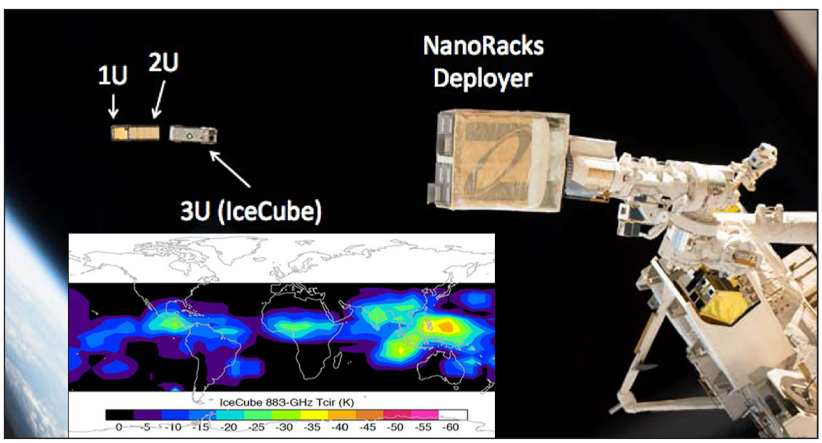
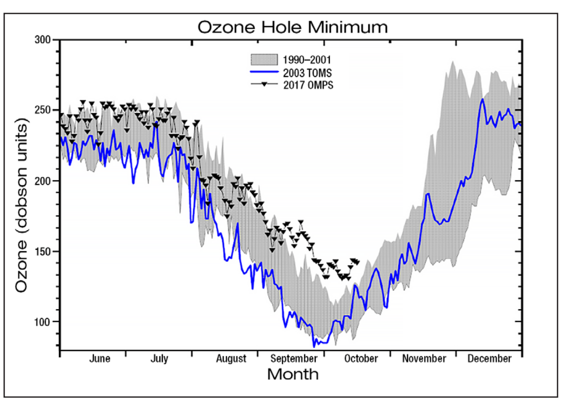
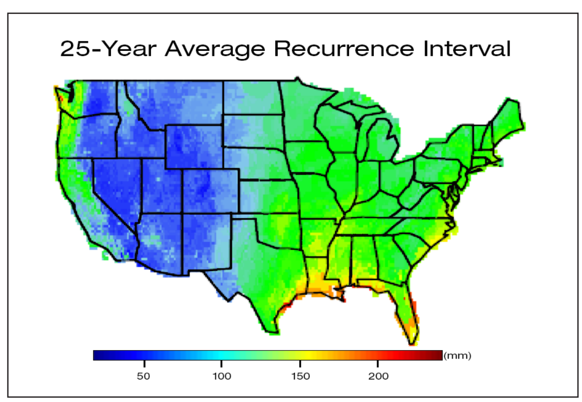
NASA/TM 2018-219030

Atmospheric Research 2017 Technical Highlights

Goddard Earth Sciences Division - Atmospheres







June 2018

Cover Photo Captions

TOP

The D3R radar shown with the Goddard and Colorado State University engineering teams, with technicians standing atop the roof of the Korean Meteorological Administration at the Daegwallyeong Weather Office.

NASA's GPM Ground Validation program assisted the Korean Meteorological Administration with the execution of the International Collaborative Experiment for the Pyeongchang Olympics and Paralympics (ICE-POP) 2018 field campaign. D3R collected multi-frequency, polarimetric observations of snowfall developed to improve GPM satellite retrievals of orographic falling-snow and verify predictions and physics of snow represented in numerical cloud models. Image Credit: M. Vega, GSFC

MIDDLE

NASA's Science Mission Directorate (SMD) selected Goddard to build its first Earth cloud observing CubeSat to demonstrate a compact radiometer technology (http://www.nasa.gov/cubesat/). The 1.3-kg payload in 1.2 U CubeSat units (1U=10x10x10 cm3) demonstrated and validated a new 883-Gigahertz submillimeter-wave receiver to advance cloud-ice remote sensing to better understand the role of ice clouds in the Earth's climate system. It produced the first cloud ice map ever taken at 883-Gigahertz frequency (inset). The map of cloud-induced radiance (Tcir) is defined as the difference between observed and modeled clear-sky radiances. It is roughly proportional to the cloud-ice amount above ~11 km and is negative because cloud scattering acts to reduce the upwelling radiation atsubmillimeter-wave frequencies, Image credit: NASA's ICECube team.

BOTTOM RIGHT

The surprise of extremely low ozone readings over the Antarctic in the 1980's led directly to the Montreal Protocol and a NASA emphasis on understanding stratospheric ozone. The Antarctic Ozone Hole was not very deep in 2017. Minimum ozone measured 131 Dobson Units by the Suomi NPP OMPS Total Column Mapper on October 9, 2017, higher than seen since the 1980s. Is this a sign of ozone recovery or just unusual dynamics in the south polar region? The shaded region in the image is the range of lowest ozone values in the period from 1990 to 2001 when the ozone hole was always large.

BOTTOM LEFT

The 25-year Average Recurrence Interval (ARI) reflects the daily precipitation amount expected to occur on the average of every 25 years across the continental United States based on 16 years of TRMM Precipitation Analysis data.

Level of Review: This material has been technically reviewed by technical management.

NASA/TM–2018-219030

Atmospheric Research 2017 Technical Highlights

Goddard Earth Scenes Division - Atmospheres
Goddard Space Flight Center, Greenbelt, MD

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

June 2018

NASA STI Program ... in Profile

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National Aeronautics and
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Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Reader:

Welcome to the 2017 Atmospheric Research Highlights report, summarizing Earth atmospheric science and communication/outreach accomplishments from NASA's Goddard Space Flight Center (GSFC). As in previous years, this report is intended for a broad audience, including colleagues within NASA, scientists outside the Agency, science graduate students, and members of the public.

Organizationally, the report covers research activities under the Office of Deputy Director for Atmospheres (Code 610AT), which is within Earth Sciences Division (610) in the Sciences and Exploration Directorate (600). Laboratories and office within 610AT include: Mesoscale Atmospheric Processes Laboratory (612), Climate and Radiation Laboratory (613), Atmospheric Chemistry and Dynamics Laboratory (614), and the Wallops Field Support Office (610.W). As of this writing, 610AT personnel is 59 civil servants and 218 cooperative agreement or contractor scientific and technical staff. While the report provides a comprehensive summary of 610AT 2017 activities, a few items of note are worth reporting here.

Satellite observations: As part of NASA's In-Space Validation of Earth Science Technologies (InVEST) program, GSFC's IceCube was successfully deployed from the International Space Station (ISS) on May 16 on a spaceflight technology demonstration of sub-millimeter ice cloud radiometry. During the mission, IceCube produced the first-ever ice cloud map at a frequency of 883-GHz. The mission, led by Project Scientist Dong Wu (613), was completed at the end of August.

Early 2017 also marked the spaceflight anniversaries of three 610AT-related projects. GPM entered its third year in orbit on February 27, while the CATS laser (installed on the International Space Stations (ISS)) and DSCOVR/EPIC completed their second year in orbit on January 10 and February 11, respectively. Some additional details follow.

- The Global Precipitation Measurement (GPM) core observatory mission reached several significant milestones this year including product updates, recalibration of TRMM (previous precipitation mission) datasets, a highly successful conclusion of the OLYMPEX field campaign, new visualization tools, and a vigorous outreach and education effort.
- The Goddard Earth Polychromatic Imaging Camera (EPIC), one of two NASA instruments on the DSCOVR mission, captured unexpected flashes of light reflecting off our planet over the span of a year. Alexander Marshak (613), DSCOVR deputy project scientist, determined the flashes to be specular reflections off tiny ice platelets floating in the air nearly horizontally. An article, entitled "Spotting Mysterious Twinkles on Earth from a Million Miles Away," appeared in *The New York Times* on May 19.
- The Cloud-Aerosol Transport System (CATS) operated on the ISS from February 2015 until October 2017, well beyond its 6-month design lifetime. CATS collected data to help improve our understanding of aerosols and clouds, and their interactions. The CATS principal investigator Matthew McGill (610) and science lead John Yorks (612) continue to collaborate with the scientific community to utilize the measurements.

Suborbital deployments: Many of our scientist were involved in major NASA suborbital (ground-based and aircraft) field campaigns during 2017.

- Paul Newman (610) and Thomas Hanisco (614) are members of the NASA Earth Venture Suborbital (EVS) Atmospheric Tomography Mission (ATom) science team. ATom deploys an extensive gas and aerosol payload on the NASA DC-8 aircraft for systematic, global-scale sampling of the atmosphere in four separate seasons. Measurements of formaldehyde in August 2016 revealed a distinct pattern that provides new insights to the chemistry of the remote troposphere.

- The CARbon Airborne Flux Experiment (CARAFE) completed a second set of flight measurements in May 2017. CARAFE flies on the NASA Wallops C-23 Sherpa aircraft, and flights have been made across a variety of biomes in the U.S. mid-Atlantic region, based from WFF. Nine science and one test flights were successfully completed, and a great cache of data has been acquired. The CARAFE PI was Randy Kawa (614) along with Co-I's Paul Newman (610), Glenn Wolfe (614), Thomas Hanisco (614), Geoffrey Bland (610.W), and others.
- During July and August 2017 GSFC's CO2 Sounder team completed eight flights on the NASA DC-8 from Palmdale, CA, and Fairbanks, AK, in support of precursor instruments designed for the Active-Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS) mission-in-development. The CO2 Sounder investigation is led by James Abshire (690) with team member Stephan Kawa (614).
- During late August, two 610AT teams were stationed across the path of totality during the Great American Eclipse. Jay Herman (614/UMBC), Nader Abuhassan (614/UMBC), and Alexander Marshak (613) in Casper, WY; and Si-Chee Tsay (613), Ukkyo Jeong (613/UMD-ESSIC) and Peter Pantina (613/SSAI) in Columbia, MO. At each site, teams deployed two Pandora spectrometers (one pointing at the sun for direct radiation measurements and one pointing vertically for diffuse radiation measurements) and a set of SEBRA radiometers (thermal-dome-corrected pyranometer and pyrgeometer).
- The Ozone Water-Land Environmental Transition Study (OWLETS) field campaign was conducted in Summer 2017 in the Tidewater Virginia region to better characterize O3 across the coastal boundary. Participating in the OWLETS campaign from the 614 lidar group were John Sullivan (614), Laurence Twigg (614/SSAI), and Thomas Mcgee (614). Pandora personnel were Robert Swap (614), Joesph Robinson (614/UMBC), and Nader Abuhassan (614/UMBC). The GeoTASO group included Matthew Kowalewski (614/USRA) and Scott Janz (614). Code 614 personnel also worked closely with the NASA Student Airborne Research Program (SARP) team and the Smithsonian Environmental Research Center (SERC) during the campaign.

<u>Kudos:</u> As in previous years, 610AT scientists garnered professional honors and other recognition during 2017. A few shout-outs:

- Paul Newman (610) received the Scientific Leadership Award during the Montreal Protocol 30th Anniversary Awards Honour Ozone Heroes on November 24. The awardees were nominated for their awards and selected by an international jury comprised of eminent environmental leaders and based on the recommendations of a technical screening committee made up of experienced ozone experts from around the world. Paul also received NASA's Distinguished Service Medal at NASA Langley on June 15 from Acting Administrator Robert M. Lightfoot for sustained leadership strengthening the scientific basis of the Montreal Protocol resulting in the 2016 Kigali Amendment controlling hydro-fluorocarbon emissions.
- Dennis Chesters (612) received the Robert H. Goddard Award of Merit for exceptional and sustained leadership of Goddard's role in the NOAA GOES satellite series missions.
- Geoffrey Bland (610.W) received the Ames Honor Award for the Volcanic Emissions Retrieval Experiment (VEREX) for excellence in the category of group/team.
- Matthew McGill (610) was selected as the recipient of the 2017 National Organization of Gay and Lesbian Scientists and Technical Professionals (NOGLSTP) GLBT Scientist award for his outstanding achievements in the application of lidar technology in the study of atmospheric conditions to better understand climate change impacts on Earth.

<u>I am happy to announce the following project-related changes in 2017:</u>

- Bryan Duncan (614) was selected as the new Aura Project Scientist, replacing Anne Douglass who retired in January. Bryan has expertise in air quality and tropospheric trace gas composition. He is a member of NASA's Health and Air Quality Applied Sciences Team, which facilitates the use of NASA satellite data by the health and air quality communities.
- Scott Braun was selected as the new GOES Project Scientist, replacing Dennis Chesters who will be retiring next year. Scott was the project scientist for the Tropical Rainfall Measuring Mission (TRMM) mission, a joint mission with the Japanese Space Agency (JAXA) from 2008–2017. Scott is an expert in understanding how hurricanes form and intensify, and he has markedly increased our fundamental understanding of how the hurricane eye-wall region functions.

Civil Servant Transitions:

- Anne Douglass (614) transitioned to phased retirement (a 2-year process) in January following 36 years of service. During her 31-year association with the chemistry laboratory, Anne served as the Aura Project Scientist, the Deputy Project Scientist for the Upper Atmospheric Research Satellite (UARS), and the PI of the Stratospheric General Circulation with Chemistry Project (SGCCM) starting in the early 1990's. Anne is a fellow of the American Meteorological Society and winner of a Clare Boothe Luce Award for Women in Mathematics and Science. She was one of the first to use assimilated meteorological fields in a three-dimensional chemistry and transport model for interpretation of constituent observations from satellite, balloon, aircraft and ground-based platforms.
- David Whiteman's retirement in January marked the completion of more than 37 years of service. Over the years, his Raman Lidar work demonstrated the first meteorologically useful measurements of the evolution of water vapor in the troposphere; he developed new lidar remote-sensing techniques including ones for retrieving both warm and cold cloud physical properties; and he was the scientific and technical lead of the ACE Optical Lidar Simulator Lidar System for understanding retrieval information content of aerosol microphysical properties from multi-wavelength lidar measurements.
- Mathew Schwaller retired as Deputy Lab Chief of Code 612 in March with over 20 years of GSFC service. Matt was most known for his work with GPM where he served in a multi-faceted management role as the GPM Ground Validation (GV) Project/Systems Manager for over 10 years. As the GPM GV Project Manager, he led the early formation and organization of the GV Program, oversaw its implementation and its budget, and greatly facilitated ongoing GV activities and successes of the program as a whole. He actively supported and facilitated the development of the NASA Wallops Island GPM GV supersite and Precipitation Research Facility—one of the largest concentrations/inventories of ground-based precipitation measurement equipment in the world.
- Georgianne Batluck retired after 48 years of service. She was an invaluable asset to the AT Laboratories, who depended on her as the computer security official whose role was to keep the labs up-to-date on security issues and protocols. In addition, she was responsible for management of system scientific clusters.
- William Cook transferred from Code 612 to the Optics Branch, Code 551. He came to GSFC from Langley in July 2010 and was Deputy Project Scientist for ICESat2/ATLAS and PI for ICESat2/MABEL test bed instruments.

I was delighted to welcome Ian Adams (612), Qing Liang (614), Kerry Meyer (613), John Sullivan (614), Robert Swap (614), and Hongbin Yu (613) as new civil servants over the past year.

- Ian Adams received his Ph.D. in Electrical Engineering from the University of Central Florida in 2007. Most recently, he was employed at the Naval Research Lab where he worked on TRMM and WindSat microwave radiative transfer, ATMS microwave radiometer calibration and quality control, and retrieval of near-surface ocean winds from QuickSCAT and WindSat/TRMM. His research focus is microwave and millimeter-wave active and passive remote sensing of clouds, precipitation, and ocean surface winds. In joining Code 612, Ian will be extending his research interests to include analysis and radar development activities and science related to GPM precipitation retrievals.
- Qing Liang received her Ph.D. in Atmospheric Sciences from the University of Washington in August 2006. Qing began working in the Lab in 2006 as a NASA Postdoctoral Fellow. She has experience in both stratospheric and tropospheric chemical-modeling, and contributed to multiple international SPARC and UNEP scientific assessments. She recently led the analysis of the CCl4 atmospheric budget.
- Kerry Meyer received his Ph.D. from Texas A&M University in Atmospheric Sciences in 2007. His research interests include satellite and aircraft remote-sensing of clouds and aerosols. He is a member of the MODIS, Suomi NPP, and DSCOVR science teams, working on the operational cloud optical and microphysical property products as well as efforts to develop climate data record continuity for EOS MODIS and Suomi NPP VIIRS cloud products. He has also been involved with remote-sensing field campaigns using the enhanced MODIS Airborne Simulator (eMAS), most recently flown on the NASA ER-2 during SEAC4RS, RADEX, and ORACLES.

- John Sullivan received his Ph.D. in Atmospheric Physics from UMBC in 2015. His research interests lie in utilizing spectral and optical properties of the atmosphere to monitor important atmospheric constituents relating to air quality and human health, and expertise in sensing techniques in lidar measurements and retrievals. John was critical to designing, calibrating, and deploying a transportable lidar for measuring tropospheric ozone profiles in NASA campaigns, such as DISCOVER-AQ and KORUS-AQ. He is a member of the AGU and AMS.
- Robert Swap received his Ph.D. in Environmental Sciences from the University of Virginia in 1996. As a research professor at the University of Virginia, he served as the U.S. Principal Investigator of the Southern Africa Regional Science initiative (SAFARI-2000), a campaign involving numerous NASA scientists. He has more than two decades experience of conducting environmental research and experiential education in southern Africa. He served as a rotating Intergovernmental Personnel Act program officer with the Radiation Sciences Program of the Earth Sciences Division at NASA Headquarters beginning in October 2014. He now manages the PANDORA network project in Code 614, a ground-based network of solar spectrometers that measure and retrieve atmospheric gas and aerosol information.
- Hongbin Yu, who received his Ph.D. in Atmospheric Chemistry from the Georgia Tech in 2000, has been studying the diffusion and transport of air pollutants and their environmental impacts from local to regional to continental to global scale. In most recent years, he has been conducting satellite and model integrated studies of aerosol long-range transport and impacts on the earth system and human health.

