launched on December 3, 2015 the first-ever weather balloon to profile the weather conditions at Morgan State University. Subsequently, he is producing daily weather reports for MSU campus TV (BEARTV) and radio station (WEAA) using data from the MSU weather station. Additionally, he has upgraded the MSU weather station to include camera and lightning sensors.

Dr. Damoah also collaborated with All Nations University College (ANUC) of Ghana. On September 17, 2015, his personal initiative culminated in a historic signing of an agreement between NASA and All Nations University College (ANUC) for the establishment of an AERONET ground station at ANUC. Dr. Brent Holben signed on behalf of NASA and Dr. Samuel Donkor (President, ANUC) for ANUC. Following the agreement, an AERONET station was installed at ANUC on December 15, 2015 with Dr. Damoah as the PI for that station (see http://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_opera_v2_new?site=Koforidua_ANUC&nachal=2&level=1).

In the coming months, Dr. Damoah will attend and present a talk at ANUC’s Satellite workshop in May 2016 in Ghana. Other talks are planned at a workshop organized by WASCAL, a German West Africa initiative in Burkina Faso in May 2016 and at St. Monica University in Cameroon during their Research Forum conference in June 2016. He will continue to update the system he constructed for the analysis of ARC rainfall data as part of the vector-borne diseases study in Kenya.

Dr. Junchang Ju (sponsor: J. Masek) works toward building a harmonized Landsat and Sentinel-2 dataset of frequent observations. This past year, the processing system for the harmonized Landsat and Sentinel-2 data project was implemented and tested in the NASA Ames high-performance environment. The system provides atmospheric correction and BRDF adjustment for both Landsat and Sentinel-2 data. Landsat data are rendered into the Sentinel-2 spatial data frames and mis-registration between the two data sources is corrected. The system also compensates for any bandpass difference between the two data sources. Sample data sets for a few test sites have been generated. He gave a presentation on this at the Multi-Source Land Imaging (MuSLI) meeting in Rockville, MD and also at the Landsat Science Team meeting in January 2016. Dr. Ju
also had two papers published recently in Remote Sensing of Environment, one as first author and another as third author. Future work involves running the system for all 39 MuSLI test sites, and making the data available at the project ftp site http://hls.gsfc.nasa.gov/pub.

Dr. David Lagomasino (sponsor: T. Fatoyinbo) processes and analyzes passive and active remote sensing imagery in order to develop forest biomass and carbon models. He uses a combination of Landsat, WorldView, TanDEM-X, SRTM, and airborne lidar data to measure changes in the spatial cover and vertical structure of carbon-dense mangrove forests. His research efforts help to support several international research projects in the Americas, Africa and Asia. As part of his membership with the NASA Carbon Monitoring Systems Program Science Team, Dr. Lagomasino serves as the chair for the External Communications Working Group; as such, he helps guide the direction of information transfer between stakeholders, data users, and scientists. He also has assisted with an intensive forest survey with partners in the US and Tanzania. Several scientific publications have resulted from his research in 3D modeling of mangrove forests with several more planned. He also assists with the development of domestic and international research proposals. His recent efforts have led to a three-year funded wetland vulnerability study and a potential collaboration between Mexico, Puerto Rico, and Cuba.

Dr. Lagomasino was awarded a NASA New Investigator Grant and will lead a three-year project to study wetland vulnerability in Everglades National Park. His project, titled “Linking Carbon and Water Dynamics in the Pursuit of Predicting Peat Collapse in Coastal Wetlands”, will investigate the effects of sea level and salt water intrusion on soil stability and habitat structure. A combination of field, airborne, and spaceborne measurements will be integrated in order to predict areas prone to rapid changes in soil elevation. His project leverages several established, long-term ecological research sites along with a network of interdisciplinary scientists, water managers, and students.

He assisted with a four-week field campaign in the Rufiji delta of Tanzania. He and other researchers from NASA, US Forest Service, Forest Department of Tanzania, and the University of Dar es Salaam conducted intensive forest and soil surveys in the largest intact mangrove forest in Tanzania. The field campaign was part of a larger NASA Carbon Monitoring Systems project investigating changes to blue carbon, or coastal wetland ecosystems. During his trip to the Rufiji delta, Dr. Lagomasino led a Blue Carbon Remote Sensing workshop held at the Tanzanian Forest Department. During this workshop, he described current forest monitoring applications as well as new 3-dimensional remote sensing techniques using radar and very high resolution imagery.

During the Coastal and Estuarine Research Federation's biennial science meeting in Portland, OR, Dr. Lagomasino presented his team's blue carbon research to other scientists focused on coastal processes. The presentation covered the physics behind vertical mangrove mapping, and the ability to estimate biomass concentrations across large swaths of mangrove forests. This meeting allowed for the exchange of remote sensing information from NASA with data collected on the ground. He met with several potential collaborators and would eventually conceive and submit an international research project that was proposed to this year’s NASA Carbon Monitoring Systems Program solicitation.

He was lead author of an open-source science paper published in Remote Sensing. The paper describes the variability, accuracy, and bias of several remotely sensed mangrove canopy height models. Mangroves in the Zambezi delta served as the test site to compare models derived from airborne lidar and spaceborne radar and optical imagery. Recent improvements in satellite technology have led to increased spatial resolutions providing extremely detailed canopy height models. In his paper, “A Comparison of Mangrove Canopy Height Using Multiple Independent Measurements from Land, Air, and Space”, Dr. Lagomasino reports that satellite-derived models using polarimetric SAR and stereophotogrammetry compare extremely

Dr. Lagomasino reads a GPS with a student from the University of Dar es Salaam in order to record the location of various land cover types in the Rufiji delta. Observing the actual land cover on the ground will provide a way to validate land cover models that are determined using satellite imagery. Image provided by D. Lagomasino.
Dr. Lagomasino plans to mentor a summer intern, supervise an international remote sensing researcher from Bangladesh, and advise a graduate student. Similarly, he will assist with reports and manuscripts related to the visiting researchers. Dr. Lagomasino also will begin his new wetland vulnerability study in the Everglades, consisting of a dedicated graduate student and a coupled field-airborne campaign. He will continue his work with Dr. Fatoyinbo and assist with field work in Gabon, which will lead to several publications related to forest height and carbon modeling for coastal wetlands ecosystems around the world. Through his responsibilities with the NASA Carbon Monitoring Systems, Dr. Lagomasino will assist with developing remote sensing datasets into several NASA Hyperwall modules that will be presented at conferences and meetings around the world.

Dr. Tian Yao (sponsor: J. Masek) uses a land surface model to estimate vegetation carbon flux based on atmospheric forcing data and remote sensing data from MODIS and EO-1 Hyperion. She has optimized the fAPARchl computer algorithm with parallel computing approaches to speed up the remote sensing data processing. She also evaluated the MODIS fAPARchl/LAIChl Product in selected AmeriFlux Tower sites covered by cropland, forest and grassland by using land surface model CLM4.5. Dr. Yao co-chaired a session with Dr. Qingyuan Zhang at the 2015 AGU Fall Meeting titled “Mapping and Monitoring Terrestrial Vegetation Carbon Stocks and Fluxes: Inventories, Remote Sensing, Modeling, and Policy Support”, and she gave a presentation of her work during a NASA Code 618 Brown Bag Seminar. Work will continue on parallel computing, and Dr. Yao will work on her manuscript draft. She also is planning to present at the 2016 HySpIRI Product Symposium.

Dr. Qingyuan Zhang (sponsor: E. M. Middleton) supports two NASA missions: the Earth Observing One (EO-1) satellite mission, and the Hyperspectral Infrared Imaging (HySpIRI) concept satellite mission. He provides scientific and technical guidance and support to the GSFC EO-1 Mission Science Office in the areas of imaging spectroscopy and advanced multispectral sensor systems, and retrieval of biophysical parameters with images from such systems for earth science investigations. This past year, he gave several talks, including one invited talk in which he presented a fAPARchl-PRI integrated model to estimate GPP that has the potential to be extended for global application, and another at the 2015 AGU Fall Meeting titled “Mapping, Validation and Applications of MODIS fAPARchl product for GPP modeling”, which led to much discussion and opportunities for potential collaborations. He also co-chaired a well-attended session at AGU titled “Mapping and Monitoring Terrestrial Vegetation Carbon Stocks and Fluxes: Inventories, Remote Sensing, Modeling, and Policy Support”. Going forward, he will be presenting scientific findings at the MODIS Science Meeting and at the 2016 IGARSS Conference. Also, a journal paper is being drafted as well as a proposal for a session at this year’s AGU Fall Meeting.

CODE 699: PLANETARY ENVIRONMENTS LABORATORY

Mr. Charles Malespin (sponsor: P. Mahaffy) is the lead testbed operator for the SAM testbed at GSFC. He also is part of the MSL Science and Tactical team and serves as the SAM strategic science lead. He works on the development and testing of experimental procedures for the Sample Analysis at Mars (SAM) instrument suite. A major accomplishment for SAM occurred this past April when Xe and Kr were detected in the Martian atmosphere by the SAM instrument on Curiosity. Mr. Malespin developed the experiment that was run on Mars over the course of several months using the SAM testbed at GSFC, and he was part of the related NASA press release.

Last July, the first use of the SAM calibration cell gas was completed on Mars on Sol 1042 (approximately July 10, 2015). The calibration cell contains a mixture of gases loaded onto the instrument before launch and is used to help monitor any possible instrument bias or change over the course of the mission.
This experiment was developed and tested by Mr. Malespin at the SAM testbed at GSFC, and he presented preliminary results at the 2015 AGU Fall Meeting in December.

Mr. Malespin presented at the Lunar and Planetary Science Conference (LPSC) in Houston, TX during a special session that highlighted NASA planetary science facilities across the country. He presented on the SAM chamber at GSFC along with the soon-to-be-completed Mars Organic Material Analyzer (MOMA) chamber. Additionally, he co-authored a paper about light Chlorine isotope variations found in various Martian samples. The paper, titled “Light and variable 37 Cl/35 Cl ratios in rocks from Gale Crater, Mars: Possible signature of perchlorate” was published in Earth and Planetary Science Letters.

In the coming year, SAM will continue its search for organics. This search will be aided by the first use of the onboard derivatization reagent. This experiment will require significant testing and development at GSFC on the SAM testbed, and Mr. Malespin will lead this campaign.

Dr. Adrian Southard (sponsor: S. Getty) has been involved in several objectives this past year, from working on a liquid chromatograph-mass spectrometer (LCMS) interface for the Organics Analyzer for Sampling Icy Surfaces (OASIS) instrument, the first LCMS for in situ measurements in space, to supporting the integration and testing of a MEMS pirani pressure sensor to the MOMA-MS instrument on the ExoMars 2018 rover, which is critical to insuring that the ion trap mass spectrometry designed to search for organic molecules in Martian soil can function safely over the six-month mission to Mars. He also has worked on modeling a field emitter array for the Miniature Electron Probe for In situ Elemental Microanalysis (MiniEPMA), an instrument for doing spatially resolved mineralogy by creating characteristic X-rays, and designing an interface between a linear ion trap and orbitrap for the Advanced Resolution organic molecular analyzer (AROMA), a high-resolution ion trap mass spectrometer for resolving the components of complex mixtures. He also has worked on optimizing liquid deposition under vacuum for subsequent laser desorption ionization mass spectrometry for the Molecular Analyzer of Complex Refractory Organic-Rich Systems (MACROS).

Dr. Southard presented work on the pirani pressure sensor of the MOMA-MS at the Hazardous Environment Mass Spectrometry workshop in 2015. He has delivered a calibrated, fast-acting pressure sensor for the MOMA-MS instrument on the 2018 ExoMars rover. Prior to being accepted for integration into the flight version of MOMA-MS, the sensor underwent baking, vibration testing, shock testing, and lifetime testing. This delivery

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Image provided by A. Southard.
represented the culmination of two years of work and required a team of individuals led by Dr. Southard.

Dr. Southard gave updates on testing the OASIS ESI interface at the 2016 Lunar Planetary Science Conference (LPSC), the 2015 Astrobiology science conference, and the 2015 American Society of Mass Spectrometry conference. His work on the miniEPMA instrument (PI: Lucy Lim) was also presented at LPSC 2016. Future work will involve completing the design of the electrostatic lens for the emitter array and testing the emitter array with and without the electrostatic lens used to focus the array onto a target roughly 5 to 6 cm away from the lens.

Dr. Southard worked with Melissa Trainer (PI) in proposing an instrument for aerosol collection to the Homesteader call, and a related IRAD, which was funded. He also worked with John Hagopian on an SBIR phase 1 proposal for developing an instrument that can both suppress UV light while collecting ions for mass spectrometry. He is working with Ricardo Arevalo on MattisSE funding for an Orbitrap mass spectrometer.

**Dr. Samuel Teinturier** (sponsor: P. Mahaffy) works on the development and testing of experimental procedures for the Sample Analysis at Mars (SAM) instrument suite, and on GCMS lab experiments in order to analyze and interpret the results from Mars. He helps Mr. Charles Malespin and the SAM team to operate the SAM testbed at Goddard, and is part of the MSL Science and Tactical team. Dr. Teinturier worked on a new experiment on Mars for SAM and MSL. He designed and wrote the first 2-column experiment on Mars. The objective is to run a GCMS experiment, using two different columns in a row. Each column can specifically slow down different molecules, allowing for the examination of a different range of chemical compounds with the same run and the same sample. He conducted the first tests on the testbed at Goddard, and assembled the material in order to run it on Mars. The first run on Mars was completed in summer 2015, and initial results look promising.

Dr. Teinturier and the SAM team designed and worked on a new calibration experiment. The objective of this experiment was to puncture a cup with known materials to analyze with SAM on Mars. This calibration experiment is important for future runs; of interest, this is the first punctured cup used on Mars. He also was involved with new GCMS experiments with column 4 (the Chirasil-betaDex CB) which were completed on Mars with SAM. As one of the columns on Mars is unusable right now (the column 5, MXT CLP column), Dr. Teinturier worked on testbed experiments, script writing, and reviews, in preparation for the use of column 4.

The next important step with SAM on Mars will be the wet chemistry. By using a method called derivatization, SAM will be able to identify organic compounds on Mars. Derivatization is a technique used in chemistry which transforms a chemical compound into a product of similar chemical structure, called a derivative. The product (usually more volatile) is then analyzed with a gas chromatograph column. Much work needs to be done in preparation, and Dr. Teinturier will work on SAM testbed experiments.
Members of the Office of Communications (Code 130, sponsor W. Sisler), GSFC’s Scientific Visualization Studio (Code 606.4, sponsor H. Mitchell), High-End Computing (code 606.2, sponsor: P. Webster) and the Science Program Support Office (POC: Winnie Humberson, GST; sponsor: S. Platnick) have provided support to a variety of events and missions, and have continued to generate products to convey the discoveries from NASA research. Products are distributed on a growing variety of social media platforms and are often picked up by high-profile news media outlets. The SVS website http://svs.gsfc.nasa.gov/ offers improved search capabilities and showcases work by its partners: the Conceptual Image Lab, Goddard Multimedia Studios, and Scientific Hyperwall Presentations. Hyperwalls were again a key part of several events this past year, domestically and internationally: the 2015 AGU Fall Meeting (California), the AMS Meeting (Louisiana), the USA Science & Engineering Festival and NASA’s Earth Day events (Washington, DC), plus the COP 21 Climate Change Conference (France), the Japan Geoscience Union meeting (Japan), and the International Geoscience & Remote Sensing Symposium (IGARSS) (Italy). Ongoing collaborative efforts combining scientific research with technology, animation, visualization, and interviews continue to engage and inform.

CODE 130: OFFICE OF COMMUNICATIONS

This year, Jefferson Beck supported three Operation IceBridge field campaigns both from his location at Goddard and in the field. For the first time, IceBridge flew overlapping missions over both poles, with an Antarctic spring campaign coinciding with a melt season campaign in Greenland. Jefferson provided daily updates on planned flight lines and photos from each day’s mission, supported visiting video producers in the field, and helped coordinate the first-ever Goddard Google+ Hangout live
from both polar regions. He also traveled to Thule, Greenland for the first time, providing the first coverage of IceBridge in that location since 2010, and produced an array of 4k footage documenting the following: the mission itself, U.S. Air Force support of NASA science, the activities of this year’s visiting PolarTREC teacher, and the visit of former astronaut, earth scientist, and Goddard administrator Piers Sellers. In addition to providing field campaign support, Jefferson has helped move forward two major data visualizations for IceBridge: one on snow radar measurements over sea ice, and one using lidar data over the Helheim Glacier.

Jefferson devoted more of his time to strategic planning and implementation for NASA-wide earth science campaigns. He helped support the planning process for an unprecedented campaign, called Earth Expeditions, to support eight different Earth science field campaigns this year. He helped define the video requirements for videographers and producers in the field, helped designate individuals to cover each campaign, and researched and helped purchase equipment for communal campaign use. In the coming months, he also will support one of these missions in the field himself. In addition, he directed the creation of a major conceptual animation for the campaign, with individual components for all eight missions and more than 70 different distinct deliverables, and created a narrated version of that animation for release with the kickoff package of the campaign.

In summer 2015, Jefferson led a team to Greenland to document researchers working on the Greenland Ice Sheet and studying natural phenomena related to sea level rise. The team traveled by helicopter, by boat, and over land to visit the science teams, and shot some of the agency’s first 4k footage in the field. Many of these items have since been used in short web videos, a live television broadcast, a media telecon, and television live shots. They also were made available for download to the general public and are airing on the brand-new NASA TV UHD channel. He also worked with Goddard’s distance learning team to develop and present an hour-long educational broadcast on the subject.

In addition to many other activities, Jefferson supported one major press conference and media availability at the 2015 AGU Fall Meeting. The press conference focused on the scientific potential of the new EPIC instrument on the DSCOVR satellite newly in orbit around the L1 point. He helped guide the creation of the presenters’ slides and narratives, created GIFs and other shareable media, and produced a short video that was picked up by multiple media outlets and has been viewed more than 130,000 times. He also supported media availability on the Antarctic Ice Sheet, presented two posters on field campaign outreach, attended a day-long NASA communications workshop, and filmed two interviews on behalf the GPM validation study, OLYMPEX.

Also, this year Jefferson shot interviews of Goddard researchers who traveled to Antarctica to measure the movement of a small ice sheet and shot an interview for the AfriSAR campaign, which he turned into a video supporting the kickoff of the carbon-measuring mission to Gabon.

In the coming year, Jefferson will continue to work with his footage from Greenland to create a variety of products on Operation IceBridge and NASA climate science. He also will travel to Alaska to support the ABoVE campaign as part of the Earth Expeditions push. He will continue to support Operation IceBridge science results and field activities, as well as support general earth science news results.

Genna Duberstein, Lead Multimedia Producer for Heliophysics, maintains hands-on creative responsibilities, organizes the overall multimedia team, and plans media campaigns and release strategies. She initiated and project-manages Solarium, a large-scale video art project that uses ultra-HD footage of the sun from NASA’s Solar Dynamics Observatory (SDO). Solarium ran at the American Museum of Natural History on March 19, 2016. This is the museum’s second showing of Solarium. The event and public outreach leads have expressed interest in bringing Solarium back as an annual tradition for their Sun Earth Day

Screenshot of Solarium, provided by G. Duberstein.
programming. Later this year, Solarium will show at new venues in the U.S. and London. All of Solarium’s past installations can be viewed at www.nasa.gov/solarium. In June, Genna won the 2015 Office of the Center Director Peer Award in the “Wild Card” category for her “vision, persistence, and dedication” on Solarium.

A producer from National Geographic came to interview Genna, Scott Wiessinger, and Dr. Alex Young about Solarium. The resulting video was featured National Geographic’s website and will be screened at USRA’s headquarters in Columbia, MD.

Genna and Scott Wiessinger produced a 30-minute Ultra-HD video of footage from the SDO. The piece was featured on sites like CBS News, Smithsonian Magazine, PBS, and USA Today, and has become the all-time most-watched video on the GSFC channel, pushing toward 5 million views. Also, in September 2015, SOHO spotted its 3,000th comet. Genna created shareables and infographics, and worked with data visualizer Tom Bridgman to create a video about the story. Slate, BBC InFocus Magazine, EarthSky, Astronomy Now, and Space.com picked up the content.