This report is published in two media: a printed version and an electronic version on our Atmospheric Science Research Portal site, http://atmospheres.gsfc.nasa.gov/. It continues to be redesigned to be more useful for our scientists, colleagues, and the public. We welcome comments on this report and on the material displayed on our Web site.

Steven Platnick

Deputy Director for Atmospheres

Earth Sciences Division, Code 610

March 2018

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1. INTRODUCTION

Atmospheric research in the Earth Sciences Division (610) consists of research and technology development programs dedicated to advancing knowledge and understanding of the atmosphere and its interaction with the climate of Earth. The Division's goals are to improve understanding of the dynamics and physical properties of precipitation, clouds, and aerosols; atmospheric chemistry, including the role of natural and anthropogenic trace species on the ozone balance in the stratosphere and the troposphere; and radiative properties of Earth's atmosphere and the influence of solar variability on the Earth's climate. Major research activities are carried out in the Mesoscale Atmospheric Processes Laboratory, the Climate and Radiation Laboratory, the Atmospheric Chemistry and Dynamics Laboratory, and the Wallops Field Support Office. The overall scope of the research covers an end-to-end process, starting with the identification of scientific problems, leading to observation requirements for remote-sensing platforms, technology, and retrieval algorithm development; followed by flight projects and satellite missions; and eventually, resulting in data processing, analyses of measurements, and dissemination from flight projects and missions. Instrument scientists conceive, design, develop, and implement ultraviolet, infrared, optical, radar, laser, and lidar technology to remotely sense the atmosphere. Members of the various Laboratories conduct field measurements for satellite sensor calibration and data validation, and carry out numerous modeling activities. These modeling activities include climate model simulations, modeling the chemistry and transport of trace species on regional-to-global scales, cloud resolving models, and developing the next-generation Earth system models. Satellite missions, field campaigns, peer-reviewed publications, and successful proposals are essential at every stage of the research process to meeting our goals and maintaining leadership of the Earth Sciences Division in atmospheric science research. Figure 1.1 shows the 23-year record of peer-reviewed publications and proposals among the various Laboratories.

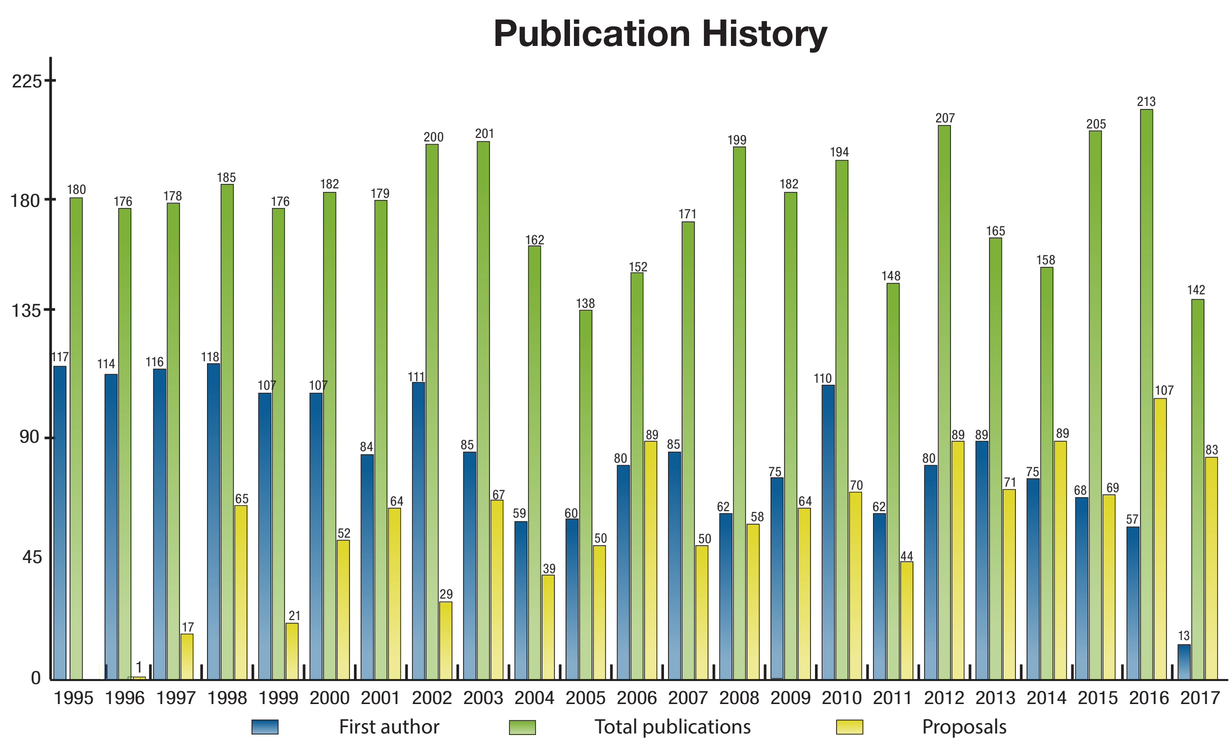

Figure 1.1: This bar chart shows the number of proposals and referred publications by Atmospheric Sciences members over the years. The green bars are the total number of publications and the blue bars the number of publications where a Laboratory member is first author. Proposals submitted are shown in yellow.

This data shows that the scientific work being conducted in the Laboratories is competitive with the work being done elsewhere in universities and other government agencies. The office of Deputy Director for Atmospheric Research will strive to maintain this record by rigorously monitoring and promoting quality while emphasizing coordination and integration among atmospheric disciplines. Also, an appropriate balance will be maintained between the scientists' responsibility for large collaborative projects and missions and their need to carry out active science research as a principal investigator. This balance allows members of the Laboratories to improve their scientific credentials and develop leadership potentials.

Interdisciplinary research is carried out in collaboration with other laboratories and research groups within the Earth Sciences Division, across the Sciences and Exploration Directorate, and with partners in universities and other government agencies. Members of the Laboratories interact with the general public to support a wide range of interests in the atmospheric sciences. Among other activities, the Laboratories raise the public's awareness of atmospheric science by presenting public lectures and demonstrations, by making scientific data available to wide audiences, by teaching, and by mentoring students and teachers. The Atmosphere Laboratories make substantial efforts to attract and recruit new scientists to the various areas of atmospheric research. We strongly encourage the establishment of partnerships with Federal and state agencies that have operational responsibilities to promote the societal application of our science products. This report describes our role in NASA's mission, provides highlights of our research scope and activities, and summarizes our scientists' major accomplishments during calendar year 2017. The composition of the organization is shown in Figure 1.2 for each code. This report has been published in a printed version with an electronic version on our atmospheres Web site, http://atmospheres.gsfc.nasa.gov/.

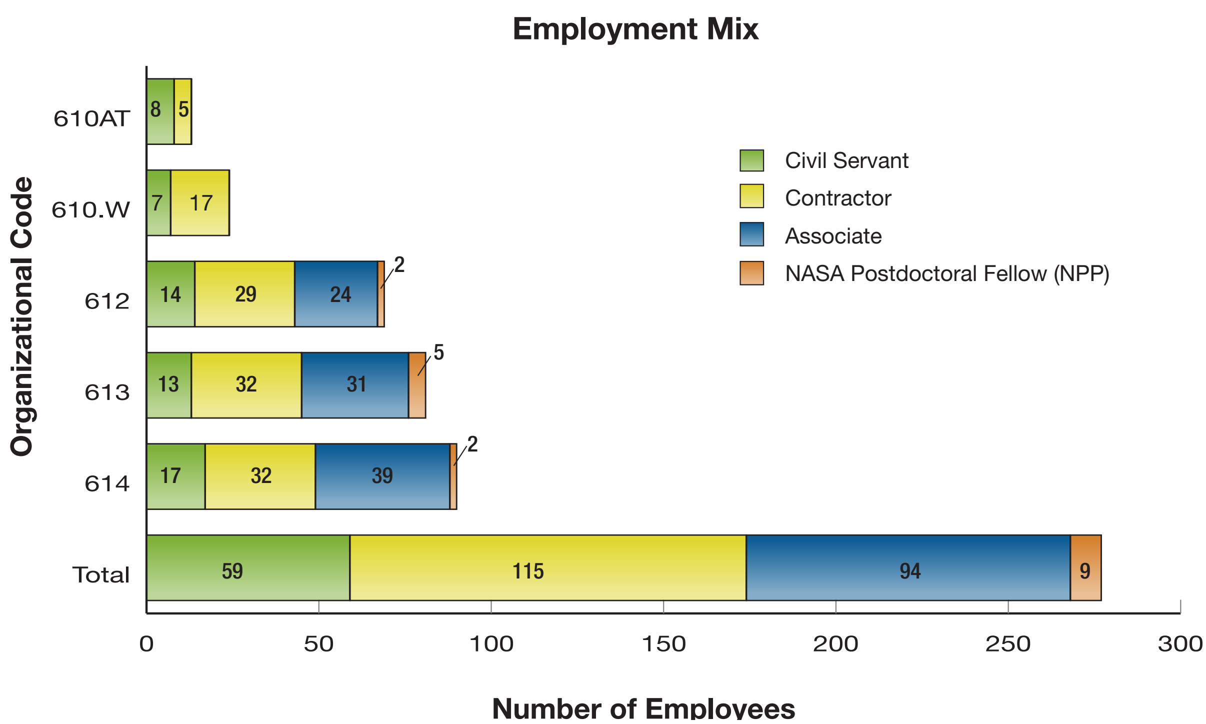

Figure 1.2: Breakdown of the organizational employee mix

2. SCIENCE HIGHLIGHTS

Atmospheric research at Goddard has a long history (more than 50 years) in Earth Science studying the atmospheres of both the Earth and the planets. The early days of the TIROS and Nimbus satellites (1960s1970s) emphasized ozone monitoring, Earth radiation, and weather forecasting. Planetary atmosphere research with the Explorer, Pioneer Venus Orbiter, and Galileo missions was carried out until around 2000. In recent years, EOS missions have provided an abundance of data and information to advance knowledge and understanding of atmospheric and climate processes. Basic and crosscutting research is being carried out through observations, modeling, and analysis. Observation data is provided through satellite missions as well as in-situ and remote-sensing data from field campaigns. Scientists are also focusing their efforts on satellite mission planning and instrument development. For example, feasibility studies, improvements in remote-sensing measurement design, modeling and technology are underway in preparation for the planned missions recommended in the 2007 Decadal Survey by the National Academy of Sciences (http://www.nap.edu/catalog/11820.html. ESAS (Earth Science and Applications from Space) is the 2017–2027 Decadal Survey that will help shape science priorities and guide agency investments into the next decade. Many of our scientists are expected to contribute to surveys and other functions.

The following sections summarize some of the scientific highlights of each Laboratory and the Wallops Field Office for the year 2017. The individual contributor(s) are named at the end of each summary. Additional highlights and other information may be found at the website: http://atmospheres.gsfc.nasa.gov/.

2.1. Mesoscale Atmospheric Process Laboratory

The Mesoscale Atmospheric Processes Laboratory seeks to understand the contributions of mesoscale atmospheric processes to the global climate system. The Laboratory conducts research on the physical and dynamic properties, and on the structure and evolution of meteorological phenomena—ranging from synoptic scale down to micro-scales—with a strong focus on the initiation, development, and effects of cloud and precipitation. A major emphasis is placed on understanding energy exchange and conversion mechanisms; especially cloud microphysical development and latent heat release associated with atmospheric motions. The research is inherently focused on defining the atmospheric component of the global hydrologic cycle, especially precipitation, and its interaction with other components of the Earth system. The Laboratory also played a key science leadership role in the Tropical Rainfall Measurement Mission (TRMM), launched in 1997, and in developing the Global Precipitation Measurement (GPM) mission concept and continuing to lead scientific investigations. Another central focus is developing remote-sensing technology and methods to measure aerosols, clouds, precipitation, water vapor, and winds, especially using active remote-sensing (lidar and radar). Highlights of Laboratory research activities carried out during the year are summarized below.

2.1.1. Microphysically Detailed Precipitation Retrievals Using the GPM Combined Algorithm

The Global Precipitation Measurement (GPM) Combined Algorithm derives accurate estimates of precipitation amounts and particle size distributions from GPM's Dual-Frequency Precipitation Radar (DPR) observations. These estimates agree with the Global Precipitation Climatology Project (GPCP) estimates and facilitate the development of GPM radiometer retrieval algorithms. The combined algorithm described in this study is crucial in the achievement of one of GPM's main objectives—namely, the derivation of uniformly calibrated precipitation estimates at every location around the world every 2–4 hours. To achieve this objective, GPM relies on a constellation of satellite microwave radiometers of different designs. The GPM combined algorithm is a major tool in the derivation of precipitation/brightness temperature databases that support the development of physically consistent, uniformly calibrated retrieval algorithms for the GPM radiometer constellation. Thus, the GPM combined algorithm facilitates the achievement of higher level GPM objectives, i.e. the contribution of information imperative in understanding the space-time variability of precipitation around the globe and how climate change affects the global energy and water cycle (GWEC) in terms of changes in regional precipitation characteristics (type, frequency, intensity), as well as extreme hydrologic events. The multiple scattering and non-uniform beam-filling parameterization developed within the study are expected to be applicable to future missions involving precipitation and cloud radars.

M. Grecu (612, MSU), W.S. Olson (612, UMBC), S. J. Munchak (612), S. Ringerud (612, USRA), L. Liao (612, MSU), Z. Haddad (JPL), B. Kelley (612, SSAI), and S. F. McLaughlin (SSAI)

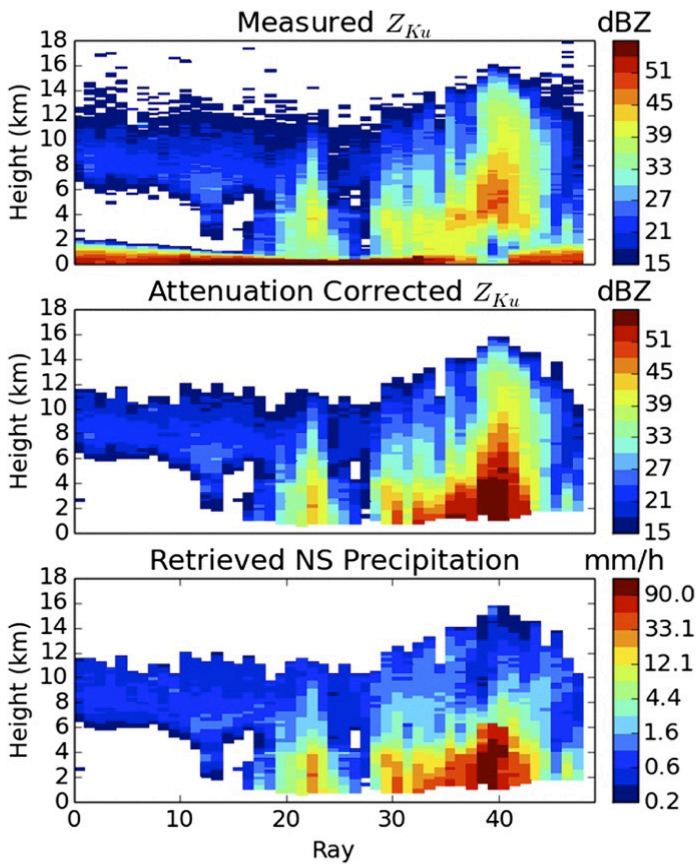

Figure 2.1: Example of GPM DPR observations and GPM combined estimates for a storm over Kansas and Missouri on September 2, 2014.

2.1.2. Cloud-Aerosol Transport System (CATS) Level 1 Data Products

The CATS lidar has been operating semi-continuously on the International Space Station for nearly two years, primarily using the Number-2 laser fired over 100-billion shots. CATS has directly supported NASA's strategic goal to advance understanding of Earth and develop new technologies for future Earth Science missions by utilizing the ISS as a low-cost platform for Earth Science. CATS has advanced the space-based lidar record, which is vital to understanding the Earth's climate system by providing diurnally varying vertical profiles of clouds and aerosols to determine their transport and radiative effects, which are key uncertainties in predicting the Earth's radiation balance. CATS provides minimal data latency, producing NRT data products within six hours of data collection. This enables aerosol forecast modeling that reduces economic loss and air quality-related deaths through applications such as forecasting volcanic plume transport for aviation safety, severe dust events for transportation, and air quality during haze and biomass burning, which improve health alerts globally. CATS Level 1 Data Products demonstrate the ability to accurately detect thin atmospheric layers. This sensitivity, along with the orbital characteristics of the ISS, enables the use of CATS data for cloud and aerosol climate studies.

J. Yorks (612) and M. McGill (610)

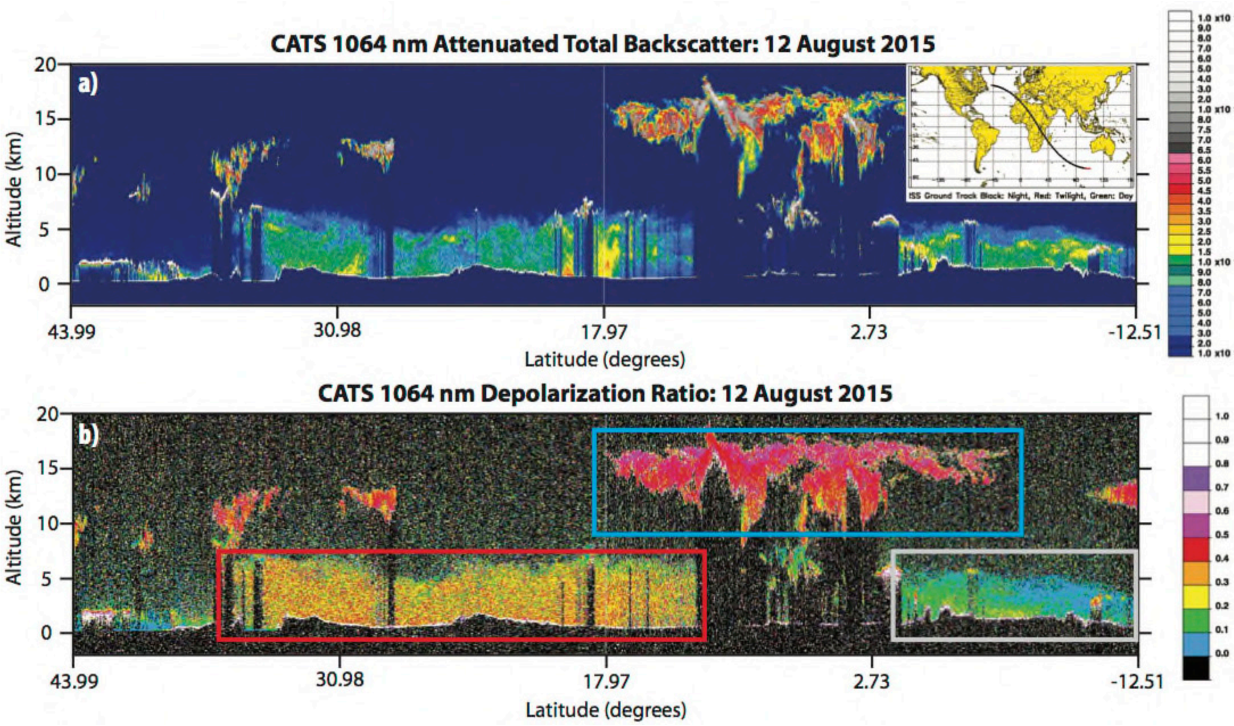

Figure 2.2: The CATS backscatter (a, bottom left) and depolarization ratio (b, bottom left) data products are being utilized by the science community to study dust (red box), smoke (grey box), and cirrus clouds (blue box).

2.1.3. The Multiscale Modeling Framework with a Cloud-resolving Model is New Improved Approach for Global Modeling of Convective Systems

The Goddard Multi-scale Modeling Framework (GMMF) is an economical approach to a global cloud-resolving (or cloud-permitting) model that removes the uncertainties associated with cloud parameterizations in traditional global models. This study demonstrates the importance of model domain size and grid spacing in simulating mesoscale convective systems (MSC) in the tropics. The GMMF has a larger domain and finer resolution in its embedded two-dimensional cloud-resolving models and can better represent the MCSs and improve precipitation statistics in the tropics from two-year MMF simulations (2007–2008). The convection-wind-evaporation feedback between cloud and large-scale interaction plays a key role in simulating tropical rainfall. A realistic representation of MCSs in global models will advance our understanding of energy and water cycles and of nonlinear cloud and large-scale interactions. The high-resolution cloud-resolving model dataset from the GMMF simulations has been incorporated into a satellite-retrieval database for the cross-track scanning sensors of the GPM constellation satellites. The improvement of global rainfall simulation in the GMMF will lead to better GPM surface rainfall retrieval products. The diagnostics dataset from this two-year hourly model came from a series of GMMF simulations with different model configurations. The model outputs used in this study data are available upon request from wei-kuo.tao-1@nasa.gov. The dataset will also be available in a public domain using FTP access made available from the Goddard Cloud Library, http://cloud.gsfc.nasa.gov. The GPCP and TRMM datasets used in this study are accessible from http://precip.gsfc.nasa.gov.

J.-D. Chern (612, UMD) and W.-K. Tao (612)

2.1.4. The Relationship between Latent Heating, Vertical Velocity, and Precipitation Processes: The Impact of Aerosols on Precipitation in Organized Deep Convective System

Aerosol indirect effects, i.e., the impact of aerosol on cloud lifetime and precipitation formation, has the biggest uncertainty in climate radiative forcing identified by the IPCC AR5. The aerosol effects on the global water and energy cycle remain controversial. Aerosols may enhance or suppress surface precipitation through their influences on different precipitation processes. The Goddard Cumulus Ensemble Model, with a sophisticated spectral-bin microphysical scheme, is used in this study to unravel three competing mechanisms and their roles in aerosol-cloud-precipitation interactions, for two representative organized deep-convective systems: one continental and one oceanic. Two sets of simulations, i.e., low and high aerosol-loading, are carried out for each case. The TOGA COARE control case uses a background oceanic aerosol spectrum with lower overall concentration, but with a higher number of large aerosol particles, than the background continental aerosol used in the PRESTORM case. This modeling study contributes to our understanding of aerosol-cloud-precipitation interaction mechanisms related to different mesoscale convection systems. In addition, studying precipitation formation processes and aerosol-cloud interactions are among the main objects for several future satellite mission concepts, including the Aerosol/Cloud/Ecosystems (ACE) and the Cloud and Precipitation Processes Mission (CaPPM).

W.-K. Tao (612) and X. Li (612, MSU)

2.1.5. So, How Much of the Earth's Surface Is Covered by Rain Gauges? Illustrating the Need for Satellite Observations of Precipitation

The number of gauges available for measuring global precipitation is very limited. Near real-time gauge information extends to a few thousand gauges whose combined orifices total an area equivalent to the center circle of a soccer pitch, or just 0.000000000593 percent of the Earth's surface. Using the best available gauge data set, the total catchment area of GPCP gauges is less than half the area of an American football field; even assuming that each of these gauges is representative of the rainfall within 5 km of them, they cover less than one percent of the Earth's surface. Due to the critical importance of precipitation to our society and environment, as well as to all life on Earth, the accurate and timely measurement of precipitation across all of the Earth's surface is of great importance. This effort emphasizes the need for satellite observations to provide data from which quantitative global precipitation measurements may be generated. NASA's GPM mission, together with the international constellation, is tasked with addressing this need. Through the combination of multi-satellite, multi-source observations, GPM is able to provide global estimates of precipitation (both rain and snow) at resolutions up to 10 km every 30 minutes.

C. Kidd (612, UMD), A. Becker (DWD), G. J. Huffman (612), C. L. Muller (RMS), P. Joe (WMO), G. Skofronick-Jackson (612) and D. B. Kirschbaum (617)

2.1.6. Improvement in Path Attenuation Estimates from the Dual-Frequency Precipitation Radar

A critical part of estimating precipitation parameters from space-borne weather radars is the correction for signal attenuation. One way to do this is to use the surface as reference target where the path attenuation is taken to be equal to the difference between the surface cross sections in the absence and presence of rain. However, the accuracy of the method depends on the stability of the target. It has been shown that the frequency difference of the surface cross sections, $\sigma^0(K_a) - \sigma^0(K_u)$, provides a more stable reference, relative to the single frequency reference, and a more accurate estimate of path attenuation. This represents a significant improvement over the single-frequency retrieval and shows one way in which a dual-frequency radar can improve rain retrieval accuracy. Improvements in rain retrievals will translate to better water resource and flood monitoring, while algorithm advancements will further the capabilities of current and future sensors.

R. Meneghini (612), H. Kim (612, MSU), and L. Liao (612, MSU)

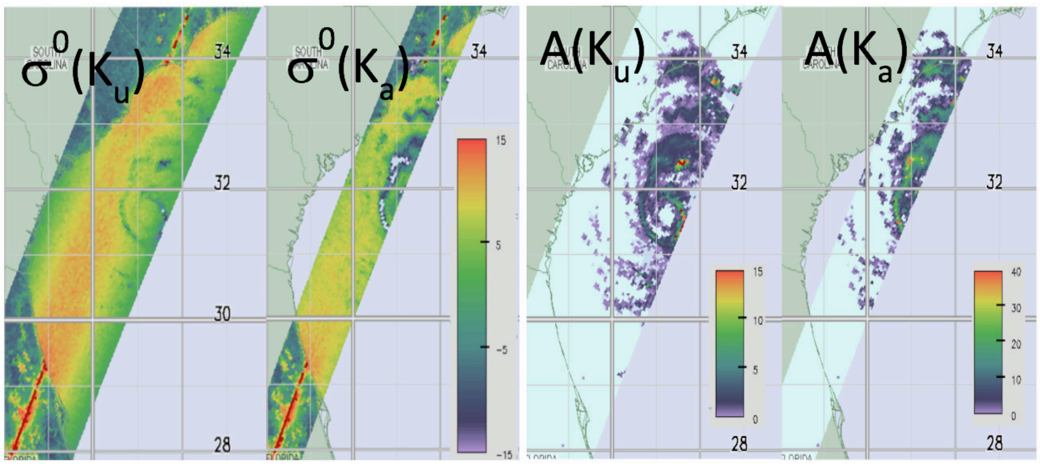

Figure 2.3: Dual-frequency radar surface backscatter cross-sections (σ^0) at Ku-band and Ka-band frequencies are used to improve estimates of path attenuations ($A(K_u)$, $A(K_a)$), leading to more accurate estimates of rain parameters from the DPR. The method relies on the fact that the standard deviation of the σ^0 difference, $\sigma^0(K_a) - \sigma^0(K_u)$, is smaller than the standard deviation of either $\sigma^0(K_u)$ or $\sigma^0(K_a)$. The images shown are from an overpass of Hurricane Arthur on July 3, 2014.

2.1.7. A Dual-Wavelength Space-/Air-borne Radar Technique to Detect Hydrometeor Phases

One of the challenges for the GPM Dual-frequency Precipitation Radar (DPR) algorithms in accurate estimates of precipitation rate is to identify hydrometeor types. Light rain exhibits a similar range of reflectivities as snow, leading to errors in separating snow, rain, and mixed-phased hydrometeors from single-frequency radar measurements. The capability to distinguish hydrometeor types is important not only in achieving an accurate precipitation rate, since estimates of precipitation rate and water content differ for the cases of snow and rain, but also for weather forecasting, hydrology, detection of aviation hazards, and other remote sensing applications. This study investigates 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 has been developed from the radar measurements of snow, mixed-phase, and rain obtained from stratiform storms. The algorithm, presented in the form of the look-up table that links the Ku-band radar reflectivities and dual-frequency ratio (DFR) to the phase states of hydrometeors, is checked by applying it to the APR-2 measurements. In creating the statistically-based phase look-up table, the attenuation-corrected (or true) radar reflectivity factors are employed, leading to better accuracy in determining the hydrometeor phase. Analysis of the classification results in stratiform rain indicates that the regions of snow, mixed-phase, and rain derived from the phase-identification algorithm coincide reasonably well with those determined from the measured radar reflectivities and LDR.

L. Liao (612, MSU) and R. Meneghini (612)

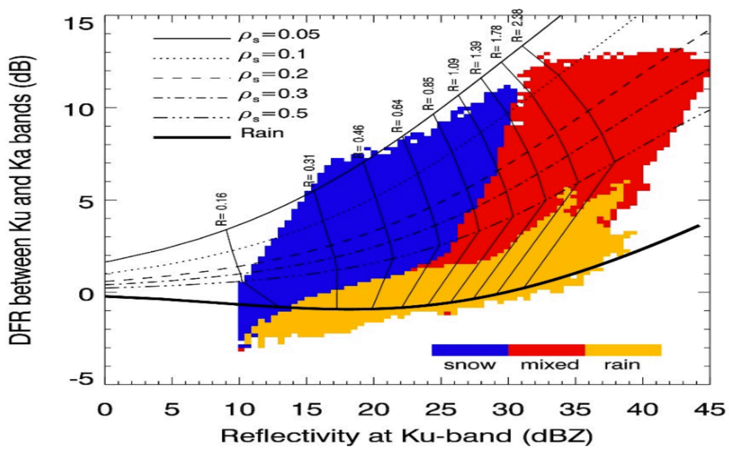

Figure 2.4: Phase look-up table as developed from the APR-2 measurements from stratiform rain events taken on January 23, 2003, in which hydrometeor phase states (snow in blue, mixed-phase in red, and rain in orange) are expressed in terms of DFR and ZKu. This table forms the basis for identifying the predominant phase states of hydrometeors within the storm by using Ku- and Ka-band dual-wavelength radar.

2.1.8. Validation of the GPM Version 05 precipitation products

Precipitation products generated by the GPM Core Observatory and constellation sensors have reached Version 05. This version unifies measurements across the sensors based upon the GPM Dual-frequency Precipitation Radar and additional data sets. The results show good agreement between the satellite and surface data even at the instantaneous scale, particularly for moderate and high precipitation intensities. Version 05 of the GPM precipitation products represents the most recent evolution of the precipitation retrieval schemes. The Level 2 products are derived from the GPROF retrieval scheme which in Version 05 incorporates information from the GPM DPR and other satellite, surface, and model information to provide unified precipitation products across the different GPM sensors on a global basis. These results illustrate the ability to transfer precipitation information from the DPR to the GMI and other constellation sensors. Statistical analysis shows good performance of the retrievals over both the United States and Western Europe across the different seasons. (*Kidd, C., Tan, J., Kirstetter, P. and Petersen, W.A.: Validation of the Version 05 Level 2 precipitation products from the GPM Core Observatory and constellation satellite sensors. Submitted to the Quarterly Journal of the Royal Meteorological Society*) Ensuring the accuracy and reliability of retrievals is fundamental for both subsequent utilization of the data in Level 3 precipitation products and as direct inputs into hydro-meteorological models.

C. Kidd (612, UMD), J. Tan (612, USRA), P. Kirstetter (NWC), and W. Petersen (MSFC/NSSTC)

2.1.9. Making Better Estimates of Extreme Precipitation with TRMM Data

The new Point Process (PP) statistical model was developed to address perceived issues in the initial *Zhou et al.* (2015) extreme value analysis. That study fitted a Generalized Extreme Value probability distribution to the set of annual maximum daily precipitation accumulations that TMPA provides in each latitude/longitude grid box separately. This approach gave relatively noisy estimates for ARIs longer than the 16-year data record when compared to the NOAA/CPC analysis of daily precipitation gauge data. (The CPC analysis uses 65 years of data, over some 8,000+ stations, and is considered the standard of comparison.)

In the new study, the entire domain was partitioned into clusters of about 30 grid boxes based on the 90th percentile daily precipitation, then event-maximum daily values (for days exceeding the 99th percentile) were pooled. A PP analysis was used to create fitted extreme parameters for each cluster. The PP results were relatively smooth and close to the NOAA/CPC analysis. Despite a better overall pattern, the PP generally gave somewhat higher values than the CPC in the eastern half of the country. Although demonstrated here just for the coterminous United States, the analysis has been performed for the entire latitude belt 50°N-S, providing extreme value estimates for all areas—land and ocean—without regard to the density of surface observations. Once the new Integrated Multi-satellitE Retrievals for GPM (IMERG) mission datasets are extended to cover both the TRMM and GPM eras, this methodology will be directly applicable.

L. Demirdjian (UCLA), Y. Zhou (613, MSU), and G.J. Huffman (612)

2.1.10. Daytime, Top-of-the-Atmosphere Cirrus Cloud Radiative Forcing Properties in Singapore

Cirrus clouds are the most commonly found cloud in the atmosphere (40–60% global frequencies, 70% in tropical regions). Optically-thin cirrus clouds (optical depths<0.3; COD) represent roughly half of all such occurrence, making a significant component of cirrus impossible to resolve with passive satellite sensors alone and why ground-based lidar networks like MPLNET are optimal to conduct this study. While all clouds warm the atmosphere at night, during daytime cirrus are the lone cloud genus that can readily act as to both warm and cool the underlying atmosphere depending on their varying physical properties. Results from this study support the open hypothesis of a hemispheric gradient in cirrus cloud daytime TOA CRF globally, varying from positive near the equator to neutral in the midlatitudes and presumably negative approaching the non-ice-covered poles. The NASA MPLNET shares an extremely rich measurement database that spans for almost two decades for some observational stations, to the credit of the excellent work by the MPLNET staff. Cloud-Aerosol Lidar with Orthogonal Polarizations (CALIOP) Level 2 Cloud Profile Data. (https://eosweb.larc.nasa.gov/project/calipso/calipso_table)

The NASA MPLNET shares an extremely rich measurement database that spans for almost two decades for some observational stations. For this reason, a multi-site and multi-year analysis of MPLNET data will bring a new and critical understanding of daytime/diurnal cirrus radiative impact in the climate budget. This characterization will permit better parameterization of cirrus cloud radiative behavior to improve both forecast and climate models.

S. Lolli (612, UMBC), J. R. Campbell (NRL), E. J. Welton (612), J. R. Lewis (612, UMBC) et al., 2017

2.1.11. Land-Ocean Contrast in Tropical Convection

Classifying and quantifying beneficial moderate rain versus catastrophic intense deep convection is important for a range of societal applications from agriculture to safety. By evaluating model-derived land-ocean contrasts against 14 years of TRMM observation, this study offers the first intercomparison of next-generation ultra-high–resolution global convection-resolving simulations from the NASA Multi-scale Modeling Framework (MMF) and the Non-hydrostatic Icosahedral Cloud Atmospheric Model (NICAM). The NASA MMF better captures both the frequency and the land-ocean contrast of shallow warm rain; while NICAM overestimates warm rain, particularly over land, due to moister boundary level conditions than MMF. Conversely, only the NICAM simulations exhibit enhanced deep convection frequency over land because the NASA MMF lacks heterogeneous surface heat flux, which can drive sea-breeze-type mesoscale waves over land. Understanding the detailed cloud-precipitation processes from satellite observations and providing guidance for the development of next-generation ultrahigh-resolution global modeling is a central element of future satellite mission concepts, namely the Cloud and Precipitation Processes Mission (CaPPM). This study provides one such satellite-to-model evaluation with respect to the land-ocean contrast in tropical convection.