Genna will be involved with the “Electric Wind of Venus” video, the release of the “Faint Young Star” video, products from MMS first results, and deliverables for the ICON website. In 2016, Solarium will be shown at new venues: Baltimore’s Artscape Festival, San Diego State University’s Filmatic festival, and The Natural History Museum (London).

**Ryan Fitzgibbons** supports the GPM and ICESat-2 missions in all multimedia needs, including the documentation of mission milestones, production of web videos and live press events, and support for the Education/Public Outreach (E/PO) programs. Over the past year, Ryan produced and executive produced several large-scale multimedia products along with fellow producer Joy Ng. (Joy, a fellow and junior producer, was brought on this past year to help with the workload for GPM products, and Ryan constructively guided Joy’s work in order to meet the satisfaction of the GPM team.) These videos and presentations focused on how GPM data can be used to see global precipitation from many perspectives. Among these products were an in-depth look at monsoons in South Asia (visualizations and a web short), a Science on a Sphere presentation of how the IMERG product is created and used, a video on GPM’s ability to measure drop size distribution and what that means for weather modeling, and a retrospective on all the storms captured by GPM for 2015. In summer 2015, Ryan completed the second in the Water Falls spinoffs, “Getting the Big Picture,” which focused on remote sensing. He wrote and animated the web short (see https://youtu.be/rA_VCLzvbvM). The web short remains in the top five most popular GPM videos. Additionally, Ryan produced a few narrated versions of data visualizations on storms, including Winston (over Fiji), Kilo (Pacific and Hawaii), and the monsoon season. These products continue to be popular and require a minimal amount of production time on top of the visualizers’ efforts.

Ryan oversaw the production of several multimedia products in preparation for and during the OLYMPEX field campaign for GPM. The Olympic Mountain Experiment (OLYMPEX) was GPM’s final field campaign for ground validation and focused on how precipitation transitions across oceans and varying terrains. As part of this campaign, Ryan and Joy Ng produced several products, including a pre-campaign overview video, two researcher profile videos, and a wrap-up video highlighting some of the extreme weather captured and studied in the Pacific Northwest. The products can be seen at http://svs.gsfc.nasa.gov/Gallery/OLYMPEX.html.

In support of the ICESat-2 mission, Ryan continued documenting major integration and environmental testing as the ATLAS instrument for ICESat-2 progressed toward its launch date. Instrument milestones included the integration of the flight lasers, integration of the receiver telescope assembly, electromagnetic interference, acoustic and vibration testing. In coordination with these events, Ryan produced short 30- to 60-second video inserts for ICESat-2’s Facebook account. By updating the public with major developments in the prelaunch life
of the mission, Ryan helped engage the public in the engineering aspects of the ICESat-2 mission. He also continued producing both web videos and conceptual animations for the ICESat-2 mission. These products included a core animation showing the laser path in coordination with the reference track (animated by Michael Lentz) and the second in the “Laser Focus” series which looks at how the receiver subsystem works. Additionally, Ryan produced a video-only overview of ATLAS that will be used on an informational kiosk. Finally, Ryan continued to build the gallery of products and resources on the SVS Gallery, which will provide outside users with a centralized depository for all media products (http://svs.gsfc.nasa.gov/icesat2.html).

In the upcoming year, much of Ryan’s work will focus on ICESat-2 as the mission approaches launch in fall 2017. He will continue to document I&T milestones at Goddard, the departure from Goddard for Orbital in Arizona, and I&T milestones at Orbital. Ryan also will produce a few core data simulation visualizations with the SVS as part of the core content necessary for the mission. Finally, he will be involved in the planning and execution of social media events that engage the public in ICESat-2’s messaging.

As a multimedia producer, Daniel Gallagher creates videos that inform the public about missions and scientific research being conducted at NASA’s Goddard Space Flight Center. As the lead producer for the Solar System Exploration Division at Goddard, he provides video support for the OSIRIS-REx and MAVEN missions, as well as for general planetary research.

Daniel edited a short Jupiter globe video in 4k Ultra HD to support the release of new maps from Hubble. Goddard planetary scientist Amy Simon was involved in creating the new Hubble maps – the highest-resolution global maps of Jupiter to date – as part of a campaign to map all of the solar system’s gas giants. STScI animation lead Greg Bacon wrapped the two 4k maps onto rotating globes and sent them to Goddard for public release. Daniel edited a short video with music and titles from one of the globes, and coordinated its release with a written feature by science writer Liz Zubritsky. To date, the video has received over two million views on NASA Explorer (see https://youtu.be/3afEX8a2JPg). It also was reposted by CNN.

Additionally, Daniel produced, edited, and released an interview with Goddard planetary scientist Dennis Reuter about the New Horizons mission to Pluto. Dr. Reuter is the instrument scientist for Ralph, New Horizons’ infrared spectrometer and primary camera for color photographs. “Four Questions About
New Horizons” (see http://svs.gsfc.nasa.gov/goto?11950) was released on NASA Explorer, nasa.gov, and the SVS archive on July 13, 2015, one day before New Horizons’ historic flyby of the Pluto system. To date, the video has received over 53,000 views on NASA Explorer.

To support a televised MAVEN Science Update at NASA Headquarters in November 2015, Daniel edited Greg Shirah’s signature MAVEN data visualization of Mars ion escape. Daniel added music, titles, and the MAVEN animated logo, and released the finished video on NASA Explorer. In addition, he posted high-resolution copies of the visualization and associated media for download on the SVS website. To date, “Solar Wind Strips Martian Atmosphere” has received over 700,000 views on NASA Explorer (see https://youtu.be/gX5JCYBZpcg).

Daniel also produced, edited, and released “Mapping Mars’ Upper Atmosphere,” a video about MAVEN science observations at Mars. The video features Bruce Jakosky, the PI of MAVEN, along with spacecraft animations from Goddard’s Conceptual Image Lab and data visualizations from the SVS. This video was released on Sept 2, 2015 on NASA Explorer, nasa.gov, and the SVS archive; to date, the video has received over 16,000 views on NASA Explorer (https://youtu.be/KHDXeXXoP3c).

Daniel wrote, narrated, and edited a video about the Goddard Mars Model 3 gravity map. “Mars Gravity Map” features new globes of the Martian gravity field created by Ernie Wright of the Scientific Visualization Studio. The video accompanied a written feature by Bill Steigerwald on nasa.gov, and has been reposted to Business Insider, Fox News, Space.com, and other outlets. To date, the video has received over 100,000 views on NASA Explorer (see http://www.space.com/32362-mars-gravity-map-best-ever-video.html).

Daniel will continue with several production and support activities. He will support the OSIRIS-REx mission to asteroid Bennu with media products leading up to launch in September 2016. Currently, he is overseeing a new mission overview video featuring principal investigator Dante Lauretta; editing a profile video for the OVIIRS instrument featuring GSFC scientists Dennis Reuter and Amy Simon; and overseeing a short video on the sample return capsule parachute drop test. For the DAVINCI proposal, Daniel will work with CI Lab animator Brian Monroe to support this proposed mission to Venus. If selected, DAVINCI will travel to Venus and drop a probe into its atmosphere to take in situ measurements. Brian Monroe will create artist concept animations to illustrate DAVINCI’s voyage from Earth to the surface of Venus, and Daniel will provide producing and editing support, and coordination with DAVINCI Principal Investigator Lori Glaze. The animations will be shown during a selection committee site visit in November.

Daniel will work with videographer Rob Andreoli to continue filming the testing of the Mars Organic Molecule Analyzer (MOMA) instrument at Goddard. He will continue working with MOMA team members Rick Arevalo and Veronica Pinnick on versions of the MOMA animations and footage for public release.

Robert Garner serves in various capacities, including translating complex scientific and engineering content into products consumed by a wide spectrum of audiences, creating sites, posting to and updating nasa.gov, and working with archives. In fact, at the Office of the Director’s Peer Awards ceremonies in early June 2015, he received an “On-The-Spot Dot” Award, “for receiving the recognition and admiration from his peers of his expansive efforts and accomplishments in this spontaneous award event.”

Robert took multimedia products from NASA Headquarters associated with the Aug. 5, 2015 announcement of the DSCOVR view of the moon transiting Earth and adapted them for nasa.gov and social media. The resulting products (from the satellite’s EPIC instrument) vaulted Goddard to its best week by page views (857,369) on nasa.gov in the site’s history. The EPIC story was one of more than 350 individual webpages Robert worked on during this year-long reporting cycle. Among those pages, he created new sites for WFIRST, ICESat-2, ICON and Hitomi, bringing to 40 the number of nasa.gov mission websites his team is responsible for maintaining.

Beginning in September 2015, Robert took on overall responsibility for the heliophysics line of business on nasa.gov. Apart from day-to-day posting and curation of nasa.gov’s several heliophysics websites, he manages after-hours availability of the overall team to ensure timely breaking news coverage (e.g., weekend occurrences of X-class solar flares).

In August 2015, NASA Headquarters solicited thoughts and feedback from center web team members regarding additional functions slated for nasa.gov; Robert was the only Goddard representative the Headquarters team asked for input. Additionally, he has worked regularly with the Earth Science Directorate at NASA HQ, Earth science staff at Goddard and other centers, and external contractors to construct and curate several websites for Earth science communications campaigns:

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Robert has continued to curate the Goddard Office of Communications photo archives. In June 2015, with just two days’ notice, he was able to select and digitize 36 images for a video tribute of former Center Director Dr. Noel Hinners in time for the ceremony dedicating Goddard’s Building 8 auditorium in his honor. Center Director Chris Scolese later wrote, “I was very moved by the video as it really captured Noel at his finest - - how you found images that not only showed Noel at his best but also displayed his personality was just incredible.”

Further, in November, Robert provided historical imagery of Alberta Moran and the center overall to a local film crew for a profile on the long-time employee and Visitor Center volunteer. Because of his efforts, management tapped him to liaise with the NASA Headquarters archivist during her part-time detail at the center. Subsequently, Robert has consulted with the center’s full-time archivist on collecting policy and historical resources at Goddard.

In the coming months, Robert anticipates trips to Wallops in support of Antares return-to-flight this summer and subsequent launches.

As lead producer for the satellite media tour program, Michelle Handelman Seff coordinated 13 comprehensive campaigns throughout the past year, ranging from the rare Supermoon eclipse to sea level rise. She holds media training sessions to prepare scientists for interviews, creates web pages for the SVS, and regularly assists media and documentary filmmakers with interview and file video requests. For the rare

Supermoon eclipse of September 27, 2015, Michelle coordinated a complex live shot campaign that incorporated television, print, radio, Skype and in-person interviews. Altogether she booked 37 satellite interviews for the four scientists with whom she worked. Highlights include interviews with CNN International; Univision.com; Space.com and 15 stations in top 20 local television markets. She also booked radio interviews with KLIF radio news in Dallas and Radio Caracol, which both have a large audience. Michelle held media training sessions to prepare the scientists for interviews. The SVS web page that she made for the media to download the canned interviews and b-roll has more than 16,000 combined views and downloads.

Michelle created “breaking news” style, quick turnaround live shots for Hurricane Joaquin on October 2nd. With just three days’ notice, Michelle coordinated with scientists, visualizers and the studio team to produce a robust live shot campaign showing NASA’s latest images from the Global Precipitation Measurement mission of the hurricane developing in the Atlantic. She booked 15 interviews, including FOX News network, Reuters and the Wall Street Journal. Michelle also worked with the Social Media team on the development of a new short promotional video showing new NASA views inside hurricanes that was popular on Twitter. The web page Michelle created for media to download video has received more than 4,000 combined views and downloads.

Far, far away in our own Milky Way galaxy, the Hubble Space Telescope saw what looks like a cosmic “lightsaber”. Michelle led a satellite media tour highlighting this new lightsaber image in addition to Hubble’s other great images taken over the last 25 years. She held two media training workshops to prepare the scientists for these live shots, which included the use of a lightsaber prop in the interview. She booked a total of 29 interviews for the scientists, including Reuters, FOX affiliate service division and Radio Caracol, whose listeners are in Miami, Spain and South America as well as 10 stations in top 20 markets like Philadelphia (#4), San Francisco (#6), Tampa (#11) and Univision in Orlando (#14). The webpage Michelle created for the media to download interviews and b-roll has more than 16,000 combined views and downloads.

Using the total solar eclipse that happened March 8th as a hook, Michelle led a live shot campaign that focused on NASA’s
research and images of the sun from the Solar Dynamics Observatory. The two scientists participating in the live shots discussed as well the 2017 eclipse that will be visible throughout the U.S. She booked 30 interviews, which included Space.com; FOX NewsEdge affiliate news service, CNBC.com; CHCH (an independent network in Canada), Radio Caracol, and with eight stations in top 20 local markets including Los Angeles (#2), Chicago (#3) and San Francisco (#6).

In late March, Michelle conducted a media campaign highlighting the latest NASA data showing the wintertime sea ice maximum. The campaign also highlighted two NASA missions that were preparing to leave for the Arctic: Operation IceBridge and Oceans Melting Greenland. Michelle booked 26 interviews for the two scientists participating in live shots.

At present, Michelle is planning out campaigns for the rest of the year, including the upcoming Mercury transit across the sun on May 9th, and Mars at opposition happening on May 22nd. She is planning to have at least six more campaigns before the end of the year. In an effort to further extend the reach of live shots, Michelle is working to update the media contact lists, including working with other producers to reach out to new contacts at radio stations and podcasts. Also, she plans to try out new variations on social media spots that correspond with the live shot campaigns.

Katrina Jackson, a science video producer for the Hubble Space Telescope and planetary science, coordinates with project leads and communications officials to provide multimedia in support of mission goals and communication campaigns. Since joining GESTAR in January 2016, Katrina produced and hosted the fourth Hubble Memorable Moments video and wrote an accompanying web feature; produced a short video about Hubble in culture that kicked off a #SpotHubble social media campaign; produced a short video about Hubble discovering a moon orbiting dwarf planet Makemake; filmed the traveling Hubble exhibit in Buffalo, NY; and prepared for upcoming Hubble live shots taking place in May and July 2016.

Also, Katrina’s Makemake video was reported by Goddard’s Office of Communications to the director’s office as their top story of the week, was the second most popular nasa.gov page, and was shared by CNN, Smithsonian Magazine, Scientific American, Mashable, and several other outlets. This video is available at https://youtu.be/er1sBpyih0s and in this feature on nasa.gov: http://www.nasa.gov/feature/goddard/2016/hubble-discovers-moon-orbiting-the-dwarf-planet-makemake.
Katrina edited a video that gave an overview of the OSIRIS-REx mission and a video about a Ceres science results. In the coming year, she will provide multimedia support leading up to the launch of OSIRIS-REx and will provide video coverage of other planetary science results.

For Hubble Space Telescope Multimedia, Katrina will support live shots in May and July 2016. She plans to produce at least two more Hubble Memorable Moments videos, and to continue providing multimedia support for Hubble science results.

David Ladd, a Video Producer with Goddard Television, works in the Planetary Science division, and produces and edits videos for numerous NASA missions, including the Lunar Reconnaissance Orbiter (LRO), MAVEN, and OSIRIS-REx. His work expands into other areas of multimedia support for the Planetary Department. This past year, David was the Producer and Editor for the video “Supermoon Lunar Eclipse” that gave a tutorial about this rare and unique event that occurred on September 27, 2015. Krystofer Kim served as animator. This video immediately went viral upon its release, being picked up by numerous news organizations including ABC, NBC and CBS News, the Huffington Post, Space.com, and many others. It generated nearly 4 million views on the NASA Goddard YouTube page, making it one of Goddard’s most viewed videos of all time (see https://www.youtube.com/watch?v=vKAw_wrIr5s).

He also was the Producer and Editor on the video “Driving A Lunar Spacecraft”, which explains how NASA operates the LRO around the Moon (see https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11949).

David produced and edited the video, “Student Scientists: Building REXIS” for the OSIRIS-REx mission. This video puts a spotlight on a group of college students in Boston who are getting the chance to help NASA explore an asteroid. These student scientists have built an instrument called REXIS, which will fly on the OSIRIS-REx spacecraft, scheduled for launch in September 2016. The video can be seen on Goddard’s YouTube Page: https://www.youtube.com/watch?v=Q7jikonvOlc.

Working with SVS Visualizer Ernie Wright, David produced and edited two videos: “2016 Moon Phase and Libration - Northern Hemisphere” and “2016 Moon Phase and Libration - Southern Hemisphere”. Both videos were released to the Goddard website, the Goddard YouTube page, and to the SVS website in 4k resolution and are available at the following links: Northern Hemisphere View: https://www.youtube.com/watch?v=Cm7FGBSo9UL; Southern Hemisphere View: https://www.youtube.com/watch?v=Y3xokCzDwLI.

The National Association of Broadcasters is the world’s largest electronic media show covering filmed entertainment and the development, management and delivery of content across all mediums. David was chosen to give a presentation at the 2016 NAB conference. His presentation was titled “Masters of the Universe: NASA Animations and Visualizations”. Panelists included fellow USRA colleague Ernie Wright, who discussed...
aspects of the SVS, and Walt Feimer, Lead Animator and Manager of Goddard’s Conceptual Image Lab.

In the coming year, David will continue producing and editing videos for Planetary Science, with a particular focus this year on videos for the LRO and OSIRIS-REx.

Michael Lentz creates animations and visuals to support NASA Goddard missions and science for the Office of Communication, and provides creative and technical guidance to the Conceptual Image Lab and supervision of other artists. In relation to the launch of OSIRIS-Rex, the animation “Journey to Bennu” will show how OSIRIS-Rex will be getting to the asteroid Bennu to take a sample and return it to Earth. This will be an ambitious animation project with many complex visual elements to create under a tight deadline. Michael has created all of the storyboards and art direction for the project in addition to working on many of the shots. With over 60 shots and three artists, the new asset management and job tracking software Michael implemented for the CI lab has been an immense help in keeping this complex animation on track.

Michael created animations for Dr. James Garvin (NASA/GSFC) to accompany talks he was giving on the “Greenhorn” rock on Mars and the creation of Hunga Tonga Island in the Pacific. The animation for “Greenhorn” rock on Mars illustrated how fine details could be seen with Curiosity’s cameras. The animation for Hunga Tonga showed the growth and change in the island after a volcanic eruption.

Several animations were produced this year for MAVEN in the Conceptual Image Lab. Michael created a number of these, two of which showed the passing of comet Siding Spring and animations showing MAVEN’s orbit insertion around Mars. He also worked on an animation that showed drop size distribution within a cloud and how drop sizes can be detected by GPM.

Virtual Reality (VR) is an exciting new media for storytelling that Michael has begun to research, and he is exploring how it can be integrated into production. It has the potential to open up a new venue for telling NASA’s stories in an exciting way. In the upcoming year, Michael will continue to research Virtual Reality and hopes the first VR production will begin in the Conceptual Image Lab. With the lab expanding to six artists, Michael’s role in helping supervise and reviewing work will increase. Also, the bulk of the animations for “Journey to Bennu” will be completed. Michael will continue to refine the animation pipelines for the CI lab in addition to developing new visual styles.

Since transitioning from a scientific animation fellowship role to a multimedia specialist for the Conceptual Image Lab, Brian Monroe’s objective over the past year was to help guide any newcomers to the lab through the pipeline, help develop the organization and evolution of the lab as it grows, and to continue to provide visual support for NASA Goddard missions and productions through the creation of animations. He also was given the responsibility of facilitating heliophysics animations through the lab and being the liaison between the department and the artists.
In putting a new spin on the typical package for a launch and deployment campaign for a spacecraft, Brian approached and is developing a realistic and less than conventional way to light and render the JPSS and GOES-R spacecrafts for the purposes of showing off their build and function. The textures on the JPSS craft and even the environment in which the spacecraft appears in the animations have been worked up to have a greater level of detail, meaning animators can focus on dynamic and interesting views as well as camera moves to highlight instruments - perspectives that animators wouldn’t normally take in typical turnarounds of a spacecraft project.