T. Matsui (612, UMD), J.-D. Chern (612, UMD), W.-K. Tao (612), S. Lang (SSAI), M. Satoh (U. Tokyo), T. Hashino (U. Kyushu), and T. Kubota (JAXA)

2.1.12. GPM Retrieval Performance

Integrated Multi-satellitE Retrievals for GPM (IMERG) combines GPM Microwave Imager data with 10 other satellite-based microwave estimates, geostationary infrared observations, and rain-gauge analyses. IMERG precipitation estimates for September 18, 2017, at UTC 08:30 are shown in Figure 2.5. This image captures Hurricanes Jose and Maria, Tropical Depression Lee, and Tropical Storms Norma and Otis. The IMERG product provides precipitation estimates every 30 min at a 0.1° x 0.1° grid box and with a 4–5-hour latency (for application users) and ~3 month latency (for science users).

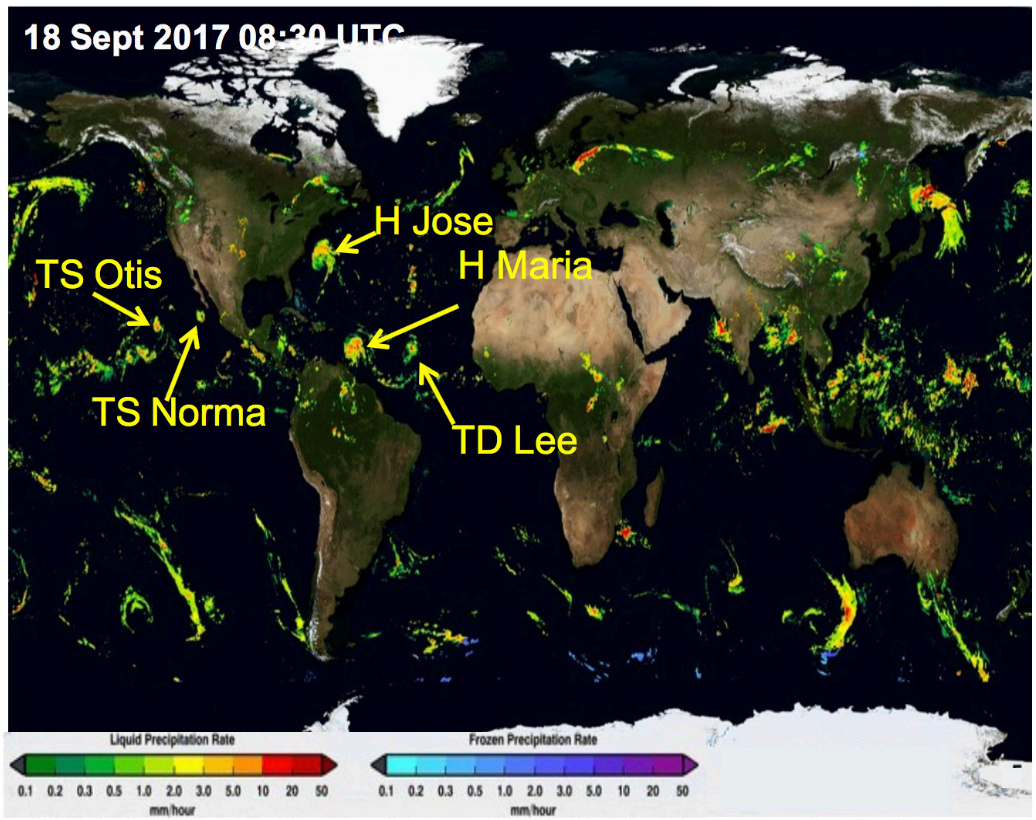

Figure 2.5: GPM's IMERG product precipitation estimates for September 18, 2017, showing Hurricanes Jose and Maria, Tropical Storms Otis and Norma, and Tropical Depression Lee.

The GPM Core Observatory (GPM-CO) spacecraft, a NASA–JAXA (Japanese) partnership, was launched in February 2014 and operates in a non–sun-synchronous orbit with an inclination angle of 65°. This orbit allows the GPM-CO to sample precipitation across all hours of the day, from the tropics to the Arctic and Antarctic circles, and observe hurricanes and typhoons as they transition from the tropics to the mid-latitudes. The GPM-CO has sophisticated satellite instrumentation, intercalibrates datasets from 10 other microwave radiometers from partners sharing data; coordinates merged precipitation datasets; and has reduced latency for delivering data products, simplified data access, expanded global ground-validation efforts, and integrated user applications. Because of the application focus of GPM, the public release of precipitation products is required in near-real-time (1–5 h after observations are downlinked to the ground stations). GPM-CO's well-calibrated instruments allow for scientifically advanced observations of precipitation in the midlatitudes, where a majority of Earth's population lives.

G. Skofronick-Jackson (612), and 17 co-authors

2.2. Climate and Radiation Laboratory

One of the most pressing issues humans face is to understand the Earth's climate system and how it is affected by human activities now and in the future. This has been the driving force behind many of the activities in the Climate and Radiation Laboratory. Accordingly, the Laboratory has made major scientific contributions in five key areas: hydrologic processes and climate, aerosol-climate interaction, clouds and radiation, model physics improvement, and technology development. Examples of these contributions may be found in the list of refereed articles in Appendix II and in the material updated regularly on the Code 613 Laboratory Web site: http://atmospheres.gsfc.nasa.gov/climate/. Key satellite observational efforts in the Laboratory include MODIS and MISR algorithm development and data analysis, SORCE solar irradiance (both total and spectral) data analysis and modeling, and TRMM and ISCCP data analysis. Leadership and participation in science and validation field campaigns provide key measurements as well as publications and presentations. Laboratory scientists serve in key leadership positions on international programs, panels, and committees, serve as project scientists on NASA missions and PI's on research studies and experiments, and make strides in many areas of science leadership, education, and outreach. Some of the Laboratory research highlights for the year are described below. These cover the areas aerosol-cloud-precipitation interactions, aerosol effects on climate, reflected solar radiation, land-atmosphere feedback, polar region variations, and hydrological cycle changes. The Laboratory also carries out an active program in mission concept developments, instrument concepts and systems development, and global climate models. The Projects link on the Climate and Radiation Laboratory Web site contains recent significant findings in these and other areas.

The study of aerosols is important to Laboratory scientists for many reasons: (1) Their direct and indirect effects on climate are complicated and not well-quantified; (2) Poor air quality due to high aerosol loadings in urban areas has adverse effects on human health; (3) Transported aerosols provide nutrients, such as iron (from mineral dust and volcanic ash), important for fertilization of parts of the world's oceans and tropical rainforests; and (4) Knowledge of aerosol loading is important to determine the potential yield from the green solar energy sources. Highlights of Laboratory research activities carried out during the year 2017 are summarized below.

2.2.1. Clouds at High Resolution: ASTER Cloud Optical Retrievals

When a moderate resolution imager like MODIS or VIIRS detects cloud within a single field-of-view (pixel), there is always a question of whether that field of view is homogeneously filled with cloud and, if not, the impact of heterogeneity on retrieved cloud property statistics. MODIS has two channels that acquire data at a relatively higher 250 m resolution; VIIRS has some channels that can acquire data at 375 m resolution. These higher resolution channels can give some indication of heterogeneity within the larger 1-km/750-m pixel at which retrievals are run, but the information is quite limited.

ASTER provides a unique view of cloud structural detail, particularly for marine boundary layer stratocumulus clouds. Over 4000 ASTER 15-m pixels fit within a single MODIS 1-km footprint. ASTER then allows observations of cloud spatial detail to better understand sub-pixel inhomogeneity effects on MODIS and other moderate resolution cloud retrievals.

Often, a smooth MODIS cloud scene will resolve into an artwork of light and shadow when viewed using ASTER. This study is the first attempt to port EOS-developed cloud retrievals to the ASTER instrument, thus providing an empirical framework for studying retrieval sensitivities to sub-pixel spatial structure, scale dependencies, and the influence of 3D radiative effects. The results will also inform spatial resolution requirements for future cloud imaging sensors.

Land imagers like ASTER (or the Landsat OLI instrument) have rarely been used for cloud studies. Both the land and atmospheric community can benefit from closer cooperation.

F.Werner (613, SSAI), G.Wind (613, SSAI), Z. Zhang (610,UMBC), S.Platnick (610), I.Di Girolamo (Univ. of Illinois at Urbana-Champaign), G. Zhao (613, Univ. of Illinois at Urbana-Champaign), N. Amarasinghe (613, SSAI), and K. Meyer (613)

2.2.2. Spectral Observations Support the Hypothesis of Inhomogeneous Mixing

Understanding the variability in loud properties near cloud edges helps scientists better determine how microphysical properties of clouds can affect cloud-aerosol interactions and how clouds are mixed during the entrainment of dry air. The mixing process between clouds and dry air generally follows the two limiting scenarios of homogeneous and inhomogeneous mixing. To test the inhomogeneous mixing hypothesis, this study applied a novel method using spectral measurements of zenith radiance from two ground-based instruments. Researchers analyzed shortwave spectral radiometric data captured during the MAGIC field campaign, applying the spectrally invariant method to assess cloud properties. The results indicated that cloud droplet size did not change significantly near the cloud's edge, which supports the hypothesis that inhomogeneous mixing dominates near cloud edges. The results also demonstrated that, by using spectrally invariant method cloud-air mixing, information could be obtained not only from the conventional *in situ* aircraft measurements but also from ground-based spectral measurements.

W. Yang (613, USRA) and A. Marshak (613)

2.2.3. Trends of Mean and Extreme Precipitation

An understanding of rainfall distribution and rainfall trends is critical for predicting the climate system's response to global warming. This study introduces a novel metric that captures many important features of the relationship between average and extreme precipitation and confirms an overall trend towards a "wet-getting-wetter, dry-getting-drier" climate. Understanding precipitation distribution and trends are extremely important in predicting the climate system's response to global warming. High-resolution, long-term precipitation observations are needed for such study. High-resolution TRMM precipitation data was not included in this study due to its short data record; hopefully (in the near future) combined TRMM/GPM data will provide a longer data record with unprecedented resolution for a more in-depth study of extreme rainfall events and their trends. AAMR was defined as the ratio of total area where both means and extremes exhibit trends in the same direction and are significant to the total area where only the trend of the means is significant. This ratio can be calculated for different definitions of what constitutes "extreme," such as the number of standard deviations from the mean. The study showed that AAMR decreases with the degree of extremeness, which indicates less predictability for the more extreme events. The relative magnitude of AAMR for the positive/negative trends, in the tropics/extratropics, land/oceans and wet/dry regions provided insight into the underlining dynamic and thermodynamic factors dominating precipitation distributions and trends in various regions.

Y. Zhou (613, MSU) and W. K. Lau (610, UMD)

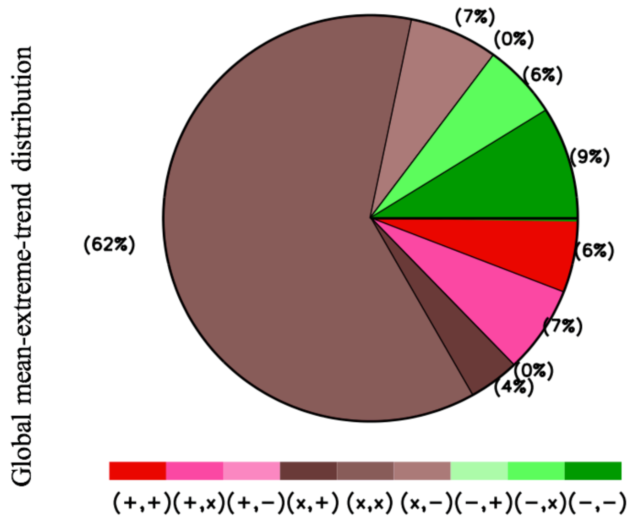

Figure 2.6: The percentage of areas of each mean/extreme matching category in the entire global for the two standard-deviation extremes in the GPCP data that provides a comprehensive view and current status between the trends in mean and extreme precipitations.

2.2.4. Solar Rotational Modulation Differs between Ultraviolet and Visible Spectra

Solar spectral irradiance variations can produce significant changes in Earth's upper, middle, and lower atmospheres. Understanding the complex response of terrestrial atmosphere to solar variations is essential for assessing climate variability. While the VIS and UV portion of the solar spectrum may have not yet been observed with sufficient accuracy and precision to determine the 11-year solar cycle variations, the National Climate Data Record of total solar irradiance (TSI) and spectral solar irradiance (SSI) uses 27-day solar rotational variations to simulate them. The temporal variations over one-hundred cycles of solar rotations, independent of the two solar cycles in which they are embedded, show distinct solar rotational modulations at the UV and VIS parts of the solar spectrum measured by SORCE.

Uninterrupted long-term records of TSI and SSI are critical for determining the Sun's impact on climate variability. The Total and Spectral Solar Irradiance Sensor-1 (TSIS-1), due for deployment on the International Space Station in late 2017, will extend TSI and SSI observations after SORCE. To fill any possible gap in the future solar irradiance measurements between SORCE and TSIS-1, the Total Solar Irradiance Calibration Transfer Experiment (TCTE) operating since December 2013 will provide cross-calibration between SORCE and TSIS-1.

J. N. Lee (613, UMD), R. F. Cahalan (613, APL/JHU), and D. L. Wu (613)

2.2.5. High-Frequency Polarized Microwave Measurements Show that Ice Crystals in Cold Clouds Are Often Oriented Horizontally

High-frequency microwave polarization difference (PD), defined as the difference between vertically and horizontally polarized channel pair radiances, embodies many important characteristics of cloud ice. PD measurements from GPM's GMI instrument indicate the presence of a feature that can only be explained by horizontally oriented, non-spherical ice crystals. This finding helps scientists understand and better retrieve cloud-ice microphysical properties. This is the first study of frozen particle microphysical properties on a global scale that uses dual-frequency microwave polarimetric signals from GPM-GMI observations. This study found the scattering by frozen non-precipitating particles is highly polarized, which implies that ice crystals in ice clouds are likely dominated by horizontally-oriented, non-spherical particles. Polarization signals from GMI and other satellite instruments containing similar channels (e.g., SSMI/S, Megha-Tropiques MADRAS) have great potential for deepening our understanding of cloud ice microphysical properties, including shape, orientation, size, etc., as well as improving future retrieval techniques. Higher frequency polarization measurements—e.g., at 640 GHz and even infrared—that take advantage of the greater sensitivity to a different part of the broad frozen particle spectrum are needed for a more complete picture.

J. Gong (613, USRA) and D. L. Wu (613)

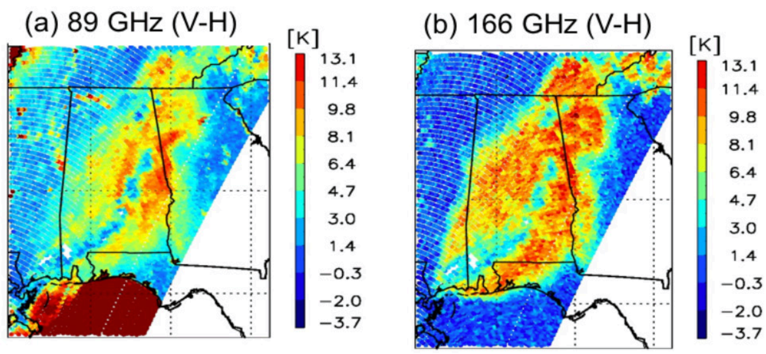

Figure 2.7: Image (a) and (b) depict the GPM-GMI's 89 and 166 GHz polarization difference measurements for a squall-line event that occurred on April 29, 2014, in the Southeastern United States.

2.2.6. MISR Space-Based Observations of Volcano Plume Dynamics Yields Insight Into Geological Processes in Remote Regions

The Multi-angle Imaging SpectroRadiometer (MISR) retrieves aerosol plume profiles. This study revealed significant differences in average plume height and plume dispersion for the Kamchatka volcanoes that reside in the northern (CKD) vs. southern (EVF) geologic sub-regions. Remote volcano geology can be studied globally in this way. This in-depth study of volcanic eruptions in Kamchatka was conducted with MISR during its over 16-year operational period. The resulting database of observed plumes was used to investigate multiple elements of volcanism in the Kamchatka region, including:

- The plume observation rate of MISR
- The correlation between MISR-derived plume heights and traditional plume observations
- The variation of eruptive dynamics at individual volcanoes in the Kamchatka region
- Differences in eruptive styles among volcanoes in the region
- The influence of local meteorological conditions and volcano peak elevation on plume properties
- Implication of these observations for the relative strength of eruptions, based upon initial plume momentum and buoyancy, the influence of local atmospheric stability on plume dispersion, and more generally, the differences and any changes in eruptive style.

Plume properties for the more northerly volcanoes that broadly correspond to Kamchatka's Central Kamchatka Depression (CKD) geological sub-region were observed to be distinct from those of the more southerly volcanoes, associated with the Eastern Volcanic Front (EVF). The more energetic CKD plumes reflect the higher water content of CKD magmas. This research validated the use of MISR-derived plume heights within existing volcanic eruption databases, particularly vital in remote regions with minimal or no monitoring. Additionally, this work highlighted the ability of these 17+ years of ~weekly, near-global data to provide insight into the underlying geological processes driving volcanism in complex volcanic regions, especially those in remote regions for which there is little if any *in situ* monitoring. The multi-angle imaging data are critical for this application, making possible the stereo-height analysis performed here, as well as plume-aerosol-type mapping, which is part of continuing work.