In early September, and in line with some of the latest findings of the Martian atmosphere, the “Mapping Mars’ Upper Atmosphere” video was released featuring an animation developed by Brian. The animation visually described the process by which MAVEN determines the components of the Martian atmosphere measuring starlight as it sets below the limb. During the 2015 AGU Fall meeting in December and the release of MAVEN’s findings, the graphic made the rounds and was prominently used in conveying the details. Also, on November 5th, a press conference was held with Bruce Jakosky, Nick Schneider, and other scientists concerning the latest findings of MAVEN about the loss of atmosphere of Mars. The visuals Brian created for this press release helped to visually show these concepts of atmospheric loss, solar wind and solar storms to the public. After the conference, the visuals were repurposed on well-known sites to share the findings from the press conference. Telegraph, the New York Times, CNN, the Verge, and ABC News were among a number of news sources that utilized the visuals Brian created and paired them with the findings. Popular Science even selected one of the graphics as its site backdrop for that day.

For the September 2015 NASM event “Our Violent Universe”, Brian helped to create the animated title and speaker intros that played on the big screen for the presentation. Taking cues from each speaker’s background, he designed the introduction slates to have elements of each speaker’s field of work and some of the missions of which they were a part. The event itself drew many influential people, and was a great opportunity for Goddard TV, and specifically CI Lab, to have visuals to highlight the work being done at Goddard.

In late October, Brian developed an animation (see page 95) that coincided with an article release (Nature, 526 (7574)), about tidal forces on black holes. The goal of this animation was to update an older graphic in which a nearby star was sucked into a black hole and formed an accretion disc. This updated animation helped to promote the article and latest scientific findings, bringing in over 1.5 million views on YouTube within a week of its release. The animation was featured on Telegraph, the Guardian and Washington Post, and was the Astronomy Picture of the Day on October 28th.

Between mid-December and mid-January, Brian took in a 3D model of the once-known-as PROBE-E spacecraft and made several animations for a proposal that was to be presented at NASA HQ. Later renamed “BEE”, the spacecraft was bidding for a spot onboard Clipper so that it may be sent off to study the composition of Europa’s plumes. The spacecraft was textured and lit and animated in a digitally-created Europa environment in order to convey the general scope of the mission and the journey that the spacecraft would travel through. Although the proposal was not funded, the graphics were a helpful aid and provided shaders and textures for future 3D spacecraft construction.

For the coming year, Brian will be working more with heliophysics-related projects. He will continue to help create 4k content and possibly try out VR capabilities with at least one future project, while learning the Renderman renderer and potentially a few other 2D/3D animation programs in order to expand his capabilities when approaching each animation project.

As a multimedia producer within the NASA Goddard Multimedia Team, Joy Ng has created numerous unique products that support NASA’s Earth science research, field campaigns, and other airborne and satellite missions in collaboration with scientists, video producers, science writers, animators and data visualizers within the Conceptual Image Lab and the SVS. In the past year, Joy’s videos have been viewed more than 700,000 times on NASA’s YouTube, Facebook, and Instagram accounts alone. As well as having immediate reach from NASA’s social media accounts and the nasa.gov website, her videos and supplementary images and animations have caught the attention of external news organizations and journalists who have redistributed or re-packaged her original Earth science
Last summer, a video produced by Joy in collaboration with then-USRA scientist Teppei Yasunari titled “Scientists Link Earlier Melting of Snow to Dark Aerosols” was picked up by AccuWeather.com and ReportingClimateScience.com. This video reported on Dr. Yasunari’s scientific paper and included new data visualizations from the SVS.

Along with video producer Ryan Fitzgibbons and science writer Ellen Gray, Joy helped coordinate filming logistics during the OLYMPEX campaign. As a whole, the outreach for the campaign was expansive. B-roll and data visualizations that were gathered and produced at NASA Goddard were utilized by many international news organizations, such as USA Today, GeekWire, Gizmodo Australia, and The Seattle Times. Joy also produced a video profiling a scientist on the OLYMPEX field campaign, which received more than 20,000 views on social media.

In collaboration with animators Michael Lentz and Krystofer Kim from the CI Lab, Joy produced a video titled “Why Do Raindrop Sizes Matter in Clouds?” This video, which showcases GPM’s capability in measuring raindrop sizes, has gained more than 200,000 views on social media platforms and was picked up by Forbes, Popular Science, UPI, and more. Marshall Shepherd also used the NASA-produced animation to explain the topic during The Weather Channel show “Weather Geeks”.

Working with the SVS, Joy produced a new visual treatment for GRACE satellite data. This visualization accompanied a YouTube video titled “Brazil’s Extreme Drought Seen from Space” (http://www.nasa.gov/feature/goddard/nasas-grace-satellites-evaluate-drought-in-southeast-brazil/), which gained more than 60,000 views on social media. It was redistributed by numerous organizations such as AccuWeather, Voice of America, Carbon Brief, NPR, and more. An Instagram video also was produced on this science paper. She also produced a video titled “Making Science Fun for Kids with Comics” to promote GPM’s comic book that was created through a worldwide competition, and produced derivative products such as GIFs and an Instagram video. The video was picked up by the Smithsonian Magazine and AOL.

In collaboration with video producer Jefferson Beck and data visualizer Greg Shirah, Joy produced a video titled ‘What Are The Chances Of Another Katrina?’ that was coordinated with a science publication release from NASA GISS. This also complemented a live shot, allowing scientists to talk to TV and radio stations in a live setting. On YouTube and Facebook, this video gained more than 130,000 views. In March 2016, Joy, Jefferson and Greg were awarded the Newsbrief Award by the D.C. Science Writer’s Association for this video. More details can be found here: https://dcswa.org/winners-announced-for-2015-dcswa-newsbrief-award-multimedia-category-offered-for-first-time/.

During this past year, Joy attended a workshop with the organization Docs In Progress. She further developed her skills as a solo filmmaker and learned how to deal simultaneously with work as a director, camera operator and producer in dynamic filming environments. In the year ahead, Joy will continue to create video products around GPM-related research and activities and to produce video products around heliophysics. She also will develop new social media strategies with the Goddard Social Media Team and help Michelle Handleman Seff reach out to radio and podcast audiences for Live Shot campaigns.

Among other responsibilities, Matthew Radcliff serves as the Lead Producer for the Landsat program and Lead Producer for Goddard’s Earth Science Division (ESD), which involves leading the creation of videos and visualizations that showcase Landsat science and collaborating with the Landsat public engagement staff to communicate the results and benefits of Landsat science. He also represents Goddard Multimedia on the agency-wide Earth science campaign called “Earth Right Now”.

In November, Matthew produced videos and visualizations for the media briefing, “Carbon & Climate.” One of the big “Frontiers of Climate Science” events for the Earth Right Now campaign, the event showcased Goddard’s research in ocean biology, carbon monitoring, and global modeling of carbon emissions. Along with supporting the media telecon and live shots, Matthew provided the media with video clips of interviews with the featured scientists. He also produced short soundbites from the scientists for NASA’s social media sites. See http://svs.gsfc.nasa.gov/Gallery/CarbonGallery.html.

More of NASA’s communication to the public happens through social media channels, like Twitter and Facebook, which are becoming more reliant on video. Yet those videos need particular formatting to make the most impact. Matthew developed a
This past year, he continued to support communications from Goddard’s ESD. Every January, NASA’s Goddard Institute for Space Studies (GISS) releases the official record of global temperatures for the previous year. They unveil the results at a press briefing held in conjunction with NOAA. Matthew produced a package of visuals used in a series of interviews with TV news stations across the country and picked up by many news outlets (http://svs.gsfc.nasa.gov/Gallery/2015GlobalTemperatureData.html).

Clouds of ash from volcanic eruptions are a major safety hazard for airplanes, requiring costly diversions and cancellations to avoid flying through them. Goddard’s Earth scientists are developing new methods to make more accurate forecasts of the area where the volcanic ash is present. They are combining data from the OMPS instrument on the NASA/NOAA Suomi NPP satellite with supercomputer models of weather patterns. Matthew and Kel Elkins have visualized the data from the April 2015 eruption of the Calbuco volcano in southern Chile. (Note, this video is not yet published.)

As lead producer for Landsat, Matthew has produced several videos on applications of Landsat data. The Landsat program continues to be a flagship of Earth observations, for the U.S. and many other countries. The long-term data archive, stretching back to 1972, has allowed detailed studies of forest health and extent. NASA scientist Jeff Masek, working with colleagues at the University of Maryland, has used Landsat data from 1984-2010 to track the dynamics of U.S. forests. The data will be used to obtain a scientific understanding of carbon sources and sinks. The visualization produced by Matthew highlights areas of change in different regions, whether from natural causes, such as fires or hurricanes, or from human causes, such as logging and mountaintop mining. Additionally, Matthew produced a visualization on high-latitude North American vegetation using Landsat data provided by GESTAR scientist Junchang Ju. As Arctic regions have warmed over the past 30 years, Landsat data shows that vegetation in Canada and Alaska has increased.

Shorebirds in California’s Central Valley are dependent on limited habitat during their annual migrations. Scientists have used data from NASA’s Landsat satellite to determine where and when surface water is needed, and for the few weeks when the birds are present, they are renting rice paddies that can double as temporary wetlands. In September, Matthew produced a video on the project called BirdReturns (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=12013). He and Joy Ng also created a short video, aimed at social media, about the project.

Matthew produced and edited a video on Landsat’s use in measuring depth of meltwater lakes on top of Greenland’s ice sheet. The video was a pilot for a new video series for the Landsat program called “About An Image”, which featured voice-over from a scientist discussing what can be seen in a single Landsat image, and an overview of her research. The pilot episode also featured Dr. Allen Pope, a post-doc at the NSIDC, discussing his research using Landsat 8 to measure the depth of the lakes (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11973).

The origins of the Landsat program lie in the need to monitor agricultural lands across the globe. In the past 15 years, the satellites have become a mainstay for monitoring water use by farm fields. In October, Matthew produced a video and feature story on the work of scientists at the University of Nebraska - Lincoln using Landsat data to quantify how much water is used to irrigate farm fields in central Nebraska. Managers at the Central Platte Natural Resources District are required to calculate how much water is consumed in their district, and they rely on the analysis of Landsat data by the UNL scientists to create this budget. See http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=12026.

In the coming year, Matthew will continue to produce videos for the Landsat program on the work needed to accurately calibrate the Landsat satellites, and the expected benefits of combining data from Landsat with the European Space Agency’s new Sentinel-2 satellite. He will support multimedia communications.
for the team building the new Landsat 9 satellite as well as communications for Goddard’s Earth Science Division.

Kayvon Sharghi oversees multiple storytelling projects and serves in many capacities to guide each project toward achieving its goal. The projects include reporting on NASA Earth science findings through digital media communication platforms and strategic online campaigns. As editor of the NASA Viz, he manages all aspects of the editorial process, including the scheduling, production and release of two new stories each week. In the past year, he directed the release of more than 100 new stories. In addition to working with a team of contributing writers at NASA Goddard Space Flight Center, Kayvon launched two student writing internships in partnership with the University of California, Santa Cruz, Science Communication Program. He worked with multiple graduate students on the creation of more than a dozen stories published in the app. Kayvon supported outreach activities at the 2015 World Science Festival in New York (June 2015) and the 2016 Earth Day festival, Union Station, Washington D.C. (April 2016).

In his role as Earth science producer, Kayvon produces video and animation products in support of NASA Earth Science news releases. This year he worked on multiple projects, many of which went viral on the web. In addition to these projects, he directed the activities of the 2015 Earth science multimedia fellow. He oversaw the release of more than a dozen video products in support of communicating NASA Earth science results.

During the past year, he attended meetings, including the 2015 AGU Fall Meeting in San Francisco, where he produced videos and visuals in support of press conferences, and handled requests from news media. At the Earth Right Now science communication planning meeting in Pasadena, CA, he provided feedback on NASA’s ongoing Earth Right Now campaign and ideas on how to elevate the campaign’s impact in the future.

Kayvon also launched NASA On Air, a Goddard-developed resource that provides short TV-ready video voice-over stories that can be inserted into newscasts. At the 2015 American Meteorological Society (AMS) meeting in Raleigh, NC, he presented a talk about the project, met with TV meteorologists from across the country, and created a contact list for the major broadcast affiliate feeds in the U.S. to explore potential partnerships.

Scott Wiessinger is lead multimedia producer for astrophysics and the WFIRST mission at Goddard as well as a producer for heliophysics. His projects include producing short videos, static graphics, hyperwall content, 4k media, and digital art installations, guiding the creation of animations and data visualizations, creating animations, providing materials to outside media and producers, collecting, creating and organizing visuals for press conferences, and curating visuals online. During the past year, Scott produced, co-produced, edited and/or animated 16 videos, which were primarily animations, visualizations, and interviews or narrated features about science results and missions. As of mid-April 2016, these videos accounted for almost 10.8 million YouTube views.

Solarium has been successful beyond Scott’s and Genna Duberstein’s expectations. There have been 11 versions of Solarium across the U.S., including temporary installations appearing at locations like the American Museum of Natural History. In June 2015, Scott and Genna helped the Virginia Air and Space Museum with a custom 30-foot Solarium installation. In April 2016, Scott was in England and had meetings at the London Natural History Museum and the Science Museum, both of which are interested in Solarium. In July 2016, a temporary Solarium installation will be featured during the Baltimore Artscape festival.

Scott produced the SDO: Year 6 video and continues to work on breaking news and Solarium. In September, he helped to advise and produce visuals for the annual presentation at the National Air and Space Museum, which was astrophysics themed. He also broke new ground by producing several videos in the new “ultra-HD” or 4k format (four times the resolution of HD). Finally, Scott began learning 3D animation software, which will expand his skill-set and potentially enable him to create even better animation products.
In addition to the work on Solarium, Scott had two large heliophysics accomplishments. The first is the release of the sixth annual Solar Dynamics Observatory compilation video titled “SDO: Year 6”. The previous video, SDO: Year 5, was a huge success and is at nearly 5 million views on YouTube. For Year 6, Scott took a different approach, partly because solar activity is winding down. Instead of a compilation of events, Scott made the video a single time-lapse of the whole sun. He also made the video at 4k resolution, which is possible because of SDO’s fantastic image size. The video now has over 1 million views, and was featured by Engadget, Yahoo News, Huffington Post, USA Today, Gizmodo, the Telegraph and the BBC. Scott’s second major heliophysics release was a 30-minute 4k video of SDO footage titled “Thermonuclear Art-The Sun in Ultra-HD.” Scott and Genna each created half of this video, which was for the NASA 4k TV partnership with Harmonic. The YouTube release of the video was wildly popular and got attention from CNN, PBS, CBS, Huffington Post, Smithsonian Magazine and even some unexpected outlets such as Forbes and MTV. The unexpected and intense interest has resulted in this video reaching nearly 5 million views on YouTube and becoming Goddard’s most watched video within only six months.

This year’s astrophysics releases were primarily results-driven and quite varied in nature. Scott worked at integrating more interviews and more collaboration between animation, visualization and the scientists. The topics included simulations of dark matter orbiting black holes, gamma rays visualized as raindrops, simulations of dust rings around other stars, and a software upgrade that nearly doubled the Fermi Gamma-ray Space Telescope’s capabilities. Scott also tried some novel approaches to presenting stories. For a Fermi story about a pulsar in a binary system, he crafted the video like a Hollywood trailer. It did extremely well for a complicated astrophysics release, and has nearly 250,000 views so far.

From a views-standpoint, Scott’s most successful video was an animation by Brian Monroe of a black hole tearing apart a passing star (see https://www.youtube.com/watch?v=hu6hlhW00Fx). That video is now at 3.8 million YouTube views, and is the sixth-most-watched video on the Goddard YouTube channel. It also is the most watched astrophysics video by a large margin.

Scott collaborated with SLAC on a story about a new software package for Fermi that allows it to see much more gamma-ray detail than previously possible. He used this opportunity to create Goddard’s first 4k interview-based video. Two of the interviews were shot by former Goddard producer Chris Smith at SLAC, and a third was shot at Goddard using a new 4k-capable camera. Scott’s work on this showed some of the possibilities and challenges to a new, higher-resolution workflow. Scott is using what he learned to produce more 4k videos and hyperwall products.

This past year has seen an enormous increase in the amount of hyperwall content that Scott has produced, including two hyperwall shows for the Fermi group to use at the August 2015 AAS/IAU conference in Honolulu, Hawaii. Scott also brought camera equipment to document important WFIRST hardware being manufactured by a Honolulu company called GL Scientific. Because of the cost of flying to Hawaii, Scott did all the production work himself. He also was able to make a last-minute hyperwall presentation for a guest speaker. Because of the sheer volume of content required, the Fermi hyperwall presentations initially recycled a lot of existing material, but both presentations were so popular that the Fermi group funded a full-hyperwall-resolution upgrade. Scott began an iterative process with the two shows, taking feedback and working to make more of the shows full hyperwall resolution, as well as altering and upgrading some of the stills and video. These visuals require a great deal of time to create and render since they can be up to 9600x3240 pixels in size, or 15 times HD. Scott worked on updating and modifying hyperwall stills and animations for both the Fermi and WFIRST missions. The Fermi group used them again at the January AAS and then in April at the Science and Engineering Festival in D.C. The AAS/IAU conference also marked the release of the Swift mission infographic poster. This project started as a web-only infographic and slowly developed into a large printed poster. The Swift group printed 2,500 copies and began handing them out at this conference.
During spring 2016, Scott increased his work on WFIRST. As the mission starts to reach development milestones, the needs for production have increased. Scott is overseeing the creation of many new animations—all at 4k resolution—and is producing a series of “explainer” videos to begin presenting WFIRST’s mission and capabilities to the public. WFIRST will be a spacecraft nearly on par with the Webb Telescope, so Scott’s role as lead producer will be significant in years ahead.

Scott’s complete collection of work can be found here: http://svs.gsfc.nasa.gov/search/Person/WiessingerScott.html and his YouTube videos produced during 2015-2016 can be found here: https://www.youtube.com/playlist?list=PL7XDp08SEcdiVhFiHnCYni-Ur_Lx2i4x.

This coming year, Scott will continue working on Solarium and occasionally produce breaking news coverage of solar flares. The interest of the London Science Museum means Scott may be working with Genna to produce new content for them. Regarding Astrophysics, his focus will be on science results. The Fermi group has been very enthusiastic about Scott’s work on the hyperwall and on videos for wide release. As for WFIRST, Scott will be producing narrated videos, interview videos and an increasing amount of social media content for WFIRST. He will be creating new hyperwall material and crafting videos and other products for use at conferences and events.

**CODE 606.4: SCIENTIFIC VISUALIZATION STUDIO**

**Tom Bridgman** provides a variety of visualizations for the NASA GSFC Office of Communications. The Solar and Heliospheric Observatory (SOHO) was approaching the milestone of 3,000 comets discovered serendipitously, mostly in the wide-field Large Angle and Spectrometric CORonagraph (LASCO) imagers. Tom coordinated with Karl Battams (Naval Research Laboratory) on possible visualization ideas. As an initial experiment, Karl provided Tom with a table of 16 significant comets observed by SOHO to use in developing a test visualization of the comet orbits. This worked out well and was rendered in a reasonable time. With that, Tom decided to ‘push the envelope’ and attempted to render a significantly larger table of comets, covering a longer range of years and more highly eccentric orbits. The final products included nearly 1,800 comets observed over 14 years, with trail colors representing the ‘family’ to which the comet belonged. Alternate views were generated, including one view from the position of SOHO that compared well with some of the actual images taken by SOHO/LASCO. The final products are released and available online at http://svs.gsfc.nasa.gov/cgi-bin/search.cgi?series=373.

Some of the experiments on how to demonstrate the imaging and spectral capabilities of Interface Region Imaging Spectrograph (IRIS) were finally released under the animation “A Slice of Light: How IRIS Observes the Sun” (https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4318). In the development process, other visualization products were explored, and some certainly will be released in the future.