V. J. B. Flower (613, USRA) and R. Kahn (613)

2.2.7. Deep Space Observations of Oriented Ice Crystals

Images taken by the DSCOVR satellite often contain colorful, bright flashes over land. The analysis of flash locations reveals that they are due to specular reflection from horizontally oriented ice crystals floating in clouds.

This study shows that it is possible to identify clouds containing horizontally oriented ice crystals even from deep space. Such observations can help determine how commonly these horizontal crystals occur and whether they significantly impact the amount of sunlight that passes through clouds and warms the surface, thus affecting the radiation budget of Earth. This information can help improve climate models by allowing them to represent ice clouds more accurately. Such data can also help improve the interpretation of other satellites' cloud observations by providing insights into the way horizontal ice crystals can shape cloud reflection. Finally, detecting glints may also help in using future satellites to characterize exoplanets orbiting distant stars.

A. Marshak (613) and T. Várnai (613, UMBC)

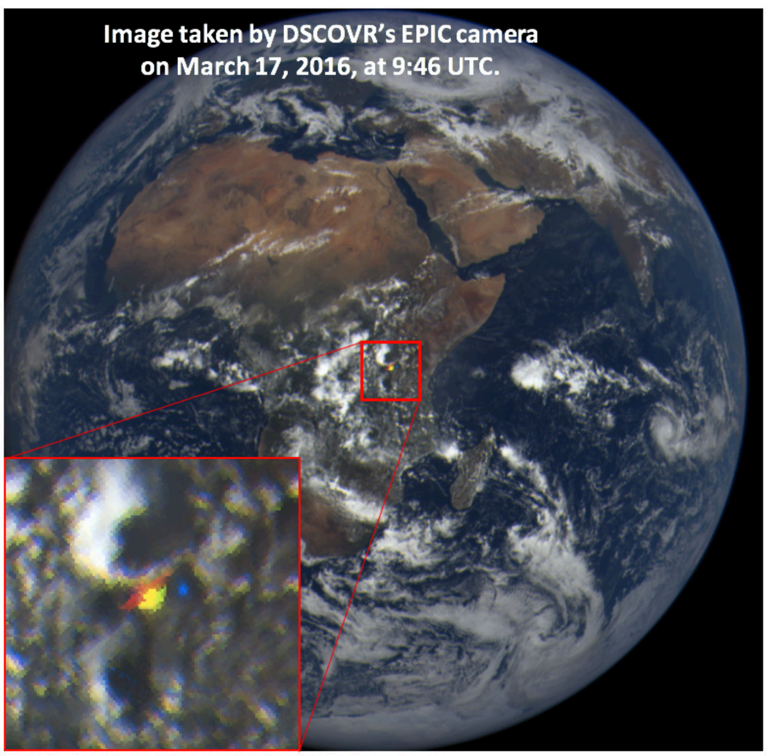

Figure 2.8: A sample image from the EPIC instrument on board the DSCOVR satellite. The image shows colorful glints from horizontally oriented ice crystals that float in clouds over Africa. Such glints appear colorful in EPIC images because the red, green, and blue images are captured a few minutes apart; during this time, the Earth's rotation changes the location where EPIC observes the specular reflection of sunlight.

2.2.8. Searching for Aerosol Effects on Clouds Using MODIS Regimes

Since clouds greatly modify the Earth's radiation budget and since aerosols can potentially greatly modify clouds, exploring appropriate ways to study how aerosol variability within the current climate impacts clouds is a scientific investigation of significant societal relevance. This study shows that a global study about diagnosing apparent aerosol effects on cloud is possible as long as there is a systematic way to organize the cloud observations. At the same time, the study exposes the limitations of present measurements that offer the widest coverage (passive observations): First, aerosol detection and retrieval near clouds is challenging and may yield biased results. Second, the temporal evolution of clouds and cloud-affected quantities within a changing aerosol environment cannot be monitored given the instantaneous nature of the observations (essentially one morning and one afternoon snapshot are available to us). Our near-global study using 12 years of data often finds conflicting signals and consistency with expectations only in select situations. Our results then do not show how a cloud is modified as aerosol varies, but rather compares similar clouds in different aerosol conditions. Future missions should, therefore, have better temporal coverage and be equipped with the optimal blend of passive and active instruments that will allow better detection of aerosols near clouds without sacrificing spatial coverage.

L. Oreopoulos (613), N. Cho (613, USRS), and D. Lee (613, MSU)

2.2.9. Cross-calibration of VIIRS Against MODIS Aqua Decreases Aerosol Retrieval Error and Improves Data Consistency

The VIIRS sensor will enable continuation of MODIS data records, such as aerosol optical depth (AOD) as long as calibration differences are accounted for. The absolute calibration of MODIS Aqua is thought to be better than that of VIIRS. We, therefore, used near-simultaneous VIIRS and MODIS Aqua pixels to derive cross-calibration coefficients that make VIIRS radiometrically consistent with MODIS. The decrease in VIIRS AOD retrieval error proves the utility of the approach.

Direct and indirect aerosol radiative effects are among the largest contributors to uncertainty in the Earth's radiation budget. Aerosol quantification is also important for air quality and human health applications, as well as hazard avoidance (e.g. dust storms, volcanic ash). Decreasing the uncertainty of aerosol properties monitored from space is therefore critical for these applications. One particularly relevant aspect is that determining accurate trends in aerosol loading often requires records longer than provided by individual satellites. As the MODIS sensors approach the end of their lifetimes, which already exceed original design, VIIRS can be used to continue these records. By ensuring the radiometric consistency between MODIS and VIIRS, our technique also results in improving the level of consistency between derived aerosol data products. This will minimize discontinuities in their time series and improve our ability to monitor long-term changes. S-NPP is the first VIIRS sensor, and additional copies will fly on follow-on satellites. By applying the same basic technique on all sensors, we will be able to eventually string together a single self-consistent record. Our calibration results are independent of our aerosol retrieval algorithm. Therefore, these results can be used to improve MODIS/VIIRS consistency in other data sets as well, for example cloud or land surface data.

A. M. Sayer (613, USRA), N. C. Hsu (613), C. Bettenhausen (613, SSAI), J. Lee (613, UMD)

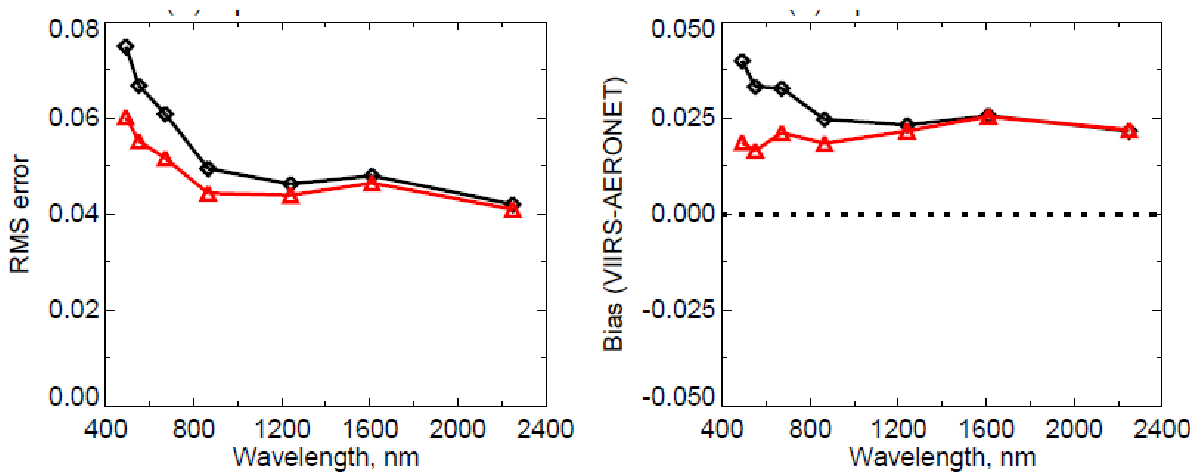

Figure 2.9: The images show root mean square (RMS) error (left) and bias (right) in spectral AOD against AERONET validation data, for standard and newly improved VIIRS calibration. The improved calibration has smaller errors, especially for visible bands.

2.2.10. Characterizing Optically Thin Clouds Over Arctic Sea Ice

The Arctic is changing rapidly. Over Arctic sea ice, aerosol microphysical effects in thin, predominantly liquid clouds decrease cloud droplet size, optical depth, and occurrence of precipitation and mixed-phase clouds. Currently, our ability to predict future changes is hampered, in part, by both a poor understanding of Arctic cloud-aerosol interactions, which affect the regional energy budget, and by the inability of models to accurately represent key Arctic cloud properties.

We studied the approximately five percent of clouds over the Arctic Ocean for which aerosol conditions were determined with highest confidence (i.e., nighttime, predominantly liquid, optically thin clouds). Clouds in this subset are sensitive to the aerosols, particularly over sea ice. For example, such thin clouds can precipitate over the Arctic given the extremely cold temperatures, but over sea ice, polluted clouds in the subset precipitated less. The polluted, thin clouds also contained fewer observable ice particles. These findings suggest that aerosols might affect freezing, which is useful information when seeking to represent the cloud-droplet freezing mechanisms in regional climate models. Quantifiable reductions in cloud optical depth would impact cloud emissivity. All else being equal (e.g., assuming standard temperature profiles), this effect suggests that aerosols may reduce regional-scale cloud-based surface heating by up to 8 percent over sea ice, excluding cloud fraction effects. Aerosol-cloud interactions were less significant over open ocean. Although we focused on a very small subset of all clouds and did not assess aerosol impact on cloud fraction, these results are an important early step toward obtaining the first observation-based estimate of regional cumulative aerosol indirect effects on the Arctic surface. This information is critically needed for constraining models of the Arctic energy balance. Our findings also highlight the need to continue developing active sensors and high-quality aerosol modeling over polar regions, and they will provide valuable context for future aircraft campaigns in the Arctic.

L. Zamora (613, UMD) and R. Kahn (613)

2.2.11. Towards a 40-Year Aerosol Record: First Near-Global (Land and Ocean) Demonstration Data Set from the AVHRRsN

The Advanced Very-High-Resolution Radiometer (AVHRR) satellite instruments have been used to study the Earth since the 1980s. While AVHRR-based AOD data sets exist over oceans, data over land have been lacking, causing an important gap in air quality and climate applications. We adapted our mature Deep Blue and Satellite Ocean Aerosol Retrieval algorithms, previously applied to SeaWiFS, MODIS, and VIIRS, to work with AVHRR data. This provided, for the first time, near-global land and ocean aerosol data from the AVHRRs. This work has the potential to generate a 40-year long-term consistent time series with the AVHRR approaching 40 years in length. The AVHRRs represent the longest single-sensor-type data record suitable for retrieving aerosol properties. Importantly, they cover the two decades prior to the EOS record; this earlier time period (from 1981 to 2000) is particularly important for understanding changes in the levels of aerosol loading over Asia, where a large fraction of global economic growth over the past several decades has occurred. The years of overlap with EOS provide important opportunities for cross-calibration and comparison against these new sensor types. Previously, AVHRR data had been used to retrieve aerosols over ocean but data over land were sparse or absent entirely. We demonstrated a new approach to quantitatively retrieve, for the first time, this much needed aerosol information from AVHRR over land and ocean on a global scale. Our work, therefore, fills a crucial observational gap for air quality and climate studies, roughly doubling the available data record length.

C. Hsu (613), A. M. Sayer (613, USRA), and J. Lee (613, UMD)

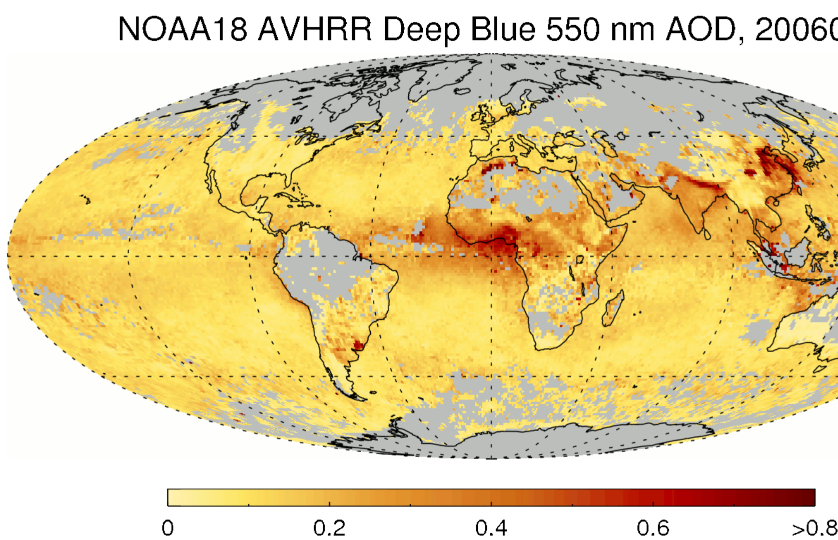

Figure 2.10: AVHRR-derived AOD for 2006–2011.

2.2.12. Comparing Rainfall of Organized Storms in Climate Models to Observation

Organized storms produce intense rainfall and are responsible for a disproportionately high amount of rain in the tropics. Observational studies have shown that they are responsible for most of the changes in rainfall in the past decades [*Tan et al.,* 2015]. Therefore, it is crucial for projections of future rainfall that climate models can represent such systems. However, our study suggests that the current generation of models underestimate the heavy rainfall associated with these organized storms by varying degrees, and some compensate this bias by overproducing the number of such storms.

We compared tropical rainfall production by organized storms in climate models against observations, examining how well each model predicts the occurrence of organized storms (red) and how well the models provide the rainfall associated with each storm (blue). All models underestimated the rain associated with organized storms by varying degrees. In some models, this is compensated for by an excessive occurrence of organized storms. This study is the first time that cloud regimes have been used to identify storm type and perform a process-based evaluation of model rainfall. It relies on continued, high-quality, collocated observations of clouds and precipitation with global coverage to assess the performance of climate models. In particular, missions such as GPM are crucial in advancing the quality of global precipitation observations and refining our results. Likewise, collaborative projects such as ISCCP, which has its genesis at NASA but now managed by NOAA, are instrumental in producing a global climatology of clouds.

J. Tan (613, USRA), L. Oreopoulos (613), D. Jin (613, USRA)

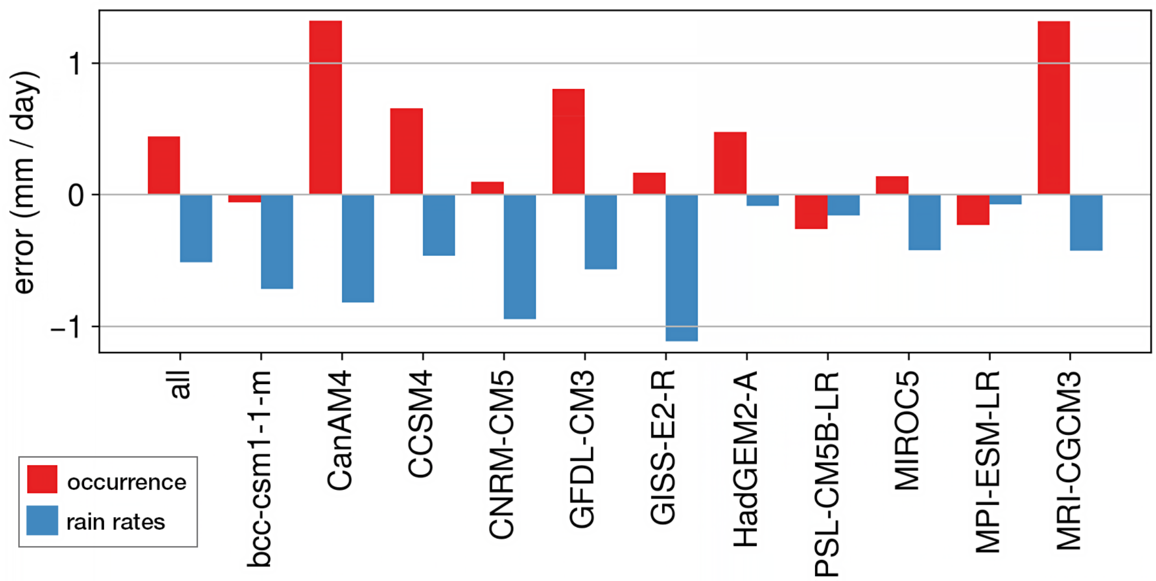

Figure 2.11: By identifying recurring cloud distributions as observed globally by a network of satellites, cloud regimes representing different storm types can be identified. Such cloud regimes can also be defined in climate models, allowing a process-based evaluation of model rainfall by each storm type.

2.2.13. Deriving Aerosol Plume Height from MODIS

We have developed a thermal technique for MODIS to derive smoke plume height (Hs) from wildfires. Wildfire Hs is an important parameter for constraining aerosol chemical transport models in GCMs. It determines whether emitted smoke remains a local phenomenon limited to the atmospheric boundary layer, or whether it is injected into a free troposphere and can travel greater distances. Hs is currently available from the CALIPSO space lidar CALIOP [*Vaughan et al.,* 2009] and the MISR multi-angle radiometer on the Terra platform [*Nelson et al*., 2013]. The MODIS-based retrievals implemented in the Multiangle Implementation of Atmospheric Correction (MAIAC) algorithm will significantly expand the retrieval coverage and provide data for both morning and afternoon orbits. The new method is also directly applicable to VIIRS.