With the successful launch of the Magnetospheric Multi-scale (MMS) mission, the Earth-orbiting heliofleet visualization was updated to include the MMS. Several missions also were dropped, including Cluster, FAST, and GOES. Significant changes were made in the underlying coordinate control for the rendering, which enabled some smoother and more flexible camera motions. The visualization “The 2015 Earth-Orbiting Heliophysics Fleet” has been released (see https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4288). A hyperwall version also is available.

After the Pluto flyby of New Horizons, there was a lot of interest in the outer solar system, and the Community-Coordinated Modeling Center (CCMC) was encouraging space-weather modeling groups to push their models to the limit and generate space weather simulations to the edge of the Solar System for comparison to New Horizons data. The CCMC generated a run of their Enlil model out beyond Pluto and expressed interest in developing a public-friendly version using the RGB color tables. The high-resolution model also made a 4kx4k rendered version practical to provide content for the new 4k video services. As expected, the higher data and frame resolution plus distance scale presented some challenges for the pipeline that had originally been developed for models run on the inner solar system (usually out to Mars, but occasionally out to Saturn), but these were eventually solved. The final version was released under “Space Weather to the Edge of the Solar System” (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4392). A hyperwall version was generated in time for the 2015 AGU Fall Meeting. The visualization received a fair amount of public attention:
- [http://gizmodo.com/this-is-the-space-weather-new-horizons-had-to-fly-throu-1746966917](http://gizmodo.com/this-is-the-space-weather-new-horizons-had-to-fly-throu-1746966917);
Tom coordinated with Marc DeRosa (Lockheed Martin Solar and Astrophysics Laboratory) on generating an update of the Solar Potential Field Source Surface (PFSS) model using more data from the Solar Dynamics Observatory (SDO). The previous versions, such as “Flight through the Coronal Loops” (informally known as the “Hairy Green Sun”), were generated for the STEREO pre-launch package in 2005. With Marc’s assistance, Tom was able to generate a series of higher-resolution magnetograms through the SolarSoft package to use with the PFSS field line models. Leveraging some of the work done for “The Sun’s Magnetic Field”, Tom propagated field lines in the corona, as well as close to the photosphere (for a better view of solar active regions). The visualization went through several iterations of the photospheric magnetograms to make the Sun look more ‘Sun-like’, but a number of those looked strange. Tom made one last attempt to improve the solar texturing and remove some of the artifacts, but the results were worse in some ways, so the previous version was used. The visualization “The Dynamic Solar Magnetic Field – Narrated” was completed and released on January 29, 2016 (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=12104).

Upcoming tasks will include the development of visualizations for presenting MMS discoveries. Tom had met with GSFC’s Craig Pollock, John Dorelli, Barbara Giles, and Dan Gershman. He has obtained sample data files, as well as access to the MMS data archive, which enabled him to generate some visualization experiments with actual MMS data. A MMS story has been selected and the development for that release is more focused on that dataset of interest. The team expects a release in the May–June 2016 time frame.

Regarding the Heliofleet Grand Tour, the original “Sentinels of the Heliosphere” is getting rather dated. It was generated back before the Voyagers had crossed the heliopause, and many old missions nearer Earth have gone inactive or new missions have been launched. There was interest in generating at least a visual (not necessarily narrated) illustrating the current configuration. To update this, Tom decided to combine his existing Geospace and Heliospace rendering frameworks to do a continuous transition for a camera near Earth to one out beyond the heliopause. This presented some particular challenges as the RenderMan rendering engine has some difficulties working across this large range of scales (the original “Sentinels” was actually a composition of three different scenes at the different scales). A potential solution was identified as part of the MMS visualization development (above) and will start testing when development resumes.

Leann Estrada provides the SVS with requested software to aid the functionality and productivity of the group. Leann developed several design templates for the SVS gallery pages. One of these templates was approved for implementation, and the gallery page-publishing pipeline was then refactored to implement this new template. Other uses of software include the addition of new filters for HD, 4k, and closed-caption content to the SVS search page. The stability of the search page’s CSS layout was improved for various devices, and the search algorithm was enhanced for quoted multi-word search terms and newer material. Leann also re-implemented the MySQL queries...
performed by the search for increased speed for all search page variants. The search interface was enhanced for filters with a very large number of choices. Also, animations with special types of related animations are now presented directly in the search results. Several sets of SVS pages were converted to the website’s new look and feel, including the WMS product, podcast, and person-by-role pages. This work concluded the overall SVS website update to the new look and feel. On the SVS animation story pages, Leann added a “freeze until date” feature to aid users in editing page content after a page has been released. Support for offering sound and closed-caption files on the SVS website also was added.

Leann reviewed an internal usability report of the SVS website and made several changes in accordance with the report. She worked extensively with an external group to publish pages on the SVS website for Earth Science Week 2015, as well as an additional external education outreach program. She also supported the NASA Viz iPhone/iPad app by updating text on the SVS website to coordinate with their app releases and by developing a new search page mode that will allow for server-side searching, a feature that will be included in a future NASA Viz app release. Also, the SVS movie-encoding GUI tool was reconfigured to be more intuitive and make certain features more apparent. Encoding jobs are now performed on the SVS render farm by default to reduce load on metadata entry machines.

Leann provides support to hyperwall content, and has developed a process that will trigger the creation of hyperwall shows when HD movies are added to the database. This is to ensure NASA has reasonable content to display on the hyperwall for all recent visualizations. Throughout the past year, she fixed several bugs in the hyperwall content formatting software, as well as added several features that were implemented in the underlying tools. She altered various default settings to be correct or more intuitive and implemented a spell-check feature to reduce any errors mistyped into the captions. She also implemented a connection between hyperwall shows and specific animation media groups to facilitate future work on displaying hyperwall information on the SVS animation pages. New hyperwall documentation was created for operating the hyperwall and was posted on the live SVS website for easy access. A one-page cheat sheet of this documentation was drafted and provided to selected users for testing. Leann updated the existing documentation on the hyperwall content creation and editing software, both in content and styling. She also provided support for operating the hyperwall, metadata entry, and cleanup of duplicate hyperwall entries. She assisted several users in preparing and fixing content for both local and conference demonstrations. Additionally, she helped operate the hyperwall at several offsite events including the National Council for Science and the Environment (NCSE), USA Science & Engineering Festival, and NASA’s Earth Day event at Union Station in Washington, DC.

In the next year, Leann will plan approaches to displaying hyperwall content on the SVS website and will perform a major reworking of the internal GUI tools to utilize newer underlying toolkits. Development will begin on a new gallery page template focused on showcasing SVS-specific material. She will continue to address known bugs in the SVS metadata software and make enhancements to the SVS website, as well as address any other software needs of the SVS and its partners.

Alex Kekesi also provides visualizations for the NASA GSFC Office of Communications. This past year, he worked on several products for the Global Precipitation Measurement (GPM) Mission. Although the 2015 hurricane season did not have many events that directly impacted the United States, several hurricanes and typhoons still were of scientific interest. One of the most interesting was Hurricane Kilo. In response to this situation, Alex completed modifications to the GPM pipeline to enable multiple passes of GPM data through time. The final narrated visualization entitled “GPM Gets a Ton of Kilo” has been submitted to several data visualizations competitions; staff members are awaiting the results of those contests. In addition to Hurricane Kilo, Alex also created several new GPM data visualizations of Cyclone Winston, and Tropical Storms Bill, Fred, and Joaquin for the GPM science team.

Image from “GPM Gets a Ton of Kilo”, provided by A. Kekesi.
Alex has been actively consulting on the development of the new GPM quick-turnaround data visualization tool, which is very near completion and actively being used by the GPM team.

In support of the Gravity Recovery and Climate Experiment (GRACE) mission, Alex created several new visualizations, one of which went viral and was carried by Mashable, Gizmodo, and Discovery.

In collaboration with JPL and NASA/Goddard, Alex provided visualization support for the Orbiting Carbon Observatory-2 (OCO-2) project. The resulting visualization was used for communications activities surrounding a successful live shot campaign and has been well received as part of the travelling hyperwall show. Additionally, in preparation for the upcoming joint NOAA and NASA Geostationary Operational Environmental Satellite-R Series (GOES-R) launch, Alex created a pre-launch visualization of lightning data over high-resolution cloud imagery obtained from the GOES-14 Super Rapid Scan Operations for GOES-R (SRSOR) experimental mission. Lightning data was provided by the North Alabama Lightning Mapping Array. This visualization was delivered ahead of schedule and has not yet been officially released. The hope is that generating such data visualizations will portray the sort of interesting visual stories that can be told with the future GOES-R mission.

Alex will continue to provide visualization support to the GPM team as needed. However, now that the GPM quick-turnaround tool has been delivered, Alex may begin to explore other visualization challenges. In conjunction with other SVS visualizers, Alex has begun developing a new visualization of high-resolution LIDAR data over the Amazon rainforest. Initial results have generated much interest from both the Office of Communications and the science team requesting the visual. It is hoped that the enhanced techniques used for this work can extend to other similar data visualization efforts.

Also, Alex will deliver a new data visualization highlighting the Atmospheric Infrared Sounder (AIRS) instrument. The data visualization will go out in conjunction with a scientific paper tying abnormally warm weather events to the melting of Arctic sea ice. Further, Alex anticipates taking on new data visualization challenges. Injecting render-time data processing into the SVS render pipeline provides an exciting opportunity for creating unique data visualizations the SVS has not done before.

**Eric Sokolowsky** provides hardware/software support for the hyperwall, provides meeting support, and updates hyperwall content, among other hyperwall-related activities. This past year, Eric continued to develop and maintain software for running the hyperwall, a cluster of machines connected to a tiled display used to convey NASA science to the public. He developed the ability to render a text document over multiple screens in the cluster. He made many small improvements so the hyperwall performs faster, especially when transitioning between different hyperwalls shows. He developed procedures to update and deploy Fedora 22 on the hyperwall machines, and tested this operating system on several sets of machines, deploying it on two sets of travel Xi3 machines, two sets of Mac Minis, and on new hardware for the hyperwalls in Buildings 28 and 33. Previously, these machines ran a variety of operating systems, including Fedora 17 and Fedora 20. He also started to use the open source video driver for AMD machines instead of the proprietary driver, improving the maintainability and performance of the software. Additionally, Eric improved the two different systems for copying hyperwall data so they work together more effectively. One of the systems was intended for hyperwall systems that travel and the other for systems that don’t. He also made the process of copying files faster.

Eric supported the NASA hyperwall at the following meetings: Earth Day activities held at Union Station, Washington, D.C.; the Japan Geoscience Union meeting, Chiba, Japan; the International Geoscience & Remote Sensing Symposium (IGARSS), Milan, Italy; the Supercomputing conference, Austin, TX; the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP), Paris, France; the American Geophysical Union meeting, San Francisco, CA; and the American Meteorological Society meeting, in New Orleans, LA. He traveled to these locations and provided on-site support for NASA scientists giving scientific presentations on the hyperwall. By preparing hardware and disks for travel, he also supported other meetings in Prague, Czech Republic; Berlin, Germany; Ocean City, MD; Honolulu, HI; Singapore; Boston, Mass.; Halifax, Canada; Baltimore, MD; Kissimmee, Fla.; Crystal City, VA; and Washington, D.C., as.
well as a visit to Goddard Space Flight Center by the president of South Korea. He also copied back data for the hyperwall permanent archive with the presentations used at these events.

For the NCCS (or, NASA Center for Climate Simulation Software Support), Eric continued to support hyperwall content creation. He has written tools to automatically generate images from the NCCS atmospheric model called GEOS-5, and he updated this software to use the latest version of the model data.

In other duties involving hyperwall content, he reorganized content to achieve greater efficiency; for example, some of database entries were very large and actually contained different animations, so those entries were split up into separate entries for each specific animation, allowing for better search capabilities and making retiring specific content more straightforward. Some hyperwall content was moved from the general events area to their own database entries to allow better searching and fine-grained control. He also removed redundancy in hyperwall shows and retired some older shows by updating them with newer versions. Some changes were in response to a lack of hard drive space on the traveling hyperwall systems and the hyperwall in Building 33.

Eric made the Digital Earth PC application much faster by removing unnecessary function calls that are needed only when the disk cache is filling up and some files need to be removed to gain more disk space. He added the ability to permanently cache particular animations so they are always available and are not accidentally erased when more cache space is needed. He added more options to the tool that manages the disk cache to mark animations as permanent or temporary, and added the ability to see the playback status, including the number of frames in the current animation, when the animation is being played. Eric also fixed another problem which caused some image sequences to have very poor image quality. He added the ability to skip frames when playing animations with time information encoded in the filename of each frame.

Eric continued to maintain hyperwall shows by updating file locations, generating preview images as needed, and fixing other problems that arose. Also, he was able to deploy a hyperwall system without a large local disk - - an advantage in situations where all hyperwall content is available through a networked file system, as potentially less time is used transferring images to the local disk. Further, he made the process of copying data files to the large travel disks faster by copying files from the network file system instead of downloading them from the web server, if the file system is available on the current machine. And, Eric built a tool that does general-purpose processing on the animation render farm. This is particularly useful when operations need to be performed on a sequence of images all in the same way, so this tool can use many machines to complete the job.

For 2016-2017, Eric will continue working on the software to play very large movies across multiple screens on the hyperwall. This software, called bigmovie, was developed at NASA Ames Research Center, and needs to be adapted to the NASA GSFC hyperwall environment. Eric intends to update the hyperwall documentation to be more useful and accessible, and will continue to update the software as needed. He also will continue to work on the hyperwall machines as required. The deployment will be completed of the machines for the Building 28 hyperwall as well as the deployment of the new machines for the Building 33 hyperwall, plus the two additional sets of travel Xi3 machines. He plans to upgrade the storage space in the travel machines, bringing many of them up to 500 GB and others to about 375 GB. Eric will continue to travel with the hyperwall to support NASA’s outreach efforts as required, and will support other meetings by preparing disks, updating and packing machines to control the travel hyperwall, and copying back changed and new content after such meetings conclude.

Cynthia Starr also provides a variety of visualizations for the Office of Communications, incorporating various techniques and tools. For the Greenland Radarsat Automatic High-Resolution Data-Mapping Technique and Animations, Cindy expanded upon a technique originally developed by Greg Shirah and automatically mapped a total of 87 gigapixels data over Greenland. She developed a method to generate #include files to geolocate the data tiles from several tiled sets of 20-meter RadarSat data and a set of 30-meter Greenland Mapping Project Digital Elevation Model (GIMP DEM) data, referencing the appropriate files sets within her slim shading network. She generated a narrated animation to explain this technique and presented the method at the SIGGRAPH 2015 Conference in Los Angeles, CA. (An ACM SIGGRAPH interview with Cindy appeared here: http://www.siggraph.org/discover/news/visualizing-earth-and-beyond-computer-graphics.) In addition, Cindy developed three animations using this technique to show the change over time in several different regions of Greenland, including the Zachary Istrom, Petermann and Helheim glaciers.

Cindy created several animations of mass loss as measured by the GRACE mission over the Greenland and Antarctic ice sheets from 2005 to 2014. From the original ungridded time-series
datasets, she used Kriging interpolation to create animations that clearly showed the change over time in both ice sheets. For the Antarctic continent, she created individual regional animations for West Antarctica, East Antarctica, and the Antarctic Peninsula.

Cindy developed an animation to show the results from the ECCO2-Darwin ocean carbon cycle model and the Darwin Project for two Jet Propulsion Laboratory (JPL) scientists. Together this data provided a time-evolving physical and biological environment for tracking ocean surface carbon dioxide flux. Horace Mitchell assisted in deriving the wind stress vector flows from the model data. Using this, Cindy created a visualization “Ocean Surface Carbon Dioxide Flux with Wind Stress” of the global ocean wind stress flows below which she displayed the air-sea carbon flux. The animation supported a hyperwall talk by JPL’s Dr. Michelle Gierach at the COP 21 Climate Change Conference in Paris.

This past year, Cindy supported the Office of Communications’ annual news releases on Arctic Sea Ice Minimum/Maximum and Antarctic Sea Ice Maximum by creating several animations of Arctic and Antarctic sea ice using Advanced Microwave Scanning Radiometer 2 (AMSR2) and Special Sensor Microwave Imager (SSM/I) data.

She also developed a visualization to support the release of a paper by Daniel Anderson (University of Maryland) titled “A Pervasive Role for Biomass Burning in Tropical High Ozone/Low Water Structures.” The animation shows the flight path of a single NCAR Gulfstream V aircraft flight originating out of Guam, outfitted to measure various trace gases in support of the CONvective TRansport of Active Species in the Tropics (CONTRAST) campaign. From the locations of these measurements, the backflow trajectories were modeled using the NOAA Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model, stepping back in time for 10 days prior to the measurement date or until the trajectories encountered convection. Cindy developed scripts to generate the flows that traced the trajectories from the flight path to their source and included the hourly active fire locations as well as data showing convective regions.

In the coming year, Cindy plans to create visualizations using Landsat data to support a paper by GESTAR scientist Junchang Ju and Jeffrey Masek (GSFC) showing the greening trend in Canada and Alaska between 1984 and 2012. In order to enhance the infrastructure of the studio, Cindy also plans to develop plug-ins to extend the native capabilities of the RIS Renderman rendering system to incorporate those features needed to support the SVS transition from Slim/RLS to RIS. Note: many of the visualization techniques developed and refined have been a collaborative effort and are a credit to the talents of the animators/programmers and technical support staff working together. Most of the accomplishments are a credit to the team members with whom Cindy has had the privilege to work. The visualizations that Cindy created during this past year are available at: https://svs.gsfc.nasa.gov/cgi-bin/search.cgi?contentType=SVS&releaseStart=2015-5-1&releaseEnd=2016-5-1&person=73+%22Lead+Visualizer%22&expanded=filters.

Over the past year, Kel Elkins has created several visualizations as part of the SVS, supporting both Earth Science and Planetary missions. He continued to support the GPM science and outreach teams by creating ‘quick-turn’ storm visualizations for Typhoon Maysak, which occurred on April 8, 2015, and Hurricane
Joaquin, which occurred on Sept 30, 2015. The same pipeline also was used to create a visualization depicting an intense monsoon near the western coast of India that occurred in 2014. These GPM visualizations depict both Earth surface and volumetric precipitation measurements taken by GPM, and allow the viewer to understand the 3D structure of a storm.

Kel developed a visualization depicting stellar occultation observations to be conducted by the MAVEN spacecraft in orbit around Mars. The visualization shows how the satellite scans the horizon of MARS from its elliptical orbit, covering the entire Martian atmosphere over the course of approximately six orbits. The visualization was used in a video produced by the Goddard Media Studios that describes how MAVEN will study the Martian atmosphere to determine how Mars lost its early atmosphere and with it its water (see http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11992).

For NASA’s Sea Level Rise campaign, Kel created visualizations depicting sea level rise over the past 22 years based on data collected from the TOPEX/Poseidon, Jason-1, and Jason-2 satellites. The visualizations were reused extensively in stories from various news websites/networks, including Reuters, Forbes, The Washington Post, CNN, NBC, and CBS. The visualizations also were used at the 2015 World Climate Change Conference (COP21).

Kel produced an extensive, fully-narrated visualization describing the NASA/NOAA Joint Polar Satellite System (JPSS) mission, including visual depictions of sun-synchronous satellite orbits, data collection, communications, and additional satellites that will be added to the constellation. He worked closely with JPSS systems engineers in order to portray concepts that were particularly difficult to communicate without the use of supporting visuals. The visualization was used at a JPSS Multi-Mission Requirements Review (MMRR) in February, and has since been highlighted on NOAA’s official JPSS webpage (http://www.jpss.noaa.gov/video_gallery.html). The entire video can be viewed here: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4430.

In August 2015, Kel gave invited talks at SIGGRAPH, an international computer graphics conference. He presented his visualizations that depicted dust from Africa travelling through the atmosphere toward South America, and also a longer talk describing the visualization production pipeline used by the SVS. He gave an invited talk on Scientific Visualization as part of the Villanova University Computer Science Department Colloquium Series in which he presented several examples of visualizations created by the SVS and discussed how scientific visualizations are produced.

Currently, Kel is working on a visualization that examines how volcanic ash and sulfur dioxide were distributed through the atmosphere following the Calbuco volcano eruption in 2015. Future projects include a visualization depicting NASA’s OSIRIS-REx mission to return a sample from the asteroid Bennu.
Kel also is working on methods to create visualizations in stereoscopic spherical formats that work with virtual reality (VR) hardware, such as the Oculus Rift and Google Cardboard, as well as 360-degree YouTube videos.

Helen-Nicole Kostis serves as the Project Manager of NASA Visualization Explorer (NASA Viz), a free iPhone, iPad, and iPod app that provides access to visualizations of current NASA research. Through the app, two visualization-based science stories are released per week about cutting-edge research efforts in Earth and Planetary science, Heliophysics, and Astrophysics. The project is comprised of two teams: i) Software Development and User Interface Design, and ii) Editorial (Editor: Kayvon Sharghi). The stories present the data visualization work of many NASA groups, including NASA’s Scientific Visualization Studio (SVS), Earth Observatory (EO), JPL and the Space Telescope Science Institute. The app’s archive of 481 stories (as of 04/24/16) includes animations, searchable images, and descriptive text. The NASA Viz app and content are developed and produced in-house by an interdisciplinary team. In addition to search capabilities, the app includes teacher-requested features, such as the ability to save stories for offline use and to create, save, and share custom playlists of stories. The app includes social networking interfaces to Facebook and Twitter for easy sharing of stories.

During this past year, NASA Viz released five versions (from 1.9.4 to 1.9.8) that addressed bug fixes and/or added capabilities. To date, a total of 85 visualization-based stories were released, covering all NASA Science themes: Earth, Planets, Sun and the Universe. In addition, the team launched a pilot project during summer 2015 to develop a version of NASA Viz for the Android platform (Google Play Store). The pilot was successful and the team started working toward an Android version for release. In the meantime, Helen-Nicole followed NASA guidelines and submitted the paperwork for New Technology Reporting (NTR), Software Release Process and Patent through the IPP Office. The Android version is in the final stage of the Quality Assurance (QA) Phase and the team is awaiting the End User License Agreement (EULA) approval from NASA legal.

The NASA Viz gained several favorable mentions and was featured at many events. NASA Viz was selected as a finalist to the Goddard-wide Software of the Year Award for 2015. The team gave a presentation to a panel of IT experts from NASA Goddard & NASA HQ. The NASA Viz was featured in the NASA 2015 Goddard Annual Report as an exemplary project. From May 27-31, 2015, NASA Viz was on display as part of an exhibit at the World Science Festival in New York City, NY. In January 2016, Helen-Nicole represented the app at the NASA Science Education CAN kickoff meeting, held in Dallas, TX.

Helen-Nicole also served as Product Manager for the NASA ICESat-2 Education and Public Outreach team. On January 30, 2014, she launched the ICESat-2 Collaborative Student Project. For the purposes of this project, Helen-Nicole collaborated with digital media faculty and students from academic institutions.

Images from the World Science Festival, New York City, NY; engaging with exhibit visitors are Kayvon Sharghi (upper left) and Helen-Nicole Kostis (upper right). Images provided by H.-N. Kostis.
for the development of innovative outreach concepts and products for the ICESat-2 mission. Throughout 2015-2016, the team achieved several goals. Helen-Nicole led the design and development of graphics for the banner, supervised tests and the printing of banner; the end result was the team’s production of a gigantic ICESat-2 banner for the Engineering Facilities Complex & Clean room area. The team also produced two pop-up banners as well as posters; for these products, Helen-Nicole led the design and development of graphics for the banners and posters, supervised tests and printing. For the Website Design & Media aspect, launched April 12, 2016, Helen-Nicole led the UI design and suggested media selections and strategy for the new ICESat-2 website sections: Home/Landing page, Mission, Science, Applications, Data, Multimedia, FunZone and their sub-pages. Also, for the Pop-up Book Concept & Storytelling (Phase A), she led the storytelling/concept effort and supervised the research of Digital pop-up book media. Finally, she led the design of the logo and branding materials for the ATLAS instrument team. She is currently wrapping up the remaining tasks before she finalizes her work with the ICESat-2 project.

On Tuesday, March 22, 2016, the 2015 Robert H. Goddard (RHG) Honor Awards Ceremony was held in the Building 8 Auditorium. The RHG Award – Outreach was presented to Helen-Nicole “for outstanding performance and implementation of a unique outreach program for a NASA mission and engagement of university students and faculty.”

She has contributed to the field of Computer Graphics & Scientific Visualization in various ways. At ACM SIGGRAPH 2015, Los Angeles, CA, August 9-13, 2015, she served as a) a Juror for courses, talks, panels, posters, and emerging technologies; b) Student Research Competition Chair, and c) “Supernatural” Session Chair. She also served on the Scientific Visualization Program Committee and as a technical paper reviewer for the IEEE Vis 2015, October 25-30, Chicago, IL. In addition, she continues to work (on her own time) toward a book publication in collaboration with professionals and pioneers from the field of the computer graphics and visualization (expected publication date: 2017; publisher: CRC Press).

As Project Lead for the NASA Viz, Helen-Nicole will work toward the following goals: a) support NASA outreach efforts by showcasing NASA Viz on outreach and science education events (e.g., NASA Earth Day 2016, Union Station, DC); b) continue to support NASA science education efforts and collaborate with NASA Science CAN awardees; c) release NASA Viz for Android at the Google Play Store; d) continue the redesign effort of the User Interface of the app, following iOS guidelines; and e) release NASA Viz 2.0. She also will continue to provide scientific visualization expertise to SVS/Code 606.4.

She will wrap up her duties as the ICESat-2 E/PO Product Manager. By summer 2016, Helen-Nicole will complete the two remaining tasks: a) deliver source of the project to ICESat-2 and b) document the projects, team members and products developed for the web. Finally, she plans to attend two conferences: ACM SIGGRAPH 2016, Anaheim, CA, in July and IEEE VIS 2016, Baltimore, MD, in October.

Ernest Wright provides scientific visualization products in support of communications and public outreach for Lunar Reconnaissance Orbiter and other missions. Ernie is actively involved in outreach for the August 21, 2017 total solar eclipse. He has developed methods of visualizing solar eclipses that he has applied to both the 2017 eclipse and the March 2016 eclipse visible from Indonesia (http://svs.gsfc.nasa.gov/Gallery/suneclipse2017.html). His visuals were used extensively by the Exploratorium (http://www.exploratorium.edu/eclipse) before and during their live coverage of the 2016 event from Woleai Atoll in Micronesia. They also were used during a GSFC live shot campaign the morning before the eclipse. Ernie is continuing to work with NASA Heliophysics and with outside organizations such as the American Astronomical Society to promote awareness of the 2017 eclipse.

Image provided by E. Wright.
Ernie continues to broaden his support for the Lunar Reconnaissance Orbiter (LRO). His annual lunar phase and libration visualizations (see visualizations 4404 and 4405) are consistently among the most popular on the SVS website. Ernie co-authored along with astronomer Jay Pasachoff a talk about lunar limb profiles developed from LRO elevation data that was presented at the 47th annual meeting of the American Astronomical Society Division of Planetary Sciences. He prepared and presented a hyperwall show to Apollo 17 astronaut Harrison “Jack” Schmitt. The show highlighted LRO imaging of the Apollo 17 landing site and fostered discussion of the site’s geology. Ernie also presented LRO data during a talk at the 2016 National Association of Broadcasters convention.

Additionally, Ernie has led or contributed to visualizations for several other missions and science results, including the newly released Mars gravity map developed at GSFC (http://sys.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4436), as well as the JPSS mission concept and results from MAVEN and MESSENGER (see visualizations 4430, 4346 and 4312, respectively, at the SVS site: http://sys.gsfc.nasa.gov).

Cheng Zhang has accomplished many visualization projects this past year. A visualization on megadrought illustrates droughts in the Southwest and Central Plains of the U.S. in the second half of the 21st century, which could be drier and longer than anything in those regions in the last 1,000 years.

“Winds over Ocean Salinity (CCMP)” visualizes the motion of wind, changes of ocean salinity, and the potential relations between the winds and ocean salinity. She also worked on two lightning projects pertaining to phenomena over South Dakota and northern Alabama. The TRMM/MERRA Precipitation Anomalies Project provided visual support for the research led by scientist Andrey K. Savtchenko and revealed the role of atmospheric rivers on drought and how the atmospheric rivers are in different places during drought versus non-drought periods by overlaying the flow data (such as wind) on precipitation anomaly data. Cheng worked on several atmospheric river projects, including visualizing atmospheric rivers in El Niño seasons in 1996-1997 and 2015-2106. Aquarius-related projects included visualizations of sea surface salinity (SSS), sea surface temperature (SST), sea surface density (SSD), and soil moisture. Ongoing projects include South Korean air quality (KORUS-AQ) and Hurricane and climate modes. Cheng also is working on various data products including MERRA-2, IMERG, and GOES. She prepared data for herself and other visualizers.

Based on various projects for Aquarius, Cheng worked on a pilot project for Interactive Aquarius Retrospective Visualizations. Aquarius retrospective visualizations included eight animations in flatmap or Mollweide projection. Since it is inconvenient for the scientists to switch from one to another for comparisons during presentations, Cheng created this interactive application in which scientists can easily select an area through zooming in/out, moving around, or switching different contents by clicking a button. This pilot project demonstrates a potential approach for a better solution.

On September 26, 2015, Cheng served as a volunteer to demonstrate “The Moon Experience” at Explore@NASAGoddard. She integrated “The Moon Experience” into Oculus Rift successfully and the demonstration went very smoothly; in fact,
it generated so much interest that people waited in a long line to try it. In six hours, she engaged with about 300-400 people.

Cheng attended the “Test of Variables of Attention” (T.O.V.A) workshop. The T.O.V.A. is an objective, neurophysiological measure of attention. It is a widely accepted approach to measure attention. One popular topic in digital media is how to effectively engage users in digital animation, computer game, visualization, virtual reality, etc., that is, how to make use of users’ attention and improve overall efficiency in digital applications, and one critical issue is how to measure attention. This workshop reveals important variables of this. She also attended “Introduction to IDL” in Herndon, VA in July. IDL is widely used in the science community for interactively obtaining insight of data. This three-day training has better prepared her for working with data. Currently, Cheng is attending Aquarius online training courses in order to gain insightful information among different parameters and develop an interesting story line.

In August 2015, Cheng attended the Gordon Research Conference (GRC) in Lewistown, ME and SIGGRAPH in Los Angeles, CA, where she learned different perspectives about visualization from people in various fields. In addition to SIGGRAPH’s leading-edge technical program, the conference’s installations provided close-up views of the latest in digital art, emerging technologies, and hands-on opportunities for creative collaboration. Cheng learned the latest research and technologies in computer graphics and visualization and the new trends in visualization industries. In May 2016, she attended the ACM CHI 2016 Conference in San Jose, CA.

Cheng’s “Geocaching on the Moon” has been accepted as a chapter in the forthcoming book “Geogame and Geoplay” (Publisher: Springer). Also, her paper “The Moon Exploration” has been accepted by the ACM CHI 2016 conference and will appear in the conference proceedings. This past year, she gave two seminars, one at University of Texas - Dallas and one at Rochester Institute of Technology. She also was invited to speak at the Universidad Panamericana, Guadalajara, Mexico.

Cheng will continue working on her various projects such as KORUS-AQ, Hurricane and climate modes/parameters comparison, Aquarius related projects, and data operation. She will be attending the SIGGRAPH 2016 conference in July.

**CODE 606.2: HIGH PERFORMANCE COMPUTING**

Jarrett Cohen and Maria Ealey (sponsor: P. Webster) provide communications, outreach/engagement, and allocations support for NASA’s High-End Computing (HEC) Program. For the NASA Center for Climate Simulation (NCCS) and Computational and Information Sciences and Technology Office (CISTO) Communications, Jarrett continued a series he developed of three NCCS Success Stories (http://www.nccs.nasa.gov/nccs_success_stories.html). “New Animation Shows Millions of Earth Observations for Forecasting” introduces a Global Modeling and Assimilation Office (GMAO) animation depicting the 5 million observations that get assimilated for weather forecasts four times per day. An @NASA_NCCS story tweet with an animated GIF had over 40,600 impressions and over 4,000 engagements. “Virtual Earth Observing: Simulating the Globe in 1-Mile Segments” describes the highest-resolution weather simulation ever run in the U.S. using the GMAO’s GEOS-5 model. “Hal Domchick: From Data Technician to Facilities Mastermind” provides the recently retired employee’s 47-year perspective.

In media support, Jarrett ran the hyperwall for National Public Radio’s Nell Greenfieldboyce, who interviewed CISTO and NCCS leaders (http://www.npr.org/2015/11/30/457794505/big-data-predicts-centuries-of-harm-if-climate-warming-goes-unchecked). He also edited a draft and took a photograph for an International Telecommunication Union story (http://itu150.org/story/october/) and got NCCS references included in “Since Katrina: NASA Advances Storm Models, Science” (http://www.nasa.gov/feature/goddard/since-katrina-nasa-advances-storm-models-science), with additional exposure in publications such as Gizmodo.

With NCCS and Technical Information and Management Services (TIMS) Branch staff, Jarrett updated NCCS Climate Computing Facility signage to reflect current performance and capacity, updated and reprinted the NCCS Fun Facts lenticular ruler, and arranged a photo shoot of the upgraded Discover supercomputer. For his upgrade communications efforts, Jarrett was part of the team receiving a 2016 Robert H. Goddard Exceptional Achievement for Mission & Enabling Support Award.
In CISTO website contributions, Jarrett coordinated updates to the NCCS Fun Facts page (http://www.nccs.nasa.gov/funfacts.html); provided new show materials for the Visualization Wall/Hyperwall Content page (http://www.nccs.nasa.gov/viswall_content.html); edited two NASA Climate Model Data Services (CDS) stories; tested and edited the “NCCS Hyperwall (VisWall) User Guide”; and revised “From Observations to Models”.

In social media highlights, Jarrett worked closely with GMAO and Office of Communications staff to promote a GMAO Science Snapshot on the 2016 blizzard, which garnered about 2,250 retweets on Twitter, about 277,440 views on Facebook, and about 128,100 views on YouTube. @GreatGovTweets recognized the @NASA_NCCS tweet as the 30th most engaging on January 22, 2016. The video appeared in media including The Atlantic, Gizmodo, USA Today, and The Washington Post. Jarrett supported NASA’s Earth 24Seven campaign by submitting photos with captions of staff installing new supercomputer racks and a scientist with a 6-kilometer global weather forecast.

Conference and Event Support is a large part of this task. The Supercomputing 2015 (SC15) conference held in November in Austin, TX had a record attendance of nearly 13,000 people. Jarrett was GSFC coordinator for 11 demonstrations (including one from NASA Headquarters). Pre-conference, he helped assemble hyperwall content, edited abstract and poster content and processed images, worked with TIMS on poster layouts, provided Discover supercomputer photos for a playing card set giveaway, compiled information for the NASA exhibit booklet, worked with management to recommend a Featured Demo and developed promotional materials including a media backgrounder, and contributed to NASA and Cycle Computing news releases. Onsite, Jarrett contacted media representatives; scheduled an interview with The Register, whose reporter wrote a major feature story; served as principal exhibit photographer; and wrote a story for the NASA@SC15 website and bullets for daily highlights emails.

The 2015 American Geophysical Union (AGU) Fall Meeting held in December in San Francisco, CA drew over 24,000 attendees. Jarrett coordinated HEC Program participation in the NASA exhibit and supported researchers’ Scientific Program activities. In exhibit preparations, Jarrett coordinated logistics for GEOS-5 virtual reality demonstrations, helped recruit presenters and edited abstracts, arranged the printing of CDS and NCCS flyers, and coordinated with NCCS and GSFC Code 547 staff on making 3D prints of the Discover supercomputer racks. For the Scientific Program, he thoroughly edited and adjusted formatting for six posters and arranged printing. Onsite activities included presenting a HEC Program poster he developed at the Science Mission Directorate (SMD) Communications Meeting, working the HEC table on a daily basis, engaging with visitors, distributing over 1,500 lenticulars and flyers, and taking photos.

In GSFC and DC-area events, Jarrett served as NCCS activity lead for Explore@NASA Goddard (September 2015), attended by 20,000+ people. Activities included planning, writing, tweeting, hyperwall driving, tours, and photography. Other supported events were the 2015 GSFC Science Jamboree (July 2015), the 8th Annual Sciences & Exploration Directorate (SED) New Year’s Poster Party (January 2016), and NASA’s 2016 Earth Day at Union Station event (April 2016). Jarrett also compiled playlists and ran the NCCS hyperwall for 16 presentations by SED, CISTO,
NCCS, and Scientific Visualization Studio leaders for audiences ranging from foreign dignitaries to school children.

For the HEC website (http://www.hec.nasa.gov), Jarrett posted 44 news items to the home page and News & Publications section; updated About Us section pages with current information on mission focus, services, NASA Advanced Supercomputing (NAS) Facility and NCCS hardware performance and capacity, and new systems; refreshed the Request Computing Time section with announcements and new SMD Call requirements and language; and updated the User Information section’s Funding Opportunities page with the latest solicitations and selection information. With SED web staff he updated the site’s Google Analytics script to link to a new U.S. government-wide resource.

Maria processed just over 480 requests submitted for NASA HEC Resources for SMD Supported Research during the FY16-Q1 and Q3 open calls. This effort included analyzing the number of Standard Billing Units (SBUs) requested by principal investigators; the number of SBUs available on the NAS Pleiades, Endeavour, and Merope supercomputers and the NCCS Discover supercomputer; and previous usage on established projects. She met with Discipline Leads at NASA HQ in October 2015 and April 2016 with recommendations for annual allocations awards. Maria also worked on tickets submitted to NAS and NCCS with questions regarding modifications to current SMD allocation awards as well as requests submitted for limited out-of-cycle awards.

This task will be ending, with respect to the GESTAR cooperative agreement, but Jarrett and Maria will continue serving NASA in the aforementioned capacities.

**SCIENCE PROGRAM SUPPORT OFFICE (SPSO)**

Over the past year, the Science Program Support Office (SPSO) (sponsor: S. Platnick), which consists of Global Science and Technology (GST) staff members, served as point of contact for science exhibit outreach and product development for the NASA’s Earth Science Division (ESD), Science Mission Directorate (SMD), and Applied Sciences Division (ASD). Each “customer” falls under a different task and activity under each task is summarized below. More information on conferences supported, products developed, and other activities of the SPSO during this time period can be found in the 2015 Science Program Support Office Annual Report. The success of all these endeavors requires contributions from the entire team, which includes Winnie Humberson (lead), Ryan Barker, Sally Bensusen, Steve Graham, Heather Hanson, Marit Jentoft-Nilsen, Mark Malanoski, Debbi McLean, Kevin Miller, Amy Moran, Ishon Prescott, Cindy Trapp, and Alan Ward.

**Earth Science Division Support**

The team provided support to numerous ESD-related conferences over this past year. The SPSO participated in three high-profile international events in the late spring and summer of 2015. The first was the Japanese Geoscience Union Annual Meeting (JpGU), which was held in Chiba, Japan in May. SPSO coordinated NASA’s hyperwall science exhibit and speakers. Earth Science Division Director Dr. Michael Freilich spoke at the Union Session. SPSO and JAXA representatives organized a visit of 100 junior high school students to NASA’s exhibit. The final international event of the summer was the Asia Oceania Geosciences Society (AOGS) in August in Singapore. The SPSO and JAXA representatives organized a visit of 100 junior high school students to NASA’s exhibit. The second international event was the XXVI General Assembly of the International Union of Geodesy and Geophysics (IUGG) Czech Republic in July. The hyperwall daily agenda was packed with highly visible science results presented by the subject experts from JPL, Goddard, and other institutes affiliated with NASA. For many speakers, this was their first time presenting on the hyperwall, and they appreciated the opportunity and the experience of presenting in a different way. The final international event of the summer was the Asia Oceania Geosciences Society (AOGS) in August in Singapore. The SPSO worked with the AOGS organizers to develop a...
comprehensive program for NASA’s exhibit. Jack Kaye, NASA’s Associate Director for Research in the Earth Science Division, gave a special public lecture and James Green, NASA’s Planetary Science Division Director, also was an invited speaker. While there, Jack Kaye received an Honorary Member Award, making him the 4th person honored with this award in AOGS’ 12-year history.