A. Lyapustin (613), R. Kahn (613), Y. Wang (613/UMBC), and S. Korkin (613/USRA)

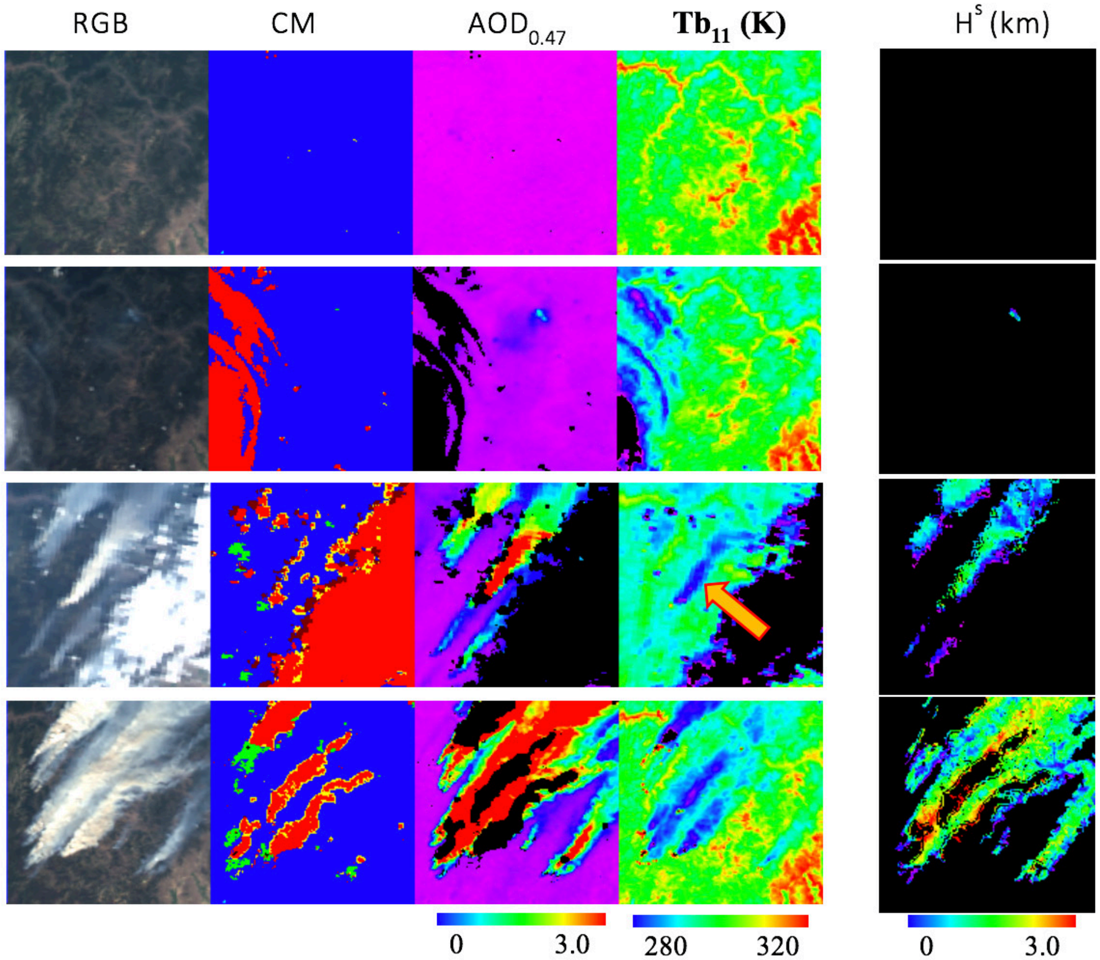

Figure 2.12: These images illustrate smoke height retrievals for the Rocky Mountains wildfires on summer of 2008. The arrow identifies the thermal contrast created by the rising smoke plume. Each row represents a different day. The columns correspond to the MODIS RGB image, MAIAC cloud mask (CM: clear=blue, cloud=bright red and yellow. shadow=dark red, and detected fire=green), AOD, 11-mm brightness temperature (Tb), and plume height above ground (Hs).

2.3. Atmospheric Chemistry and Dynamics Laboratory

The Laboratory conducts research including both the gas-phase and aerosol composition of the atmosphere. Both areas of research involve extensive measurements from space to assess the current composition and to validate the parameterized processes that are used in chemical and climate prediction models. This area of chemical research dates back to the first satellite ozone missions and the Division has had a strong satellite instrument, aircraft instrument, and modeling presence in the community. Both the EOS Aura satellite and the OMI instrument U.S. Science team come from this group. The Laboratory also is a leader in the integration and execution of the NPP mission, and is also providing leadership for the former NPOESS, now the newly reorganized Joint Polar Satellite System (JPSS). This group has also developed a state-of-the-are chemistry-climate model, in collaboration with the Goddard Modeling and Analysis Office (GMAO). This model has proved to be one of the best performers in a recent international chemistry-climate model evaluation for the stratosphere. Highlights of Laboratory research activities carried out during the year are summarized.

2.3.1. The Anomalous Change in the 2015–2016 Quasi-Biennial Oscillation

The Quasi-biennial oscillation (QBO) is a variation of the east-west (U) wind in the stratospheric equatorial zone. The QBO has an irregular period of approximately 28 months and exhibits a downward propagation from the mid-stratosphere (32 km or 10 hPa) to the lower stratosphere (16 km or 100 hPa. However, in 2015–16, there was an unprecedented upward jump of these westerly winds from ~24 km to 28 km. These westerlies cut-off the normal downward propagation of the easterly winds from 32 km. This anomalous 2015–16 event is unprecedented in the entire QBO record since 1953. Two hypotheses have been proposed: 1) it was caused by the strong 2015–16 ENSO; and 2) it resulted from increasing global temperatures. Neither of these hypotheses have been verified, although such a disruption did not occur during previous ENSO events. Was this a "black swan" event (i.e., a once in a generation event), or was this a "canary in the coal mine"?

The QBO is the major source of year-to-year variability of the stratosphere. Hence, the QBO has a major impact on the variability of stratospheric constituents such as ozone, water, methane, etc. Understanding the physics and impact of the QBO underlies our modeling framework that allows us to project the recovery of the ozone layer. The QBO is observed by a number of satellite missions. These include TOMS, UARS, AURA, SAGE. Trace gas distributions in the stratosphere are dependent on observing the QBO.

P. A. Newman (610), L. Coy (610.1, SSAI), S. Pawson (610.1), and L. R. Lait (610.1, MSU)

2.3.2. NASA's New-Generation Aura Ozone Monitoring Instrument's Volcanic SO2 Dataset and Continuation with SNPP OMPS

We introduced the new Aura Ozone Monitoring Instrument's (OMI) volcanic SO_2 dataset, produced with an advanced principal component analysis algorithm with iterative spectral fitting. As compared with the previous OMI data product, this new version significantly reduces retrieval bias for large volcanic eruptions and improves data quality for small degassing volcanoes. The new algorithm is also capable of producing highly consistent retrievals between OMI and SNPP OMPS (SO_2 time series above right) and continuing the long-term satellite volcanic SO_2 data record.

Volcanic SO_2 is a dominant natural forcing to the Earth's climate system and can also pose severe threat to aviation safety. The new OMI and OMPS datasets in this study will provide more accurate estimates of volcanic emissions, including relatively small volcanoes for which the emissions have been poorly constrained. This will help to better understand and quantify the climate impacts of volcanic eruptions. The OMI and OMPS PCA SO_2 data are now both being produced and public released within few hours of satellite overpass. The data will help operational data users in decision making in volcanic disaster avoidance.

The PCA algorithm's capability of producing highly consistent retrievals between different instruments, as demonstrated in this study, will allow the NASA SO_2 data record to be extended well beyond the EOS era. In addition to OMI and SNPP OMPS, the algorithm will also be applied to future satellite instruments such as ESA's TROPOMI, JPSS OMPS, and new geostationary missions such as NASA's TEMPO (the first EV-I instrument).

C. Li (614, UMD), N. A. Krotkov (614), S. Carn (MTU), Y. Zhang (614/UMD), R. J. D. Spurr (RT Solutions), and J. Joiner (614)

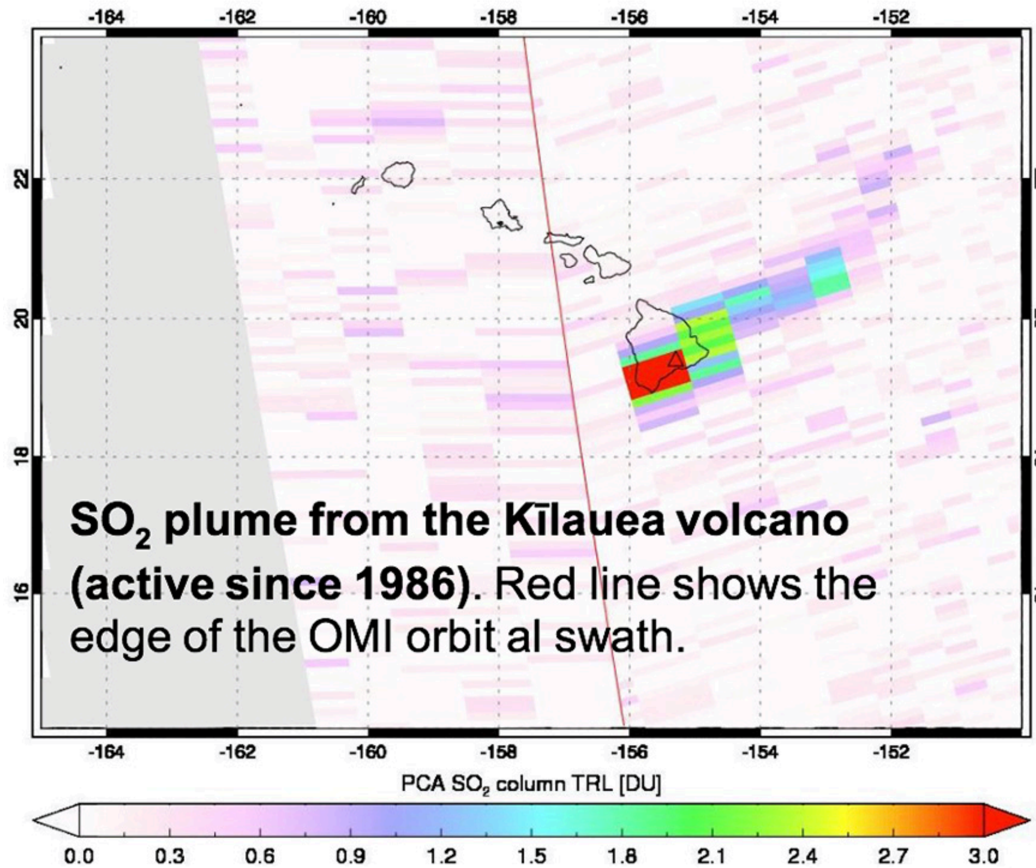

Figure 2.13: A snapshot of the volcanic SO_2 plume emitted from the Kīlauea volcano in Hawai'i, retrieved with the PCA algorithm from OMI radiance data acquired on January 5, 2017. The PCA algorithm reduces retrieval noise by a factor of two as compared with the previous algorithm, greatly improving the detection and quantification of SO_2 from degassing volcanoes such as Kīlauea.

2.3.3. Volcanic SO_2 Emissions from Space

A decade of NASA Aura/OMI volcanic SO_2 measurements (2005–2015) has been used to create the first *global* volcanic emissions inventory, providing new insights into the variability and trends in volcanic degassing.

The map below depicts locations of 32 volcanic SO_2 sources. These 32 volcanoes are a subset of the total of ~91 volcanoes with detectable SO_2 emissions in OMI data, which have been quantified in a new volcanic SO_2 emissions inventory. Inset trend plots are shown for 3 volcanoes: Miyake-jima (Japan; negative trend in 2005–2015), Dukono (Indonesia; neutral or weak positive trend), and Sabancaya (Peru; strong positive trend). In these trend plots, the horizontal axis is time (2005–2015), the vertical axis extends from zero to the max SO_2 flux measured at each volcano, the horizontal red line indicates the decadal mean SO_2 flux, and a labeled red data point indicates the SO_2 flux measured in 2015 (in units of 1000 metric tons per day or kilotons per day).

S. Carn (MTU), V. E. Fioletov (Environment & Climate Change Canada), C. A. McLinden (Environment & Climate Change Canada), C. Li (614, ESSIC/UMD), and N. A. Krotkov (614)

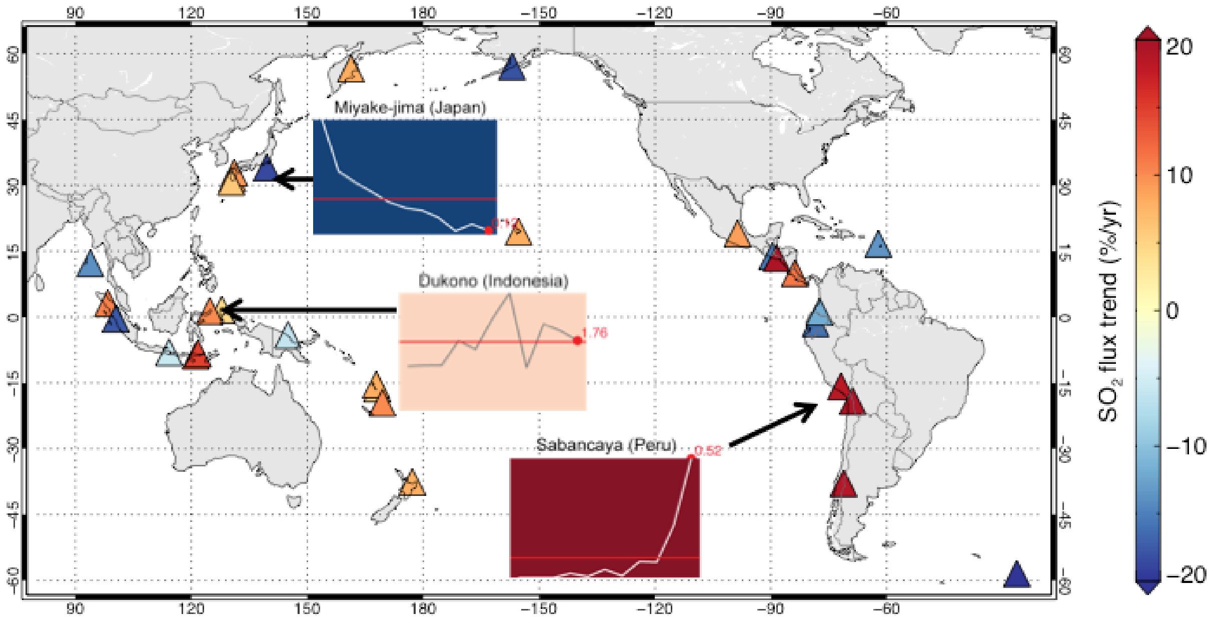

Figure 2.14: Locations of 32 volcanic SO_2 sources showing significant decadal trends in SO_2 emission, based on 11 years of OMI SO_2 measurements

2.3.4. NASA SO_2 Data Featured in New Volcanic Eruption Visualization

The Global Volcanism Program (GVP) at the Smithsonian Institution National Museum of Natural History has created a new Eruptions, Earthquakes and Emissions web visualization (http://volcano.si.edu/e3/) using NASA volcanic SO_2 data from multiple satellites. The GVP is the world's most authoritative source of information on global volcanic activity, both for the scientific community and the general public. The GVP Volcanoes of the World (VOTW) database is the most comprehensive record of Holocene volcanic activity available. To develop the Eruptions, Earthquakes and Emissions (E3) application, volcanic SO_2 data from NASA satellites (TOMS, OMI, OMPS) was added to the VOTW database for the first time, where it will be publicly accessible to database users. This will significantly increase the visibility of NASA data and permit broader use of the data for public outreach and scientific analysis. Joint analysis of volcanic eruption records, SO_2 emission data, and earthquake frequency could yield new insight into geological and volcanic processes.

S. A. Carn (MTU) and N. Krotkov (614)

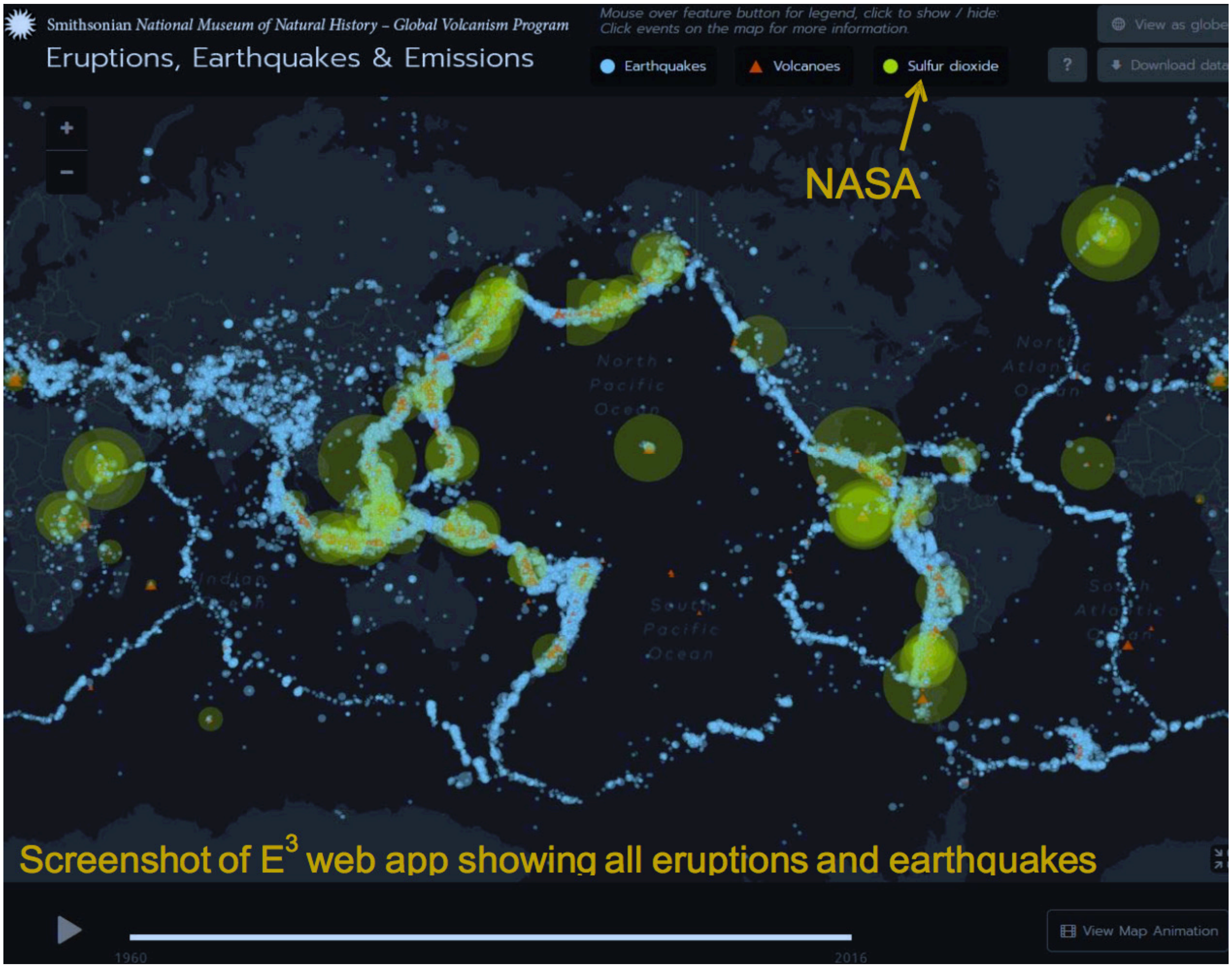

Figure 2.15: This shows a screenshot of the Smithsonian Institution Eruptions, Earthquakes & Emissions (E3) web application showing all volcanoes with recorded eruptions (red triangles), SO_2 emissions (yellow circles; circle size is proportional to SO_2 emissions measured by TOMS, OMI or OMPS), and earthquakes (blue dots) shown.

2.3.5. A Global and Decadal Record of Optical Depth of Absorbing Aerosols Above Clouds from OMI's Near-UV Observations

Aerosol-cloud interaction continues to be one of the leading uncertain components of the climate models, primarily due to the lack of adequate knowledge of the complex microphysical and radiative processes of the aerosol-cloud system. The situations when layers of absorbing aerosols overlay low-level cloud decks are commonly found in several regions of the world. Contrary to the known cooling effects of these aerosols in cloud-free scenario over dark surfaces, the overlapping situation of absorbing aerosols over cloud can potentially exert a significant level of atmospheric absorption and produces a positive radiative forcing (warming) at top-of-atmosphere. The OMI above-cloud aerosols (OMI/OMACA) product is aimed to help in addressing this problem by providing a global distribution of above-cloud aerosol optical depth on a daily scale, which, in conjunction with the clear-sky aerosol products, would make the quantification of "all-sky" radiative effects of aerosols on climate possible.

The current OMI record of aerosols above clouds can be extended by application of the retrieval technique to currently operating (OMPS), soon to be deployed (TROPOMI), and planned missions (OMPS on JPSS-1, 2) as well as PACE and ACE, all of which have near-UV observing capability. The availability of simultaneous active and passive measurements will allow the development of a more accurate aerosol-above-cloud product as knowledge of the aerosol vertical distribution will result in a better constrained retrieval and the derivations of additional aerosol properties such as the aerosol single-scattering albedo.

O. Torres (614), H. Jethva (614, USRA), and C. Ahn (614, SSAI)

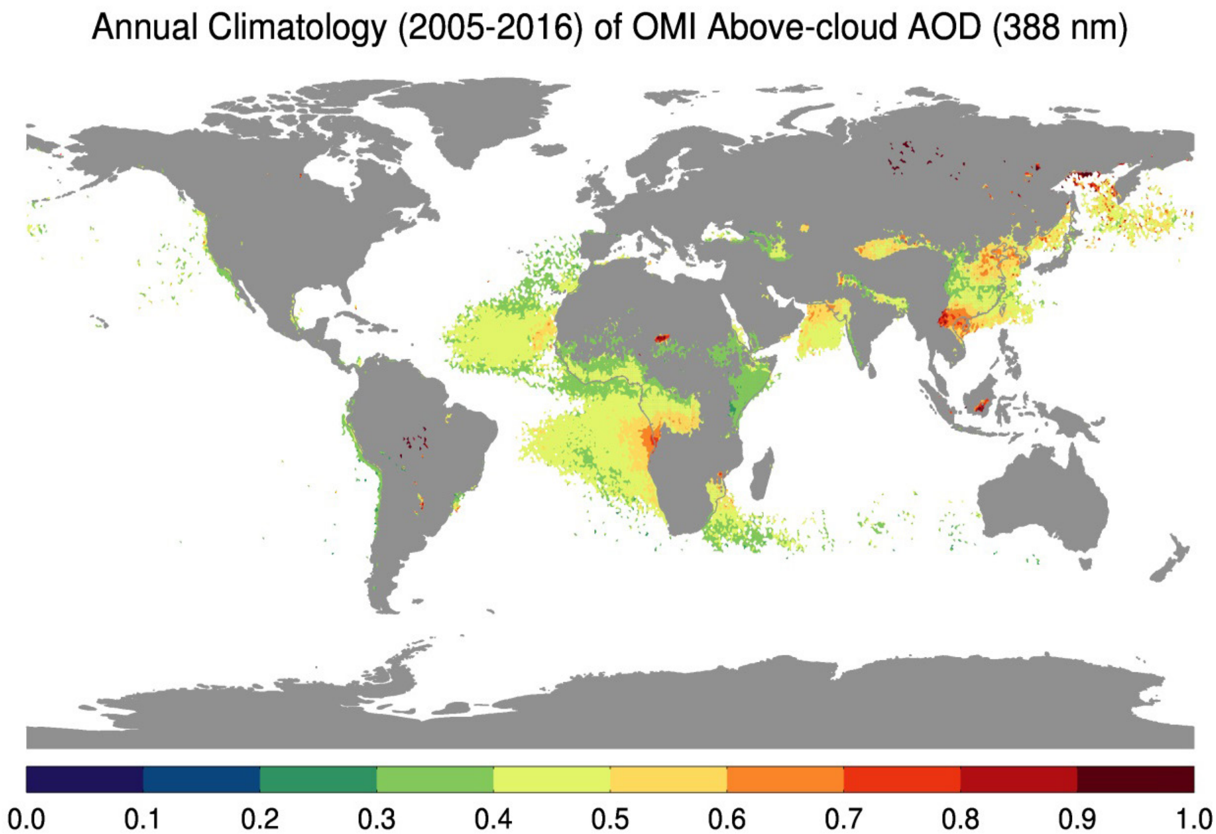

Figure 2.16: The global distribution of monthly climatology of above-cloud aerosol optical depth depicted in the Figure reveals moderate to heavy aerosol loading over several important smoke- and dust-laden regions of the world, where absorbing aerosols are found to overlay low-level cloud decks on a monthly to even a seasonal scale.

2.3.6. Optimizing Output Power Through Temporal Pulse Shaping

Work performed exclusively at Goddard resulted in a doubling of the maximum pulsed-laser power from space borne fiber amplifiers currently being developed by GSFC and OFS. By using the input seed pulse shape, optimized through computer modeling and measured experimental parameters, the study found that we can extract more power before power-limiting thresholds are reached. This result has already significantly reduced the projected weight and cost of a space-borne, active remote sensing, laser-based instruments for trace-gas detection, in particular CO_2, by reducing the number of amplifier units needed.

G. Allan (614, SigmaSpace)

2.3.7. High Sensitivity of Gross Primary Production in the Rocky Mountains to Summer Rain

In the catchments of the Rocky Mountains, peak snowpack is declining in response to warmer spring temperatures. To understand how this will influence terrestrial gross primary production (GPP), we compared precipitation data across the intermountain west with satellite retrievals of solar-induced fluorescence (SIF), a proxy for GPP. The SIF measurement itself is not sensitive to snow and therefore may be more accurate than popular vegetation indices for the Rocky Mountain region. Annual precipitation patterns explained most of the variability of SIF, but the response was dependent on site-to-site differences in the proportion of snowpack to summer rain. We found that SIF was approximately twice as sensitive to variations in summer rain than snowpack. The response of peak GPP to a secular decline in snowpack will likely be subtle, whereas a change in the amount of summer rain will have precipitous effects on GPP. The study suggests that the rain-use efficiency of Rocky Mountain ecosystems is strongly dependent on precipitation form (snow or rain) and timing. This type of study could be conducted at higher spatial resolution in the future using the planned NASA geostationary sensors: Tropospheric Emissions: Monitoring Pollution (TEMPO) Earth Ventures-Instrument (EV-I) and GeoCarb (Earth Ventures/Mission).

M. Berkelhammer (Univ. Illinois, Chicago), I. Stefanescu (Univ. Illinois, Chicago, Univ. Wyoming, Laramie), J. Joiner (614), and L. Anderson (USGS)

2.3.8. Simulation of the OMI Aerosol Index Using GSFC Earth-Observing System Aerosol Reanalysis Products

The Ozone Monitoring Instrument (OMI) on the NASA Aura spacecraft makes global measurements of the amounts of airborne particles called aerosols. Using the NASA Goddard Earth Observing System (GEOS-5) global model (MERRAero), we simulated the reflected light OMI would have observed. Using this synthetic signal as an input to the OMI aerosol algorithms (OMAERUV), we investigated the impacts of assumptions built into those algorithms. Here, for example, we show a systematic error in the OMI aerosol index (AI, a measure of aerosol amount) due to the algorithmic assumption that the atmospheric surface pressure does not change in time. When the algorithm is forced to use the MERRAero (observed) surface pressure, the error in the AI is significantly reduced.

The use of a global aerosol model to simulate the satellite observed signal provides a powerful tool for designing new missions and testing algorithms. In this particular study, we investigated two aspects of the OMI aerosol algorithms, particularly the surface pressure assumption illustrated in the Figure and, subsequently, the assumptions made in how the algorithm handles its radiative transfer calculation. This study suggested two concrete recommendations to improve the aerosol products from OMI: (1) use actual surface pressures from meteorological analyses in deriving their products; and (2) use a higher resolution lookup table of precomputed radiative properties of the atmosphere in generating products. Both of these improvements will improve the quality of the aerosol products in the future. This same kind of tool has been applied observations from the MODIS instrument, among others, and forms the basis for a number of efforts using the GEOS-5 model to inform design and algorithm strategies for future Earth science space missions.

P. Colarco (614), S. Gassó (613, MSU), C. Ahn (614, SSAI), V. Buchard (610.1, USRA), A. da Silva (610.1), and O. Torres (614)

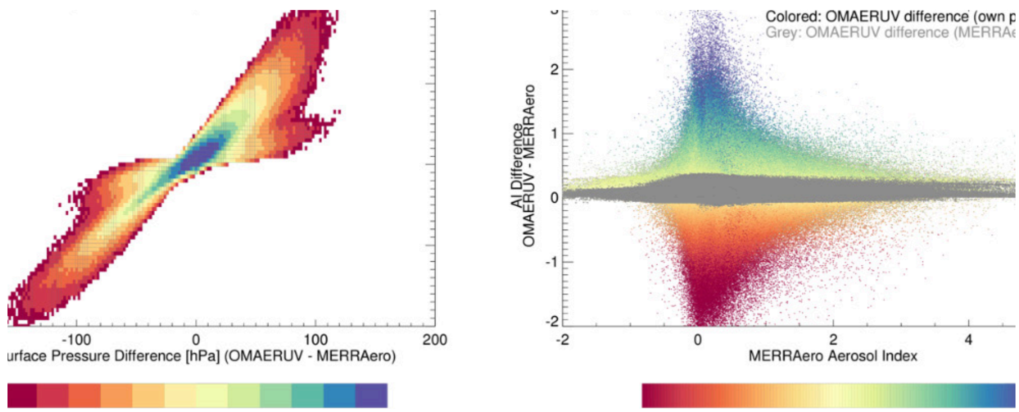

Figure 2.17: (Left): Shown in a joint-PDF histogram of the difference in the OMI aerosol index directly computed from the GEOS-5 model results (MERRAero) versus the aerosol index returned by the OMI aerosol algorithms (OMAERUV) (left axis) as a function of the difference between the surface pressure from MERRAero (based on actual, observed meteorology) and assumption of a time invariant surface pressure used in the OMAERUV algorithms (bottom axis). (Right): Essentially the same data is presented here, but now sorted to show how the error in the aerosol index (left axis) is related to the real aerosol index (as simulated by MERRAero, bottom axis). Individual pixels are colored by the surface pressure error.

2.3.9. OWLETS: Fostering GSFC Ground Network Growth and Student Involvement

During Ozone Water-Land Environmental Transition Study (OWLETS) 2017, lidars and passive sensors were deployed to Hampton Roads, Virginia, region to characterize land-water gradients in ozone. In support of SARPE, the Sherpa provided detailed chemical observations, including several direct transects between sites. The monitoring of ozone in the troposphere is of pronounced interest due to its known toxicity and health hazard as a photochemically generated pollutant. One of the major difficulties for the air-quality modeling, forecasting, and satellite communities is the validation of O_3 levels in sharp transition regions, as well as near-surface vertical gradients. Land-water gradients of O_3 near coastal regions can be large due to differences in surface deposition, boundary layer height, and emission sources. Observations in horizontal and vertical directions over the Chesapeake Bay are needed to better understand O_3 formation and redistribution within regional recirculation patterns. The OWLETS campaign has exploited available GSFC (Code 614/618) ground-based networks (e.g. TOLNet, Pandora, Aeronet) to provide a framework for future collaborative investigations and provide a novel validation platform. This combination of observations has provided a unique 4-D (horizontal, vertical, and time) view of O_3 to help provide feedback to air-quality forecast models as well as future satellite remote-sensing systems such as NASA's TEMPO and GeoCAPE missions.

J. Sullivan (614), T. Berkoff (LaRC), G. Wolfe (614, UMBC), R. Swap (614), T. Hanisco (614), T. McGee (614) and S. Janz (614)

2.3.10. Ozone Hole 2017: The Low is High

The Antarctic Ozone hole was not very deep in 2017. Minimum ozone measured by the Suomi NPP OMPS Total Column Mapper on October 9th was 131 Dobson Units, a higher low than we have seen since the 1980's. Is this a sign of ozone recovery or just unusual dynamics in the south polar region? The surprise of the extremely low ozone measurement in the Antarctic in the 1980's led directly to the Montreal Protocol and a NASA emphasis on understanding stratospheric ozone. NASA's TOMS ozone mapping instruments were used to monitor the development of the ozone hole each year. Research showed that high levels of chlorine from CFCs led to very low ozone in the 1990–2001 period. While we now expect ozone recovery as stratospheric chlorine levels drop, the dynamics of the polar vortex can strongly affect the development of the ozone hole, and an injection of volcanic aerosols can intensify the development. While the higher "low ozone" observed in the ozone hole in 2017 may be a sign of recovery, careful observations and analysis are required to make such a conclusion.

R. McPeters (614) and C. Seftor (614, SSAI)

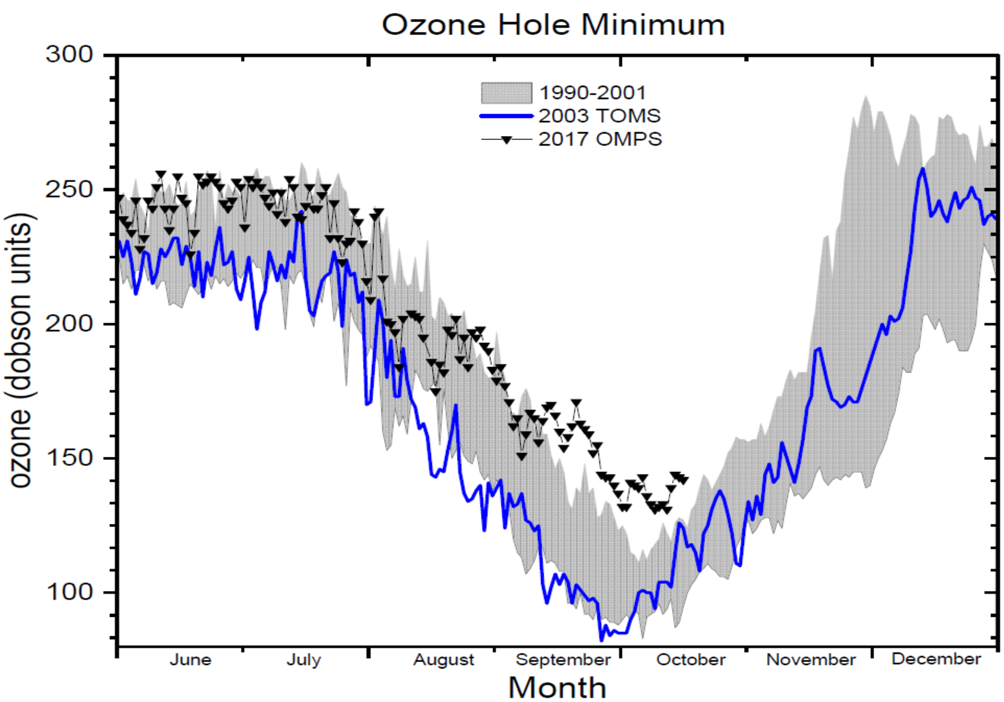

Figure 2.18: Daily minimum ozone in the south polar region for 2017 is compared with the very low ozone measured by Earth Probe TOMS in 2003. The shaded region shows the range observed between 1990 and 2001 when ozone destruction was near maximum.