The SPSO supported the Earth Science Division at the World Science Festival in New York in May. SPSO led the Earth Science participants from NASA Centers (JPL, Goddard, Wallops) in an inclusive outreach agenda. This two-day event used hands-on demos to enlighten the public about NASA’s Earth Science missions. In addition, SPSO staff supported the American Chemical Society (ACS) meeting in Boston, MA in August.

SPSO had a very busy fall, beginning with support of the Group on Earth Observations (GEO)—XII Plenary and Ministerial Summit in Mexico City, Mexico. The U.S. GEO booth, an interagency effort that collectively represents the U.S., featured a 70-inch plasma screen where four programmatic talks were given. During non-presentation times the screen was used to display 4k NASA visualizations, as well as other content from NOAA and the U.S. Geological Survey (USGS). Kathryn Sullivan, U.S. Co-chair of GEO, and Sally Jewell, U.S. Secretary of the Interior, led the U.S. delegation. Ms. Sullivan spent time at the booth explaining visualizations to visitors. In November, SPSO supported the United Nation’s Framework Convention on Climate Change’s 21st Conference of the Parties (COP-21) in Paris, France. The SPSO organized the hyperwall exhibit inside the U.S. Center at COP-21, which is a major public outreach effort to inform attendees about key climate initiatives and scientific research taking place in the U.S. Jack Kaye, Michelle Gierach (NASA JPL), Steven Pawson (NASA GSFC/Chief of the Global Modeling and Assimilation Office), and Patrick Taylor (NASA LRC) delivered a variety of NASA hyperwall and other presentations.

Moving into 2016, SPSO supported the National Council for Science and the Environment (NCSE) in Washington, DC in January. Jack Kaye and program managers from NASA HQ and GSFC gave daily hyperwall presentations that covered a range of Earth science topics related to energy and climate change. The purpose of the meeting was to explore the connections between science and decision-making associated with a particular high-profile environmental issue. Also in January, SPSO organized NASA’s exhibit at the AMS WeatherFest event (open to the public), where attendees viewed visualizations of science data on the Dynamic Planet, an interactive video globe. SPSO supported the American Meteorological Society (AMS) Annual Meeting in New Orleans, LA. Michael Freilich (NASA HQ/ESD Director), Steven Clarke (NASA HQ/Director, Heliophysics Division), and Bill Putman (NASA/GSFC) were among NASA’s hyperwall speakers during the Opening Reception. Additional hyperwall talks were scheduled throughout the week.

When not on the road, SPSO staff are busy creating products to support the activities planned for the future. The oldest continuous product produced by the SPSO is The Earth Observer newsletter, which began in March 1989. Content comes from a variety of sources and several staff collaborate on editing and design to produce six issues each year. Each newsletter begins with an editorial from Steve Platnick (EOS Senior Project Scientist) and includes feature articles, national and international meeting and workshop summaries, and a NASA Earth Science in the News section. The publication is black and white, but pdfs of color issues can be downloaded from http://eospso.nasa.gov/earth-observer-archive/.

SPSO continues its long history of producing “pre-launch” brochures for upcoming missions. This year’s addition was the SAGE III Mission Brochure, which includes information on how aerosols and ozone affect Earth’s atmosphere, information about the SAGE III on ISS instrument payload, the types of measurements the instrument package would make, how the package would be installed on the International Space Station, and much more. Other noteworthy SPSO products this year include Ocean Sciences 2016: El Niño-La Niña and Ocean Phytoplankton Lenticular Cards. These were two cards that illustrate the effects of El Niño and La Niña on sea surface heights and ocean chlorophyll, respectively. There also is a Seasonal Carbon Dioxide Jigsaw Puzzle, a 3-D puzzle showing how carbon dioxide levels change seasonally over the year, especially in the northern hemisphere.

The hyperwall continues to be the centerpiece of many of SPSO’s recent outreach efforts for all three tasks (ESD, SMD and ASD). Staff are constantly working on new content as well as maintaining the system and making its interface increasingly user-friendly. In terms of ESD-specific achievements, SPSO staff produced a new filtering option for the hyperwall catalogue that will allow searching for 4k content. Encoding 4k, 4MP movies for existing content has become a high-priority task, and this new search option will help expedite the process. Nearly half of the 592 items in the database are now properly tagged and can found with the new search filters. They also created a mailing list to keep hyperwall presenters and other interested
parties informed of new hyperwall content. The hyperwall team also worked together to create a new hyperwall content how-to document that will help new hyperwall speakers prepare their presentations.

With regard to ESD-related content, the first released image from the Earth Polychromatic Imaging Camera (EPIC) on the Deep Space Climate Observatory (DSCOVR) satellite was prepared for the hyperwall. A subsequent series of the moon crossing between DISCOVR and Earth was adapted.

The El Niño Watch 2015 hyperwall visualization was updated with data through October 31 (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30629) and the ENSO Sea Surface Temperature Anomalies: 2015-2016 visualization has been updated with data through November 15 (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30645). The recently added Yearly Cycle of Earth’s Biosphere visualization (http://svs.gsfc.nasa.gov/goto?30709) was featured in a Huffington Post article.

Several feature articles from The Earth Observatory (http://earthobservatory.nasa.gov) (EO) website were adapted into hyperwall shows and the visualizations were enhanced with new data to bring them up to date. Examples include: Northwest Fires at Night, Three Storm Night, Water Level in Lake Powell, Athabasca Oil Sands, and Mountaintop Mining in West Virginia.

**Science Mission Directorate Support**

In terms of SMD-related support, SPSO staff supported quite a few conferences during the last year, including the XXIX International Astronomical Union (IAU) General Assembly in Honolulu, HI in August. SPSO organized NASA’s hyperwall, science exhibit, and line-up of 15 different programs and astrophysics projects from across NASA’s divisions. SPSO also supported the Geological Society of America (GSA) Annual Meeting in Baltimore, MD in November. Dalia Kirschbaum, George Huffman and Allison Leidner gave hyperwall presentations that covered topics related to precipitation and biodiversity. Prior to the exhibit booth opening on October 31, SPSO participated in GSA’s Open House “Maryland Rocks!” public event. Activity passports were distributed to attendees for an opportunity to complete science activities and collect a NASA information packet.

SPSO staff have a long history of supporting the American Geophysical Union (AGU) Fall Meeting in San Francisco, CA. That tradition continued this year, with SPSO coordinating the planning of a bigger exhibit than ever. Sixteen different programs and projects from across NASA’s divisions participated in this event, sharing their missions’ and programs’ discoveries and research. John Grunsfeld (NASA HQ/Associate Administrator, SMD) provided opening remarks, welcoming participants to the booth, followed by hyperwall presentations by division directors Michael Freilich (NASA HQ/ESD Director), Jim Green (NASA HQ/ Director, Planetary Science Division), and Steven Clarke (NASA HQ/Director, Heliophysics Division) during the opening reception. The SPSO worked closely with each SMD division to create three 7.5-ft “pillars” to display communication campaign messages at the NASA booth.

Prior to the opening of AGU, SPSO organized the 2015 Annual Science Mission Directorate (SMD) Communication Meeting, held on December 13, with 83 NASA outreach professionals from various centers in attendance. The meeting opened with discussions from SMD communication leaders and division directors from Earth Science, Planetary Science, and...
Heliophysics. These and other presentations provided valuable insight and guidance to the community. The open communication setting combined with a one-on-one “share-a-thon” event proved to be an excellent communication practice. SMD’s Communication Meeting continues to grow in attendance and scope and has become a much-anticipated forum for information exchange within NASA’s science outreach community.

Each year at AGU, attendees anticipate being among the first to get the 2016 Science Mission Directorate calendar. SPSO staff work together with NASA HQ personnel to select and compile 12 feature images—one for each month—and compose the accompanying captions. The featured images were incorporated into vivid photo illustrations for the cover and opening spread.

SPSO staff planned and organized NASA’s 20’x30’ hyperwall and science exhibit; many distinguished speakers from NASA participated. Also, the SPSO joined with the U.S. Global Change Research Program (USGCRP) for Family Science Days, a one-day event open to the public that featured hands-on activities and demos. SPSO participated in a “Women in STEM” Event at NASA GSFC on March 16. The event was held in partnership with the White House Council on Women and Girls. GSFC’s Office of Communications requested the hyperwall be a component of the day’s events. Dr. Dahlia Kirschbaum, lead scientific support for Global Precipitation Measurement (GPM) mission, gave several hyperwall presentations to visiting students. Staff received a letter of appreciation from Michelle Jones, GSFC’s Deputy Chief of the Office of Communications.

In April, SPSO took part in the U.S. Science and Engineering Festival in Washington, DC. The hyperwall was a major component of NASA’s 50’ x 60’ science exhibit at this public event. Staff were onsite to assist with presentations and to provide technical support. Logistical requirements were coordinated with NASA HQ. Another major SPSO outreach event in recent years has been partnering with the Earth Day Network in the annual Earth Day observance. This year, activities took place at Union Station, Washington, DC on April 21 and 22. The SPSO organized and participated in this event, which featured hyperwall presentations, 18 hands-on demos from several NASA centers, student visits from six local elementary and middle schools—including over 400 students—and a special half-hour presentation on April 22 given by astronaut Piers Sellers, who is currently serving as Deputy Director of the Sciences and Exploration Directorate at NASA GSFC.

As with ESD, the hyperwall is a centerpiece at many SMD exhibits. Over the past year, new SMD content has been added, including two International Space Station (ISS) videos that were adapted for display on the hyperwall. The first shows Soyuz docking with ISS, and the second is footage of Earth from a new 4k video camera: EPIC View of Earth (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30610) and From a Million Miles Away (http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11971). New Horizons released its historic Pluto flyby, and images and captions were prepared for display on the hyperwall and then added to the online hyperwall catalog: http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30615. New content images from the announcement of seasonal water on Mars and higher resolution Pluto and Charon images from New Horizons were added to the catalog.
**Applied Science Division Support**

As with the other two tasks, SPSO support for ASD activities included participation in many conferences, including the 36th International Symposium on Remote Sensing of the Environment (ISRSE), Berlin, Germany in May. NASA hyperwall speakers included Michael Freilich, Lawrence Friedl, and several other NASA scientists. External partners joining NASA’s hyperwall agenda were Ivan Csiszar (NOAA) who talked about climate research operations, Jörg Schulz (EUMETSAT) presented on Weather and Climate Observation, and a representative from the European Space Agency (ESA) discussed Climate Variability. SPSO staff supported the 108th Air and Waste Management Association Annual Conference, held in Raleigh, NC in June. The hyperwall helped to provide a new perspective on the science NASA brings to this community. A team of presenters highlighted the ASD’s focus on air quality in the atmosphere and how the Ozone Monitoring Instrument (OMI) data is observing the improvement in nitrogen dioxide levels and air quality in US cities. SPSO staff participated in the International Symposium on Digital Earth, held in Halifax, Nova Scotia in October. The keynote address was given by David Green, NASA’s Program Manager for Disaster Applications, who also gave several hyperwall presentations during the symposium. Finally, the GEO-XII Plenary and Ministerial Summit (discussed under ESD) was a joint ESD-ASD event.

The major Communications Product the SPSO staff designed for ASD this year was the USGEO booth. Staff designed a feature wall for the USGEO booth that included an assortment of posters. The poster showcase consisted of some previously used but still relevant posters from the archives, and other posters that were provided “as is.” To round out the exhibit, three new posters were created featuring current Earth science stories.

As with the other two tasks, the hyperwall was prominent at the ASD events described above. SPSO staff worked with presenters to prepare hyperwall content for the GEO-XII Plenary Summit, and completed a visualization showing the dramatic effects of fires in Indonesia on air quality in Singapore, using data from MODIS and CALIPSO.

In the coming year, SPSO will continue to support ESD, SMD and ASD. This will involve a full slate of conferences, domestic and international, to attend and to staff. Exhibits will be developed, signage designed and produced, products printed. The team will continue to sort through new hyperwall content from recent conferences in order to add visualizations of general interest to the online catalog, where they can be found and used by future presenters.
**MANIAC TALKS**

The GESTAR Maniac Talks offer the opportunity to “discuss and learn”. The Maniac Talks “… promote scientific interaction between young and experienced scientists in order to learn/improve/revise the knowledge of basics/fundamentals of science and scientific methods for research.” Charles Gatebe continues to be instrumental in hosting and maintaining this exciting series.


Since late May 2015, speakers have included the following from NASA Goddard Space Flight Center:

- Frank Cepollina
- Neil Gehrels
- Spiro Antiochos
- Ralph Kahn
- Joel Susskind
- Florence W. Tan
- Jagadish Shukla

Speakers from outside NASA GSFC included:

- Rick Spinrad, NOAA
- Richard Eckman, NASA HQ
- Marshall Shepherd, University of Georgia & Host of WxGeeks
- David Miller, NASA HQ

**NASA VIZ**

The NASA Visualization Explorer (NASA Viz) is a free iOS Universal (iPhone, iPad, iPod touch) app available in the iTunes store. The app continues to excite, educate and engage audiences through its media rich content and stories. Since the app’s launch on July 26, 2011, the app has been releasing two science stories per week. As of June 1, 2016, 493 stories have been published. The collection of stories highlights findings and research efforts from all four NASA science themes—Earth, Heliophysics, Planetary, Astrophysics—and includes contributions from NASA’s science mission outreach teams.

The app has received more than 1.83 million unique downloads and continuously receives positive ratings and reviews from the general public, educators and tech websites. The NASA Viz project includes also a responsive and mobile friendly website to feature all the content that is available on the app, including links to source and related material. See [http://nasaviz.gsfc.nasa.gov/](http://nasaviz.gsfc.nasa.gov/).

Through the ongoing efforts of GESTAR team members Helen-Nicole Kostis (NASA Viz project manager) and Kayvon Sharghi (NASA Viz editor) stories are visualized, edited and released to the public, and the app is maintained and continuously grows in new directions. Among the highlights from this past year: the NASA Viz app was featured at the World Science Festival in New York City (May 27-31, 2015); participated at the NASA 2016 Earth Day events in Union Station (April 21-22, 2016); and was highlighted in the 2015 Goddard Annual Report.

This year the NASA Viz software development team released five app updates to address bug fixes and to adapt to the new iOS 9 requirements and guidelines. In addition, during June-August 2015, the team worked on a pilot project for an Android version of the app. The pilot was successful and immediately the team started working on a full-fledged Android version of the app. The New Technology Report (NTR) and Software Release processes were completed and the Android version is pending final approval for release. Furthermore, the team has been working on redesigning the user interface and has been revisiting the software infrastructure and development of the app to respond to the new practices and guidelines for iOS development using Swift. The team plans to release a revised version of the iOS app that will include new features by the end of 2016.

Student Engagements and Education/Public Outreach

STUDENT ENGAGEMENTS

Assaf Anyamba supervised Kelechi Onyemaechi, a Morgan State University student researcher, on her project "Eco-climatic Drivers of Murray Valley Fever Outbreaks in Australia". Kelechi collected and georeferenced publicly available MVE outbreak data by searching online reports of the Program for Monitoring Emerging Diseases. This global database provides early warning reports of emerging disease outbreaks worldwide. Map coordinates for each named outbreak location (town, city etc.) were recorded. These georeferenced locations will be used subsequently to profile various satellite and climate data sets to determine the ecological and climatic conditions leading to periods of MVE activity in future funded research.

Ludovic Brucker mentored five students during the past year – undergraduate, graduate and doctoral. He was co-advisor of a PhD candidate, who worked on snow microwave brightness temperature simulations using a coupled snow evolution-emission model at NASA GSFC and presented a poster of results at the Eastern Snow Conference in Canada in June 2015. A related paper was accepted for publication in Journal of Hydrology. Dr. Brucker was co-advisor of a graduate student, who worked at NASA GSFC on variations in snow water equivalent retrievals from rain on snow events and who presented this work at the 2015 AGU Fall Meeting in San Francisco, CA. He also mentored two student researchers from Morgan State University, Camilo Diaz and Claudio Sidi, and another student from the NASA MUREP summer program. These three students presented their work during the NASA summer intern day.

In January 2016, Ludovic Brucker hosted a post-doctoral scientist from the University of Utah to work on the Greenland firn aquifer project, especially to initiate a new study on the analysis of the simulated firn aquifer in southeast Greenland since 1960.

Richard Damoah mentored three MSU student researchers: Bashan Prah, Chanté Vines and Kianna Spencer, who each presented at a GESTAR All Hands Meeting. Research included studies of the MSU weather station data as well as analyses for the transmission of vector-borne diseases in Kenya.

Charles Gatebe has been working with Angela B. Crews, a doctoral student at MIT.

Manuela Girotto began an informal collaboration with graduate student Bhanja Soumendra (Fulbright Fellow & student from India Institute of Technology, Kharagpur) and Dr. Matt Rodell (Hydrological Science Laboratory) to investigate the effects of GRACE assimilation over India. This project is motivated by the extensive spatial availability of groundwater in situ data for validation purposes and the global nature of the existing land assimilation systems so that we can easily extend the assimilation of GRACE into another region of interest.

Pawan Gupta supervised doctoral student Johana Carmona from Mexico, who completed her three-month visit at Goddard on November 30. She worked on ‘Remote Sensing of Air Quality in Mexico’ under the supervision of Dr. Gupta and Dr. Levy and gave an AEROSAT presentation on her work at Goddard. Dr. Gupta plans to continue serving on her PhD dissertation as co-advisor.

Margaret Hurwitz mentored Roshelle Baily, a Morgan State University student researcher. Dr. Hurwitz provided research guidance, suggested seminars and events for her to attend, assisted Roshelle with data analysis (specifically, IDL programming) and provided feedback to her written work. Roshelle prepared a poster for presentation at the GESTAR All Hands Meeting in August 2015.

Margaret Hurwitz prepared model output files for Olga Tweedy, a graduate student at Johns Hopkins University, who is examining the 30-year spin-up phase for GEOSCCM simulations.

Matt Kowalewski mentored Ahmed Abdelmohssen, a Morgan State University student researcher, in designing and fabricating GCAS flight cooling system and conducting vacuum chamber measurements of optical ground support equipment related to JPSS OMPS. He also mentored Alexander Newman, an MSU student researcher, who presented at the GESTAR All Hands Meeting in August 2015.

Edward Nowottnick mentored Cherif Haidara, a Morgan State University student researcher. Dr. Nowottnick helped Cherif develop programming skills used to evaluate aerosol forecasts in the NASA GEOS-5 model using AERONET data.

Andrew Sayer mentored three high school student interns under the National Space Club Scholarship program. The students learned about the research on aerosols which Dr. Sayer conducts, as well as experiencing what it is like to be a researcher and gaining a bigger picture of science done at NASA Goddard. The interns’ project was to create a website for the Deep Blue aerosol project, which includes background information about aerosols for non-specialists, as well as containing key data set information and documentation for the
scientific community. The website can be viewed at deepblue,
gsfc.nasa.gov.

Kayvon Sharghi launched two student writing internships in
partnership with the University of California, Santa Cruz, Science
Communication Program, and worked with multiple graduate
students on the creation of more than a dozen stories published
in the NASA Viz app.

Adrian Southard was heavily involved with supervising two
interns: one undergraduate mechanical engineer, Brandon
Colón-Curiel (Summer 2015), who focused on ion optics for
the OASIS ESI interface, and one senior graduate student in
analytical chemistry, Brian Stamos (Spring 2016), who focused
on optimizing the OASIS ESI interface.

GESTAR MSU Student Researchers
Daniel Laughlin, Program Manager

The goal of the GESTAR MSU Student Researcher Program
was to provide authentic NASA researcher opportunities
and experiences for Morgan students working with GESTAR
researchers. A major strength of the program was the ongoing
nature of student placements. Traditionally, students doing
research at NASA facilities participate in 10 week summer
internships. The relatively short duration of those experiences
limit traditional interns in their ability to significantly impact
research or missions. The GESTAR MSU Student Researcher
Program placed students with the same researchers for
multiple semesters allowing students to make more substantial
contributions to missions while having a deeper learning
experience.

During Calendar Year 2015, three cohorts of Morgan State
University students participated in the GESTAR MSU Student
Researcher Program. Cohort 1 worked with GESTAR researchers
from February 15, to May 15. Cohort 2 was active from June
1, to August 28. Cohort 3 ran from September 8, to December
18. Due to NASA policy changes, funding for the GESTAR MSU
Student Researcher Program ended in August, 2015. Because
of the importance of the experience and the contributions to their
projects, Morgan chose to fund five students to continue working
with GESTAR researchers in Fall 2015.

Students were recruited primarily from Morgan’s science,
engineering, and mathematics programs. Acceptance into
the program was dependent on having and maintaining a 3.0
GPA and recommendation from a faculty member familiar with
the students’ work. All students participated in a series of
orientations at Morgan before beginning work with their GESTAR
researchers. Student progress was assessed and reviewed
monthly based on reports from the student’s researcher to the
GESTAR MSU Program Manager.

The Spring of 2015 was the first year the GESTAR MSU Student
Researcher Program was fully in compliance with the Goddard
Office of Education policies on student researchers. All students
were registered and badged through Goddard’s Office of
Education ensuring that their work at Goddard was captured for
reporting purposes to NASA Headquarters Office of Education.

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Table 2: Cohort 2 Students

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<td>Daniyan,</td>
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Table 3: Cohort 3 Students

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Examples of Research

At the end of the summer, mentors of Cohort 2 students provided feedback on how their student researchers performed. Beyond the basics assessments, mentors were invited to offer more elaborate feedback. Below are several excerpts of some of those reports to give a sense of the types of work student researchers performed.

Ozaveshe Daniyan (mentor Batu Osmanoglu) has been working on digital simulation of the transceiver for our newest radar, DBSAR-2. He is using the Advanced Design System software, honing in the skills he learned last spring semester. He made some progress with the design and was able to simulate the transmit mixer, and I would like him to continue and complete the simulation of the entire transmit and receive system. In the past two weeks he developed a thermal data acquisition system using HP 34970A and MATLAB. He created a MATLAB routine to talk to the HP 34970A over the USB and record temperatures of 20 thermocouples repeatedly with ~30 second intervals. We will be using his system next week when we put the DBSAR-2 in the anechoic chamber for calibration. It is crucial for us to monitor the temperature of the system during operation. Oz also programmed an alarm temperature in case the unit gets too hot, so we can shut it off immediately. He started working on a graphical interface for the temperature recording/monitoring system. It would be great if he could complete it, so that we can use it during our flights.

Ahmed Abdelmohssen (mentor Matt Kowalewski) has been an asset to our lab in designing and fabricating ground support equipment for the GeoCAPE Airborne Simulator project and there’s much more work to be done. He is also working on developing software for the oscilloscope spectrometer and developing applications using the data from GCAS.
Randeep Pannu’s (mentor Priscilla Mohammed) research includes investigating microwave radiometer receiver architectures for Earth science remote sensing. Radio-frequency interference is a problem for microwave remote sensing of Earth. Although frequency allocations are set aside for passive sensing, RFI still can degrade measurement quality. Thus, Morgan State/ GESTAR and GSFC are developing RFI mitigation technology to detect and filter RFI in radiometer measurements with a digital receiver. The intern will investigate different receiver architectures for the microwave front-end to determine driving requirements and the trade space for an optimal approach.”

Impacts from Participation
Since participating in the GESTAR MSU Student Researcher Program in 2015, all the students have either continued in their fields of study or have graduated. Two students have gone on to find employment working at Goddard. All of the student participants reported that the experience in the program was beneficial.

• Claudio Sidi graduated from Morgan in August 2015. He has taken a position with Pacific Gas and Electric working with smart grid projects in San Francisco.
• Roshelle Bailey graduated in December 2015. She is currently applying to continue her graduate studies in civil engineering
• Ahmed Abdelmohssen first entered the GESTAR MSU Student Researcher Program in 2014. He worked consistently under GESTAR USRA engineer Matt Kowalewski and was one of the five Cohort 3 student researchers. At the end of that funding, Ahmed was hired by USRA to continue his work with satellite systems at Goddard.
• Randeep Pannu continues her doctoral studies in electrical engineering at Morgan. After the GESTAR MSU Student Researcher Program, she went on to secure funding to continue her work under GESTAR MSU researcher Priscilla Mohammed. Her project is titled “wide radio frequency interference detection for microwave radiometer subsystem”. This project is the topic of Randeep’s dissertation.

• Diaz, C., and L. Brucker, “Measuring Snow Depth on top of Arctic Sea Ice”
• Prah, B., C. Vines, K. Spencer, R. Damoah, A. Kinyua (MSU/Physics Dept.), and D. Seifu (MSU/Physics Dept.), “Preliminary Analysis of Morgan State University Weather Station Data”
• Vines, C., R. Damoah, A. Anyamba (GESTAR/USRA), and A. Kinyua (MSU/Physics Dept.), “Climate Analyses for the Transmission of Vector-borne Diseases in Kenya”
• Bailey, R., and M. Hurwitz, “Interning at Goddard”
• Daniyan, O., and B. Osmanoglu, “Simulating DBSAR-2 Transceiver Modules in Advanced Design Systems”
• Newman, A., and M. Kowalewski, “Prototype Heliostat for Earth Science Measurement”
• Abdelmohssen, A., and M. Kowalewski, “GCAS Thermal Control in Lab”

Congresswoman Edwards met with MSU students at USRA
On November 12, 2015, Congresswoman Donna Edwards visited USRA and met with student researchers from Morgan State University who were mentored by various GESTAR scientists and who presented posters of their science research. Congresswoman Edwards spoke with Morgan student researchers Ozaveshe, Bailey, Diaz, Newman, Abdelmohssen and Pannu about their research and their experiences at Goddard.

MSU Student Researchers Poster Session
On August 5, 2015, the student researchers presented posters at the GESTAR All Hands Meeting. Before and after the meeting, students fielded questions from GESTAR and visiting NASA personnel. At the event, the GESTAR Directed recognized the outstanding efforts of the students and their scientist mentors.

• Sidi, C., and L. Brucker, “Analysis of snow dielectric constants in a microwave radiative transfer model”
Presentations

Camilo Diaz was invited by Congresswoman Edwards and participated in a forum on climate change and young people in Maryland in December, 2015.

Publications

EDUCATION/PUBLIC OUTREACH
On May 12, 2015, Assaf Anyamba presented on “Remote Sensing of Ecologically Coupled Diseases” to a class of visiting students from Georgetown College, Kentucky on May 12, 2015. The visit was coordinated by Dr. Blanche Meeson (Higher Education, SED).

On September 25, 2015, Assaf Anyamba gave two lectures on (a) Remote Sensing: available platforms, data and tradeoffs in spatial, temporal, and spectral resolution, and (b) Weather Extremes and Impacts on Agriculture and Vector-borne Disease Outbreaks to the Environmental Health and Policy graduate class at Georgetown University Medical School Science. Dr. Anyamba was invited by Dr. Tomoko Steen, Professor in the Graduate Program on Biomedical Science Policy & Advocacy.

On September 30, 2015, Assaf Anyamba and Compton J. Tucker (NASA GSFC) hosted collaborators from the Department of Defense, Armed Forces Health Surveillance Center (AFHSC): Dr. Martina Siwek - Science Advisor, Dr. Brett Forshey - Febrile and Vector-Borne Illness, CDR Jean-Paul Chretien - Integrated Biosurveillance. Dr. Anyamba gave an overview presentation on GIMMS Group Support to AFHSC Activities and held roundtable discussions on the global disease risk outlook during the current El Niño period and opportunities for future collaboration. Drs. Tucker and Anyamba provided a tour of NASA GSFC Testing and Integration Facilities for the AFHSC visitors.

Assaf Anyamba and his team Jennifer Small (SSAI) and Ed Pak (SSAI) contributed to the Earth Observatory Image of the Day (IOTD) for February 1, 2016 on highlighting the El Niño related large scale Southern Africa drought on EO Website during the first week of February 2016: http://earthobservatory.nasa.gov/IOTD/view_internal.php?id=87434. EO utilized GLAM MODIS data and inputs from FAS for the story. The GIMMS MODIS Global Agricultural Monitoring system (GLAM) http://glam1.gsfc.nasa.gov/ is a web-based geographic application that offers MODIS imagery and user interface tools to data query and plot MODIS NDVI time series. The system is developed and provided by the NASA/GSFC/GIMMS group for the USDA/FAS/IPAD Global Agricultural Monitoring project.

Assaf Anyamba hosted Dr. Wassila Mamadou Thiaw, Team Lead International Desks, Climate Prediction Center (CPC) National Centers for Environmental Predictions, College Park, MD. They discussed potential collaborative efforts between NOAA-CPC International Desk and GIMMS group focusing on climate and health applications. Dr. Thiaw invited Dr. Anyamba to participate in two forthcoming NOAA-sponsored Climate-Health Applications workshops in Senegal and Tanzania.

Valentina Aquila was a co-organizer of the NASA GSFC Young Scientist Forum and a committee member of the AeroCenter, an interdisciplinary union of researchers in aerosol science based at NASA GSFC.
In October 2015, **Valentina Aquila** was an invited speaker at a professional development workshop for K12 teachers organized by the Maryland and Delaware Climate Change Education Assessment and Research (MADECLEAR), Baltimore, MD. She spoke about climate change and climate models.

On February 12, 2016, **Valentina Aquila** was an invited speaker at the La Giornata del Fisico, an event organized by the Physics Department of the University of Genoa, Italy to present high-school students with different career paths available to physics graduates.

On March 11, 2016, **Valentina Aquila** volunteered as a judge for the NASA Goddard GLOBE Program’s Northeast and Mid-Atlantic regional science fair.

On April 9, 2016, **Valentina Aquila** and **David Trossman** were invited speakers at the “Scientist Meet & Greet”, a monthly event of the Koshland Museum of the National Academy on Sciences in Washington, DC to connect scientists to the local community.

In May 2015, **Ludovic Brucker** was invited by the National Science Foundation to participate in the “New Generation of Polar Researchers Leadership Symposium” at USC Wrigley/Boone Center for Environmental Leadership, California.

**Richard Damoah** was invited by the office of Educator Professional Development (EPD) at NASA GSFC to train elementary school teachers on Global Climate Change.

**Kel Elkins** was invited to give a talk on Scientific Visualization as part of the Villanova University Computer Science Department Colloquium Series.

**Manisha Ganeshan** delivered a presentation titled “Clouds and Climate” to the attendees of the Sunday Experiment held at the GSFC Visitor Center on March 20th. She explained the nature of clouds that are commonly observed in the sky and the need to study them. Her talk emphasized the important radiative effects of clouds from a climate perspective, in addition to their significance for weather and precipitation. She highlighted the role of clouds in the climate-sensitive polar regions, which is her current area of research at GSFC. She also demonstrated the use of NASA missions (MODIS and CloudSat) for studying clouds from space. (Erica McGrath-Spangler also presented at this Sunday Experiment.)

**Margaret Hurwitz** participated in the American Meteorological Society’s Congressional Visit Day in June, 2015 in Washington, DC, and she recently participated in another Congressional Visit Day in May, 2016.

During the International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO) in Santiago, Chile, in October 2015, **Margaret Hurwitz** gave a presentation summarizing her stratospheric research experience and participation in Stratosphere-Troposphere and their Role in Climate (SPARC) activities for a group of early career scientists, mainly from South American countries.

**Margaret Hurwitz** attended the American Meteorological Society’s ‘From Innovation to Societal Benefit: the way there’ workshop on December 2nd in Washington, DC, and served on the ‘study group’ tasked with writing a report summarizing the workshop and formulating policy recommendations.

**Katrina Jackson** volunteered as a workshop assistant and stage emcee at the 2016 USA Science & Engineering Festival, held in Washington, DC from April 14-17, 2016.

**Hiren Jethva** was invited by the AEROCENTER committee to be a panelist for a discussion session focused on ‘aerosols above clouds’ as a part of the AEROCENTER Annual Update held at the NASA GSFC Visitor Center on May 27, 2015.


During the NASA Earth Day events on the National Mall and at Union Station in April 2016, **Helen-Nicole Kostis** worked with **Winnie Humberson**, and was onsite to feature the NASA Viz application. Approximately 250,000 people attended the Earth Day events.

**Helen-Nicole Kostis** served on the MUSE 2015 Jury Committee for the category “Interpretive Installations”. She will present awards to the winners at the AAM annual meeting in Washington, DC on Thursday, May 26th.

**Helen-Nicole Kostis** served as a Chair of the SIGGRAPH 2015 Student Research Competition (SRC), held in Los Angeles, CA.
in August 2015. She also served as a Chair of a Session titled “Supernatural” at ACM SIGGRAPH.

**Helen-Nicole Kostis** served as a Juror for the ACM 2015 Student Research Competition (SRC). This is an international competition of the Association for Computing Machinery, sponsored by Microsoft Research.

On February 15, 2016, **David Lagomasino** presented some of his past and current research in hydrological and carbon monitoring in coastal ecosystems for the Geology Department at University of North Carolina Wilmington, Wilmington, NC. He also discussed with graduate students his experiences working at NASA.

On April 24, 2016, **David Lagomasino** served on the judging panel for the NASA Space Apps Challenge, held in Laurel, MD. Participants were challenged to create an innovative design to solve a question related to NASA, including space travel, the Earth, and planets.

**Eunjee Lee** gave short presentations to South Korean high school students visiting Goddard on October 16, 2015.

On April 1, 2016, **Allison Leidner** was interviewed by Utah Public Radio about NASA biodiversity research.

From April 21-22, 2016, **Allison Leidner** presented Hyperwall talks for Earth Day at Union Station, Washington, DC.

**Xiaowen Li** was appointed as a member of the AMS Atmospheric Chemistry Committee during the 2016 AMS annual meeting.

**Junhua Liu** gave a talk titled “Origins of tropospheric O3 interannual variation over Reunion: A model investigation” at the Young Scientist Forum in July 2015 and at the Code 614 Branch Lunch Seminar in August 2015.

**Erica McGrath-Spangler** organized the visit of two NOAA Joint Center for Data Assimilation (JCSDA) interns (Biljana Orescanin and James Taylor) to the GMAO in October 2015. The interns were visiting from the Cooperative Institute for Research in the Atmosphere, a NOAA cooperative institute in Fort Collins, CO. They each visited with 10-11 GMAO personnel, including seven GESTAR employees.

For the 5th year in a row, NASA Code 610 has co-sponsored the University of Maryland, Women in Engineering Developing Revolutionary Engineers And Mentors (WIE DREAM) conference, held in late February 2016 at University of Maryland, College Park. The mission of this event is to recruit, retain, and advance women in engineering. Over 500 local high school girls participated in this event that reaches out to students and shares the innovations, applications, and opportunities engineering has to offer. NASA’s main presence at the conference was during the information session where **Erica McGrath-Spangler** and others shared information on internships and spoke about their unique careers in science and engineering with the students.

On March 20, 2016, at the Sunday Experiment at the NASA Goddard Visitor Center, **Erica McGrath-Spangler** gave a science talk. An estimated 185 people attended with 98 adults and 87 children. Dr. McGrath-Spangler presented on “Clouds and how NASA studies them”. After explaining how clouds form and the presence of clouds on other planets, her talk emphasized the importance of NASA’s role in cloud observations, from astronauts onboard the International Space Station and satellites to the GMAO’s role in model simulation and prediction of the January 2016 east coast snowstorm Jonas.

In late May 2015, **Kerry Meyer** served as a panelist for the AeroCenter, NASA GSFC, in a panel discussion regarding satellite retrievals of above-cloud aerosols.

In June, **Kayvon Sharghi** supported outreach activities at the 2015 World Science Festival in New York, and also in April at the 2016 Earth Day festival at Union Station in Washington D.C. He spoke with hundreds of people about the NASA Viz app and NASA’s exploration of the solar system and beyond.

In April 2016, **Susan Strahan** met via Skype with an 8th Grade Honors science class at Fords Middle School, Woodbridge, NH, and discussed ozone depletion and climate change.

In April, **Samuel Teinturier** attended the Mars Fest 2016 in Death Valley, CA, a three-day-long outreach event on Space exploration, night sky and space festival. He was involved in outreach activities. The first showed how it is important to drill the rock on Mars, and the scientists used different kinds of chocolate bars (e.g., Milky Way, Mars, etc.) and transparent straws to drill it, to demonstrate that even if the “chocolate rocks” look similar on the outside, they could be different inside with different colors, layers, etc. The second activity, which was for children, was a discussion about the main differences between the Earth and Mars, which incorporated experiments with balloons and a “body” simulation of how planets move (each child was moving around the sun). The last activity was
stargazing, and Dr. Teinturier explained general concepts about the sky to people who used the 10-15 available telescopes.

On May 16, 2015, Kristen Weaver staffed a table at the Weather + Climate Day held at the National Aquarium in Baltimore, MD, sharing information about the GPM mission and having kids compare precipitation patterns for different locations around the U.S.

On June 27, 2015, Kristen Weaver staffed a hands-on activity table about GPM and precipitation measurement at the Wallops 70th Anniversary Open House, Wallops, VA.

During the Explore@NASAGoddard event on September 26, 2015, Kristen Weaver staffed a table and shared information about GPM with hand-on activities for kids. An estimated 400-450 people came by the GPM table. Overall attendance at the event was about 20,000.

On February 13-14, 2016, Kristen Weaver staffed a table at the AAAS Family Days in Washington, DC. Activities included hands-on demonstrations of GLOBE protocols for precipitation, surface temperature, and air temperature. Approximately 300 people visited the table over the course of the two days.

At the USA Science and Engineering Festival, held April 15-17, 2016 in Washington, D.C., Kristen Weaver staffed a hands-on activity table with information and activities about GPM and precipitation measurement as part of the larger NASA booth. An estimated 2,500-3,000 people came by the GPM table alone during the three days, and an estimated 350,000 attended the event overall.

For the Earth Day at Union Station event, held April 21-22, 2016 in Washington, DC, Kristen Weaver staffed a hands-on activity table with information and activities about GPM and precipitation measurement, as part of a larger NASA Earth Day event. Approximately 350 students visited the event via prearranged field trips, as well as several thousand other visitors, with 400-500 stopping by the GPM table. Winnie Humberson was instrumental in organizing staffing and event coordination.

In January 2016, Yuekui Yang was interviewed by an 8th grade student from Pennwood Middle School, Yardley, PA for a class science project. He spoke with the student about his work and experience as a NASA scientist.

Cheng Zhang served as a volunteer to demonstrate “The Moon Experience” on September 26, 2015 at Explore@NASAGoddard.

In February 2016, Cheng Zhang discussed “Computer Graphics/Scientific Visualization and its role in NASA” at the Universidad Panamericana, in Guadalajara, Jalisco, Mexico.
In early June 2015, the 2015 Contractor Peer Awards Ceremony was held at the GEWA Recreation Center at NASA/GSFC. Out of many nominees, two GESTAR members were among those selected for awards. **Genna Duberstein** (code 130, sponsor: W. Sisler) won the Code 100 Peer Award in the Wild Card category, for her vision, persistence and dedication for her work on the Solarium exhibit, as well as her talk at the prestigious TEDx Peachtree event in Atlanta, Georgia. **Robert Garner** (code 130, sponsor: W. Sisler) won the Code 100 Peer Award in the On-The-Spot category, a spontaneous event in which attendees show their admiration for another attendee’s efforts by bestowing them with dots, which were handed out at the ceremony; Rob collected quite a few and therefore was recognized with this award. Genna and Rob each were presented with a certificate by Code 100 Center Director, Chris Scolese.

The 2015 Hydrospheric and Biospheric Sciences (HOBI) Annual Awards Ceremony was held in late August 2015. Research scientist **Batuhan Osmanoglu** (code 618, sponsor: T. Fatoyinbo) was recognized for Scientific/Technical Support, and received his award “for his dedication to the EcoSAR and DBSAR instrument development and data processing.” Developed at NASA GSFC, EcoSAR is a P-band airborne radar instrument for the polarimetric and interferometric measurements of ecosystem structure and biomass, and DBSAR is an L-band airborne sensor that tests digital beamforming radar techniques (DBSAR can also operate as a scatterometer and as an altimeter).

In late September 2015, at the 2015 Earth Sciences-Atmospheres (Code 610AT) Contractor and Partners Awards Ceremony, three GESTAR members received awards:

- **Kristen Weaver** (sponsor: D. Kirschbaum) was recognized for Outstanding Performance – Scientific Communication “for outstanding service and innovation as a GPM education and communication specialist.”
- **Kerry Meyer** (sponsor: S. Platnick) was recognized for Best Senior Author Publication “for pioneering a paper showing that simultaneous retrievals of clouds and overlying aerosols are possible from MODIS.”
- **Lok Lamsal** (sponsor: N. Krotkov) was recognized for Outstanding Performance – Science “for outstanding scientific contributions leading to improving quality and widespread use of NASA nitrogen dioxide (NO2) pollution data.”

In December 2015, **Richard Damaoh** (code 618, sponsor: C. J. Tucker) was awarded a certificate of recognition during the MSU-GESTAR end-of-year party for his contribution to the program.

At the Global Modeling and Assimilation Office (GMAO) Peer Awards ceremony in January 2016, four GESTAR scientists were recognized for their efforts:

- **Nikki Privé** (sponsor: R. Gelaro) was recognized for Scientific Achievement, “For your outstanding work in developing and validating the GMAO OSSE system, including detailed examination of the use of the G5NR nature run for generating synthetic observations.”
- **Young-Kwon Lim** (sponsor: S. Pawson) was recognized for Scientific Achievement, “For exceptional scientific achievements spanning numerous subjects, including high-resolution tropical cyclone simulations, Arctic climate variability, planetary-scale teleconnections and associated Rossby wave dynamics, and extreme weather events. Dr. Lim also authored or co-authored seven peer-reviewed articles in 2015.”
- **Virginie Buchard-Marchant** (sponsor: A. da Silva) was recognized for Scientific Achievement, “For sustained excellence in evaluating GEOS-5 aerosol reanalysis products and for significant contribution to lidar simulators in support of the CATS and ACE missions.”
- **Patricia Castellanos** (sponsor: A. da Silva) was recognized for Outstanding Scientific Contribution by a New GMAO Member, “For successful development of geostationary instrument simulators and generation of synthetic observations for the TEMPO, GOES-R, GEMS and SENTINEL-4 satellites.”

**Jarrett Cohen** (code 606.2, sponsor: P. Webster) was part of the team who received a 2016 Robert H. Goddard Exceptional Achievement for Mission & Enabling Support Award.

In late January 2016, Goddard’s Climate and Radiation Laboratory (Code 613) held both their annual party and awards ceremony. The award for Best First Authored Paper* was presented to **Andrew Sayer** (sponsor: N. C. Hsu), “For excellent and innovative investigations into the physical and radiative properties of tropospheric aerosols and enhancing their retrievals from satellites.”

The Journal of Quantitative Spectroscopy and Radiative Transfer (JQSRT) honored Sergey Korkin (sponsor: A. Lyapustin) for his contributions as a reviewer with a 2016 Certificate of Excellence in Reviewing “in recognition of the significant contributions made to the quality of the journal”.

Kerry Meyer (sponsor: S. Platnick) was named an Associate Editor for the Journal of the Atmospheric Sciences.

In March 2016, Helen-Nicole Kostis (code 606.4, sponsor: H. Mitchell) was recognized with a 2015 Robert H. Goddard (RHG) Honor Award for Outreach “for outstanding performance and implementation of a unique outreach program for a NASA mission and engagement of university students and faculty.”

Lok Lamsal (code 614, sponsor: N. Krotkov) was the recipient of a 2015 Robert H. Goddard Award for Science: “For exemplary satellite atmospheric composition retrieval development, scientific analysis, and promotion of NASA data to the scientific and sciences community.”

Joy Ng and Jefferson Beck (sponsor for both: W. Sisler), along with fellow Goddard Multimedia member Greg Shirah, were recognized by the D.C. Science Writers Association (DCSWA) with a Newsbrief Award in Multimedia, one of two new categories this year. They won for the video “What are the chances of another Katrina?” The award ceremony was held in early April 2016.

AAAS (American Association for the Advancement of Science) and Science sponsored a contest for the first-ever “Data Stories” visualization prize. Three videos received this award; one of them was recognized with both the Corporate Award and the People’s Choice Award: “Martian Atmosphere Loss Explained by NASA,” created by NASA’s Scientific Visualization Studio and Mars Atmosphere and Volatile Evolution (MAVEN) Science Team. The visualization team, which included Daniel Gallagher, Ernie Wright, Joy Ng, Michael Lentz and Brian Monroe (sponsors: W. Sisler and H. Mitchell), among others, used animation to illustrate how solar winds may have helped to erode the upper atmosphere of early Mars.

In May 2016, twenty-one GESTAR members were recognized with GESTAR Annual Excellence Awards:

- **Yehui Chang** (code 610.1, sponsor: S. Pawson): For his expertise in two complementary facets of GMAO science: navigating GMAO computing systems and interpreting the results.
- **Melanie Follette-Cook** (code 614, sponsor: K. Pickering): For her support of the NASA Earth Venture Suborbital DISCOVER-AQ project for five years.
- **Pawan Gupta** (code 614, sponsor: J. Joiner): For his outstanding contributions to both the NASA Applied Remote Sensing Training (ARSET) program and the MODIS science team.
- **Michelle Handleman** (code 130, sponsor: W. Sisler): For tirelessly working to share NASA stories with the widest possible audience through the live shot program.
- **Sergey Korkin** (code 613, sponsor: A. Lyapustin): For his contribution in radiative transfer modeling and his successful development and application of SORD and IPOL models.
- **Lynette Queen** (staff): For her dedication, attentiveness and effort in successfully supporting and arranging travel for 20+ Earth Sciences Seminar Speakers.
- **Susan Strahan** (code 614, sponsor: P. Newman): For her exceptional contribution to stratospheric research and the study of trace gases.
- **Qingyuan Zhang** (code 618, sponsor: E. Middleton): For his progress in developing the fAPARchl remote sensing product.
- **Winnie Humberson**, along with Ryan Barker, Sally Bensusen, Steve Graham, Heather Hanson, Marit Jentoft-Nilsen, Mark Malanoski, Debbi McLean, Kevin Miller, Amy Moran, Ishon Prescott, Cindy Trapp and Alan Ward (code 610, sponsor: S. Platnick) were recognized with the NASA SPSO Group Award: For NASA’s Science Program Support Office’s instrumental role in NASA’s outreach efforts.
**Acronym List**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4STAR</td>
<td>Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research</td>
</tr>
<tr>
<td>6SV</td>
<td>Second Simulation of a Satellite Signal in the Solar Spectrum vector</td>
</tr>
<tr>
<td>AAC</td>
<td>Arctic Adaptation to Climate Assessment</td>
</tr>
<tr>
<td>AACR</td>
<td>Area Aggregated Matching Ratio</td>
</tr>
<tr>
<td>ABL</td>
<td>Atmospheric Boundary Layer</td>
</tr>
<tr>
<td>ACAM</td>
<td>Airborne Compact Atmospheric Mapper</td>
</tr>
<tr>
<td>ACAOD</td>
<td>Above Cloud Aerosol Optical Depth</td>
</tr>
<tr>
<td>ACCMI</td>
<td>Atmospheric Chemistry-Climate Model Intercomparison</td>
</tr>
<tr>
<td>ACCRI</td>
<td>Aviation Climate Change Research Initiative</td>
</tr>
<tr>
<td>ACMAP</td>
<td>Atmospheric Composition: Modeling and Analysis Program</td>
</tr>
<tr>
<td>ADAS</td>
<td>Atmospheric Data Assimilation System</td>
</tr>
<tr>
<td>AERONET</td>
<td>Aerosol Robotic Network</td>
</tr>
<tr>
<td>AGCM</td>
<td>Atmospheric General Circulation Model</td>
</tr>
<tr>
<td>AGU</td>
<td>American Geophysical Union</td>
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<tr>
<td>AIRS</td>
<td>Atmospheric InfraRed Sounder</td>
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<tr>
<td>AMF</td>
<td>Air Mass Factor</td>
</tr>
<tr>
<td>AMM</td>
<td>Atlantic Meridional Mode</td>
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<tr>
<td>AMS</td>
<td>American Meteorological Society</td>
</tr>
<tr>
<td>AMSR-E</td>
<td>Advanced Microwave Scanning Radiometer for EOS</td>
</tr>
<tr>
<td>AOD</td>
<td>Aerosol Optical Depth</td>
</tr>
<tr>
<td>AOGCM</td>
<td>Atmosphere-Ocean General Circulation Model</td>
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<tr>
<td>AO</td>
<td>Arctic Oscillation</td>
</tr>
<tr>
<td>AOT</td>
<td>Aerosol Optical Thickness</td>
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<tr>
<td>APRHODITE</td>
<td>Asian Precipitation–Highly-Resolved Observational Data Integration Toward Evaluation of Water Resources</td>
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<tr>
<td>ARCTAS</td>
<td>Arctic Research of the Composition of the Troposphere from Aircraft and Satellite</td>
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<tr>
<td>ARSET</td>
<td>Applied Remote Sensing Training program</td>
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<tr>
<td>ASCENDS</td>
<td>Active Sensing of CO2 Emissions over Nights, Days and Seasons</td>
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<tr>
<td>ATom</td>
<td>Atmospheric Tomography Mission</td>
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<tr>
<td>ATMS</td>
<td>Advanced Technology Microwave Sounder</td>
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<tr>
<td>ATREX</td>
<td>Airborne Tropical Tropopause Experiment</td>
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<tr>
<td>AVDC</td>
<td>Aura Validation Data Center</td>
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<td>AVHRR</td>
<td>Advanced Very High Resolution Radiometer</td>
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<tr>
<td>AWC</td>
<td>Available Water Content</td>
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<tr>
<td>BASELiNE</td>
<td>Biomass-burning Aerosols &amp; Stratocumulus Environment: Lifecycles and Interactions Experiment</td>
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<tr>
<td>CAI</td>
<td>Cloud and Aerosol Instrument</td>
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<tr>
<td>CALIOP</td>
<td>Cloud-Aerosol Lidar with Orthogonal Polarization</td>
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<tr>
<td>CALIPSO</td>
<td>Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation</td>
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<td>CC&amp;E</td>
<td>Carbon Cycle and Ecosystems</td>
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<td>CCMII</td>
<td>Chemistry-Climate Model Initiative</td>
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<td>CDA</td>
<td>Cloud Data Assimilation</td>
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<td>CDC</td>
<td>Center for Disease Control</td>
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<tr>
<td>CDOM</td>
<td>Colored Dissolved Organic Matter</td>
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<tr>
<td>CEOS</td>
<td>Committee on Earth Observation Satellites</td>
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<tr>
<td>CERES</td>
<td>Clouds and Earth Radiant Energy System</td>
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<tr>
<td>CFH</td>
<td>Cryogenic Frostpoint Hygrometer</td>
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<tr>
<td>CHORI</td>
<td>Children’s Hospital and Research Center, Oakland</td>
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<tr>
<td>CIL</td>
<td>Conceptual Imaging Lab</td>
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<tr>
<td>CLIVAR</td>
<td>Climate Change Research Initiative</td>
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<tr>
<td>CLM4</td>
<td>Community Land Model version 4</td>
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<td>CMAVE</td>
<td>Center for Medical, Agricultural, and Veterinary Entomology</td>
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<td>CME</td>
<td>Coronal Mass Ejection</td>
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<tr>
<td>CMIP</td>
<td>Coupled Model Intercomparison Project</td>
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<tr>
<td>CMS</td>
<td>Content Management System</td>
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<tr>
<td>CONTRAST</td>
<td>COVective TRansport of Active Species in the Tropics campaign</td>
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<tr>
<td>COP</td>
<td>10th Conference of the Parties to the Vienna Convention</td>
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<tr>
<td>COSMIC RO</td>
<td>Constellation Observing System for Meteorology, Ionosphere, and Climate</td>
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<td>COT</td>
<td>Cloud Optical Thickness</td>
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<td>CRM</td>
<td>Cloud-Resolving Model</td>
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<td>DAS</td>
<td>Data Assimilation System</td>
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<tr>
<td>DFR</td>
<td>Differential Frequency Ratio</td>
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<tr>
<td>DIC</td>
<td>Dissolved Inorganic Carbon</td>
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<tr>
<td>DISCOVER-AQ</td>
<td>Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality</td>
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<td>DOD</td>
<td>Department of Defense</td>
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<tr>
<td>DOE</td>
<td>Department of Energy</td>
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<tr>
<td>DFR</td>
<td>Differential Frequency Ratio</td>
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<tr>
<td>DPR</td>
<td>Dual-frequency Participation Radar</td>
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<td>DRE</td>
<td>Direct Radiative Effect</td>
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<td>DSD</td>
<td>rainDrop Size Distribution</td>
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<tr>
<td>DYNAMO</td>
<td>Dynamics of the Madden Julian Oscillation</td>
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<tr>
<td>E/PO</td>
<td>Education/Public Outreach</td>
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<tr>
<td>EA/WR</td>
<td>East Atlantic/West Russia</td>
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<tr>
<td>ECMWF</td>
<td>European Centre for Medium-Range Weather Forecast</td>
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<tr>
<td>ECOA</td>
<td>East Coast Ocean Acidification</td>
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<td>EMAS</td>
<td>Enhanced MODIS Airborne Simulator</td>
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<td>EnKF</td>
<td>Ensemble Kalman Filter</td>
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<td>ENSO</td>
<td>El Niño/Southern Oscillation</td>
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<td>EOSP So</td>
<td>Earth Observing System Project Science Office</td>
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<td>EPIC</td>
<td>Earth Polychromatic Imaging Camera</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>NCAR</td>
<td>National Center for Atmospheric Research</td>
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<td>NCCS</td>
<td>NASA Center for Climate Simulation</td>
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<td>NCEP</td>
<td>National Centers for Environmental Prediction</td>
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<td>NDACC</td>
<td>Network for the Detection of Atmospheric Composition Change</td>
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<td>NDVI</td>
<td>Normalized Difference Vegetation Index</td>
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<tr>
<td>NEWS</td>
<td>NASA Energy and Water Cycle Studies</td>
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<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<td>NOBM</td>
<td>NASA Ocean Biogeochemical Model</td>
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<tr>
<td>NPP</td>
<td>NPOESS Preparatory Project</td>
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<tr>
<td>NPP OMPS</td>
<td>NPOESS Preparatory Project’s Ozone Mapping Profiler Suite</td>
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<td>NSIDC</td>
<td>National Snow and Ice Data Center</td>
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<td>NU-WRF</td>
<td>NASA Unified Weather Research and Forecasting</td>
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<tr>
<td>OASIS</td>
<td>Organics Analyzer for Sampling Icy Surfaces</td>
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<tr>
<td>OCI</td>
<td>Ocean Color Index</td>
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<td>OCO-2</td>
<td>Orbiting Carbon Observatory-2</td>
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<td>ODS</td>
<td>Ozone Depleting Substances</td>
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<td>OIB</td>
<td>Operation IceBridge</td>
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<td>OLR</td>
<td>Outgoing Longwave Radiation</td>
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<td>OLYMPEX</td>
<td>Olympic Mountain Experiment</td>
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<td>OMAERUV</td>
<td>OMI/Aura level-2 near UV Aerosol data product</td>
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<tr>
<td>OMI</td>
<td>Ozone Monitoring Instrument</td>
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<td>OSIRIS-REx</td>
<td>Origins-Spectral Interpretation-Resource Identification Security Regolith Explorer</td>
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<td>OSSE</td>
<td>Observing System Simulation Experiments</td>
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<td>OSTP</td>
<td>Office of Science and Technology (at the White House)</td>
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<td>PACE</td>
<td>Pre-Aerosol, Clouds, and ocean Ecosystem Program for Arctic Regional Climate Assessment</td>
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<tr>
<td>PARCA</td>
<td>Program for Arctic Regional Climate Assessment</td>
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<td>PBL</td>
<td>Planetary Boundary Layer</td>
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<td>PDO</td>
<td>Pacific Decadal Oscillation</td>
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<tr>
<td>PFT</td>
<td>Plant Functional Type</td>
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<td>PIA</td>
<td>Path Integrated Attenuation</td>
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<td>PICARD</td>
<td>Pushbroom Imager for Cloud and Aerosol Research and algorithm Development</td>
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<td>PSD</td>
<td>Particle Size Distribution</td>
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<td>QBO</td>
<td>Quasi-Biannual Oscillation</td>
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<td>RCDL</td>
<td>Radiometric Calibration and Development Laboratory</td>
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<td>RFI</td>
<td>Radio Frequency Interference</td>
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<td>RO</td>
<td>Radio Occultation</td>
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<td>RT</td>
<td>Radiative Transfer</td>
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<td>SAM</td>
<td>Sample Analysis at Mars</td>
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<td>SAR</td>
<td>Synthetic Aperture Radar</td>
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<td>SDO</td>
<td>Solar Dynamics Observatory</td>
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<td>SDSU</td>
<td>Satellite Data Simulation Unit</td>
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<td>SEAC4RS</td>
<td>Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys</td>
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<td>SHADOZ</td>
<td>Southern Hemisphere Additional Ozonesondes network</td>
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<td>SLP</td>
<td>Sea Level Pressure</td>
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<td>SMAP</td>
<td>Soil Moisture Active/Passive</td>
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<tr>
<td>SMOS</td>
<td>Soil Moisture and Ocean Salinity</td>
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<td>SPARC</td>
<td>Stratospheric Processes And their Role in Climate</td>
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<td>SRT</td>
<td>Surface Reference Technique</td>
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<td>SSG</td>
<td>Scientific Steering Group</td>
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<td>SST</td>
<td>Sea Surface Temperature</td>
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<tr>
<td>SSW</td>
<td>Stratospheric Sudden Warming</td>
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<tr>
<td>STE</td>
<td>Stratosphere-Troposphere Exchange</td>
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<tr>
<td>STEM</td>
<td>Science, Technology, Engineering and Mathematics</td>
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<tr>
<td>SVS</td>
<td>Scientific Visualization Studio</td>
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<tr>
<td>TC</td>
<td>Tropical Cyclone</td>
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<tr>
<td>TMI</td>
<td>TRMM Microwave Imager</td>
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<tr>
<td>TOA</td>
<td>Top of the Atmosphere</td>
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<tr>
<td>TOMS</td>
<td>Total Ozone Mapping Spectrometer</td>
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<td>TRMM</td>
<td>Tropical Rainfall Measuring Mission</td>
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<tr>
<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<tr>
<td>VIIRS</td>
<td>Visible Infrared Imager Radiometer Suite</td>
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<tr>
<td>VLIDORT</td>
<td>Vector linearized radiative transfer model</td>
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<td>WCRP</td>
<td>World Climate Research Program</td>
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<tr>
<td>W-E-F</td>
<td>Water-Energy-Food</td>
</tr>
<tr>
<td>WFIRST</td>
<td>Wide-Field Infrared Survey Telescope</td>
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<tr>
<td>WISM</td>
<td>Wideband Instrument for Snow Measurements</td>
</tr>
<tr>
<td>WMS</td>
<td>Web Map Service</td>
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<td>WRF</td>
<td>Weather Research and Forecast</td>
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<td>WSIST</td>
<td>Water Strategy Implementation Study Team</td>
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