2.3.11. India Is Overtaking China as the World's Largest Emitter of Anthropogenic SO_2

Severe haze has become an important public health issue in India and China, causing an estimated over 1 million premature deaths each year. Both countries rely heavily on sulfur-rich coal as an energy source to fuel their fast-growing economies. The resulting emissions of SO_2, a toxic pollutant gas, lead to production of sulfate aerosols that reduce visibility and adversely affect human health. Accurate information on the sources of SO_2 and other pollutants is needed for predicting and mitigating air pollution. For India and China, such information has been difficult to obtain, due to incomplete or outdated knowledge of emission sources. Here, we demonstrate that OMI data can provide "top-down" constraints on SO_2 emissions. We show that China and India are on opposite trajectories in terms of SO_2 pollution. Since 2007, SO_2 emissions in China have declined by 75 percent due to effective pollution control. Meanwhile, SO_2 emissions in India have increased by 50 percent due to increased production and continued lack of control. As a result, India is now becoming the world's top emitter of anthropogenic SO_2. Our results highlight the value of long-term, consistent satellite observations in detecting changes in global and regional environment.

C. Li (614, UMD), C. McLinden (614), V. Fioletov (614), N.Krotkov (614), S. Carn, J. Joiner (614), D. Streets, H. He, X. Ren, Z. Li, R. Dickerson

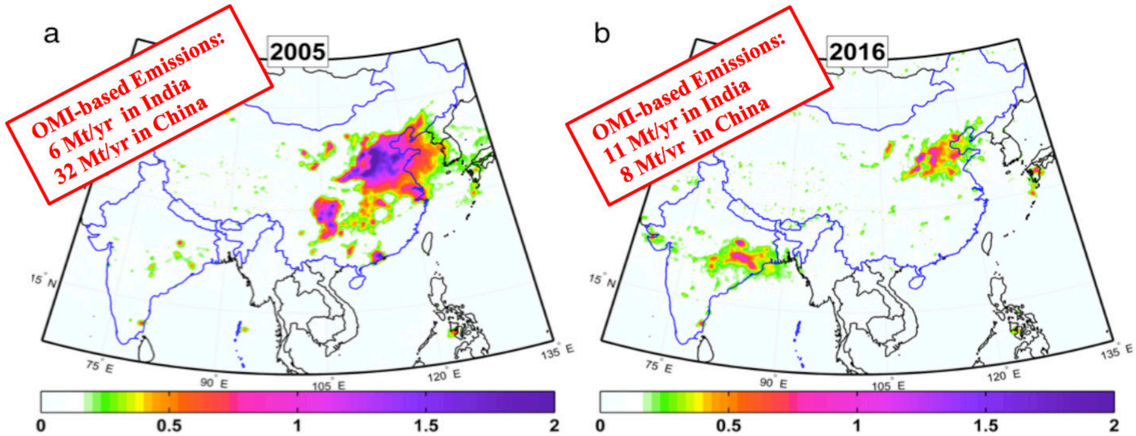

Figure 2.19: OMI anthropogenic SO_2 data, produced with an advanced principal component analysis algorithm, reveal significant increases in SO_2 pollution over India and decreases over China from 2005 to 2016.

- *OMI-based, top-down estimates of annual SO_2 emissions from the two countries indicate that India is becoming the top emitter of anthropogenic SO_2 in the world, a development largely unexpected in recent bottom-up projections.*
- *Comparison of estimated emissions with coal consumption suggests that effective controls of SO_2 pollution in China remove ~80% of potential sulfur emissions. There is a continued lack of emission controls in India.*

2.3.12. New Concerns for Ozone Recovery

As a result of successful regulation by the Montreal Protocol, atmospheric halogen concentrations have been decreasing since the 1990s. Recent observations show rising emissions of some regulated and unregulated ozone-depleting substances, which may delay the recovery of stratospheric ozone. The individual impacts of these issues are small, but their combined effect will decrease the Antarctic total column ozone by ~10% between 2050 and 2100, posing a substantial concern. Unregulated, manmade ozone-depleting substances, incomplete compliance with the Montreal Protocol, and climate change present emerging concerns for ozone layer recovery. The main sources of atmospheric reactive halogens are the long-lived synthetic chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), carbon tetrachloride (CCl_4), methyl chloroform (CH_3CCl_3), and bromine-containing halons—all of which persist in the atmosphere for many years. These ozone-depleting substances are now controlled under the Montreal Protocol and its amendments. Natural methyl bromide (CH3Br) and methyl chloride (CH_3Cl) emissions are also important long-lived sources of atmospheric reactive halogen. Recent research has highlighted rising concentrations of very-short-lived substances (VSLSs) with atmospheric lifetimes of less than half a year and their potential contribution to future stratospheric ozone depletion. A greater concern to ozone recovery is incomplete compliance with the Montreal Protocol, which will impact stratospheric ozone for many decades, as well as rising natural emissions as a result of climate change.

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2.4. Wallops Field Support Office

The Wallops Field Support Office (Code 610.W) supports the Earth science research activities of Code 600 scientists at the Wallops Flight Facility. The Office also conceives, builds, tests, and operates research sensors and instruments at both Wallops and remote sites. Scientists in the Office use radars, aircraft, balloons, *in situ* and laboratory instruments, autonomous surface vehicles, and satellite platforms to participate in the full complement of Earth science research activities. These activities include measurements, retrievals, data analysis, model simulations, and calibration/ validation. Office personnel collaborate with other scientists and engineers across Goddard and other NASA centers as well as universities, and other government agencies, locally, nationally and internationally. The Office has provided instrumentation and scientific research expertise to several NASA missions and field efforts in 2017.

2.5. Atmospheric Science

- Maintain the GPM Wallops Precipitation Research Facility
- Participated in the International Collaborative Experiment – Pyeongchang Olympics and Paralympics (ICE-POP) 2018 field campaign (Winter 2017–2018)
- Shipment of Particle Imaging Processor (PIP), Multi-Rain Radar (MRR), Autonomous Parsivel Unit (APU disdrometer) and D3R to South Korea to support ICE-POP 2018 and the 2018 Winter Olympics.
- PIP deployment and execution in Colorado (Snowex 2017) and Barrows, Alaska.
- Development of a high-resolution snow site in Marquette, Michigan containing PIP and APU disdrometers, and twelve Pluvio snow gauges.
- GPM passed its End-of-Prime Review

2.6. Cryospheric Science

- Airborne Topographic Mapper Summer Arctic deployment in Operation IceBridge March thru July 2017 (6 missions)
- Airborne Topographic Mapper Antarctic deployment in Operation IceBridge November 2017 (11 missions)
- Airborne Topographic Mapper Antarctic deployment in Operation IceBridge March 2018

2.7. Ocean Science

- Submitted proposal to The Science of TERRA, AQUA and SOUMI NPP, entitled "Improving Satellite Ocean Color Algorithms Using Bootstrapped Genetic Programming."
- Participating on EVS proposal with W. Petersen (MSFC).
- Submitted manuscript "Satellite Sensor Requirements for Monitoring Essential Biodiversity Variables of Coastal Ecosystems" to "Genetic Programming for Ocean Microbial Ecology and Biodiversity" to the *Ecological Applications Journal*.

2.8. Unmanned/Remotely Operated Vehicles

- AEROKATS and ROVER Education Network (AREN) as supported by SMD Cooperative Agreement
- Instrumentation support for VEREX2 tethered blimp experiment at Kilauea volcano in support of HyspIRI
- Technical Monitor for BlackSwift Technologies Soil Moisture sUAS SBIR Civil Commercial Readiness Pilot Program (CCRPP)

3. MAJOR ACTIVITIES

3.1. Missions

Science plays a key role in the Earth Science Atmospheric Research Laboratories, which involves the interplay between science and engineering that leads to new opportunities for research through flight missions. Atmospheric research scientists actively participate in the formulation, planning, and execution of flight missions and related calibration and validation experiments. This includes the support rendered by a cadre of project scientists who are among the most active and experienced scientists in NASA. The following sections summarize mission support activities that play a significant role in defining and maintaining the broad and vigorous programs in Earth science. As shown, the impact of atmospheric sciences on NASA missions is profound.

3.1.1. Future Mission Studies

3.1.1.1 GEO-CAPE

Geostationary Coastal and Air Pollution Events (GEO-CAPE) is one of the missions recommended by the National Research Council's Decadal Survey, with the goal of measuring atmospheric pollution (aerosols and trace gases) and coastal water from a geostationary platform. Scientists in Codes 613 and 614 have been involved in GEO-CAPE atmospheric studies for several years, including defining science objectives, measurement requirements, retrieval accuracy, retrieval sensitivity, etc. In FY 2017, Goddard scientists involved in GEO-CAPE's Aerosol Working Group have focused on the following tasks: (1) testing the aerosol retrieval algorithms with the geostationary satellite data from the Himawari (a Japanese satellite over Asia) and from the NOAA GOES-16 (over the US), (2) assessing the air quality application values of geostationary satellite AOD measurements with the examination of the existing temporal co-variability of AOD and PM2.5 data over the United States and Asia, and (3) evaluating AOD products from MODIS Dark Target, Deep Blue, and MAIAC algorithms as well as the OMI UV algorithm to assess the potential of using these algorithms (combined or stand-alone) for TEMPO/GOES-16 synergistic retrievals. The outcome was reported to the GEO-CAPE leadership and NASA HQ and will be presented at the upcoming GEO-CAPE and CEOS workshop in late April to early May 2018.

For further information, please contact Mian Chin (mian.chin@nasa.gov).

3.1.1.2 ASCENDS

The Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission, recommended by the NRC's *2007 Earth Science Decadal Survey,* is considered the technological next step in measuring CO_2 from space following deployment of passive instruments such as the Japanese Greenhouse gases Observing Satellite (GOSAT, 2009) and the NASA Orbiting Carbon Observatory re-flight (OCO–2, 2014). Using an active laser measurement technique, ASCENDS will extend CO_2 remote-sensing capability to include uninterrupted coverage of high-latitude regions and nighttime observations with sensitivity in the lower atmosphere. The data from this mission will enable investigations of the climate-sensitive Southern Ocean and permafrost regions, produce insight into the diurnal cycle and plant respiration processes, and provide useful new constraints for global carbon cycle models. NASA currently plans for launch not earlier than the FY 2023 timeframe. The ASCENDS mission white paper is available at https://cce.nasa.gov/ascends_2015/ASCENDS_FinalDraft_4_27_15.pdf.

The Atmospheric Chemistry and Dynamics Laboratory supports ASCENDS through technology development, analysis of airborne simulator data, instrument definition studies, and carbon cycle modeling and analysis. Lab members are engaged in CO_2 instrument development and participate on technology projects in collaboration with the Laser Remote-sensing Laboratory, which targets instrument and mission development for ASCENDS. The laboratory plays a key role in radiative transfer modeling, retrieval algorithm development, instrument field deployment, and data analysis to develop a laser spectrometric instrument for ASCENDS. Based on experience and knowledge of carbon cycle science, they actively help to keep the technology development on track to best achieve the science objectives for ASCENDS.

They also support the ASCENDS flight project by performing observing system simulations to establish science measurement requirements and to evaluate the impact of various mission technology options.

For further information, please contact S. Randolph Kawa (stephan.r.kawa@nasa.gov) or see the NASA ASCENDS Web site: http://decadal.gsfc.nasa.gov/ascends.html.

3.1.1.3 TROPICS

The Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission was selected as part of the Earth Venture Instruments–3 solicitation. TROPICS is led by William Blackwell of MIT/Lincoln Laboratory. Scott Braun (612) is the project scientist. TROPICS will provide rapid-refresh (~40-minute median refresh rate) microwave measurements over the Tropics to observe the thermodynamic environment and precipitation structure of tropical cyclones over much of their lifecycle. TROPICS comprises 6 CubeSats in three ~550-km altitude, 30°-inclination orbital planes for at least one year. TROPICS funds will cover the project scientist, data assimilation work in the Global Modeling and Assimilation Office, and research on moisture impacts on the precipitation structure and the intensity of storms.

For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

Table 3.1: Mission Study Scientists

Name	Mission
Randy Kawa	ASCENDS
Mian Chin	GEO-Cape
Scott Braun	TROPICS

3.1.2. NASA-Planned Missions

3.1.2.1 JPSS-1

The Joint Polar Satellite System (JPSS) is the Nation's next-generation polar-orbiting operational environmental satellite system. JPSS is a collaborative program between NOAA and its acquisition agent, NASA. JPSS was established in the President's FY 2011 budget request (February 2010) as the civilian successor to the restructured National Polar-orbiting Operational Environmental Satellite System (NPOESS). As the backbone of the global-observing system, JPSS polar satellites circle the Earth from pole-to-pole and cross the equator about 14 times daily in the afternoon orbit—providing full global coverage twice a day.

JPSS represents significant technological and scientific advances in environmental monitoring and will help advance weather, climate, environmental, and oceanographic science. JPSS will provide operational continuity of satellite-based observations and products for NOAA Polar-orbiting Operational Environmental Satellites (POES) and the Suomi National Polar-orbiting Partnership (Suomi NPP) mission. NOAA is responsible for managing and operating the JPSS program, while NASA is responsible for developing and building the JPSS spacecraft. In 2017, the JPSS program continued its mission to support the operations of Suomi NPP. The JPSS program provides three of the five instruments, the ground system, and post-launch satellite operations to the NPP mission. Suomi NPP observatory operations were successfully transferred from the JPSS program to the NOAA Office of Satellite and Product Operations in February 2013.The JPSS 1 mission launched on November 18, 2017 from Vandenburg Air Force Base in California.

The J1 mission is very similar to Suomi NPP, using the same spacecraft and a nearly identical instrument complement. In late November 2017, the J1 ATMS instrument sent the first science data back to NOAA and the satellite was renamed as NOAA-20. The JPSS-2 spacecraft Critical Design Review was held in October 2107. The Polar Follow-on Program was approved, continuing the polar observation program with planned launches of JPSS-3 and JPSS-4 in 2026 and 2031. The JPSS-2, JPSS-3, and JPSS-4 missions will have the same spacecraft and similar instruments to Suomi NPP, VIIRS, CrIS, ATMS, and OMPS. The Cloud and Earth Radiant Energy System (CERES) instrument, on SNPP and J1, will be replaced with a successor NASA instrument, the Radiation Budget Instrument (RBI).

For further information, please contact James Gleason (james.gleason@nasa.gov).

3.1.2.2 TSIS-1

The main objective of the Total and Spectral solar Irradiance Sensor (TSIS) is to acquire solar irradiance measurements to monitor effects of solar radiation on climate. The TSIS total solar irradiance measurements will extend a multi-decadal uninterrupted record of incoming solar radiation, the dominant energy source driving the Earth's climate and the most precise indicator of solar energy input to Earth's system. TSIS solar spectral irradiance measurements will be used to determine the regions where solar energy is deposited in Earth's atmosphere and how this energy distribution drives atmospheric circulation and affects important gas species such as ozone. TSIS includes two instruments: the Total Irradiance Monitor (TIM) and the Spectral Irradiance Monitor (SIM), integrated into a single payload. The TSIS TIM and SIM instruments are upgraded versions of the two instruments that are flying on the Solar Radiation and Climate Experiment (SORCE) mission launched in January 2003.

TSIS-1 was launched to International Space Station (ISS) on December 15, 2017. Its instruments, the TIM and SIM, have been installed on ISS ExPRESS Logistics Carrier (ELC)-3 site 5. TSIS routine operation for solar irradiance observations begins in early 2018. The nominal mission lifetime is five years.

For further information, please contact Dong Wu (dong.l.wu@nasa.gov).

3.1.3. NASA-Active Missions

3.1.3.1 Terra

For more than 18 years, the Terra mission has been providing the worldwide scientific community with unprecedented 81 core data products making a significant contribution to all of NASA's Earth Science focus areas. These core data products are currently used for: air quality mapping by the EPA (MODIS, MISR); volcanic ash monitoring for the FAA (ASTER, MISR, MODIS); weather forecasting through NESDIS (MODIS, MISR, CERES); forest fire monitoring for resource allocation by U.S. Forest Service

(ASTER, MODIS, MISR); and carbon management and global crop assessment by USDA and USDA-FAS (MODIS, CERES). After 18 years of continuous operation, the project office has coordinated closely with the science and engineering team to advocate that the EOS science to maintain a strong Terra program.

For further information, please contact Si-Chee Tsay (si-chee.tsay-1@nasa.gov).

3.1.3.2 Aqua

Aqua is one of NASA's flagship missions for Earth Science operating in the A-Train constellation. It launched on May 4, 2002, and is still going strong after with four of its instruments (AIRS, AMSU, CERES, and MODIS) continuing to collect valuable data at an approximate rate of 88 Gbytes/day about the atmosphere, oceans, land, and ice. Aqua observations span almost all fields of Earth science—from trace gases, aerosols and clouds in the atmosphere to chlorophyll in the oceans to fires on land to the global ice cover and numerous other geophysical variables. Thousands of scientists from around the world use Aqua data to address NASA's six interdisciplinary Earth science focus areas: atmospheric composition, weather, carbon cycle and ecosystems, water and energy cycle, climate variability and change, and Earth surface and interior. In addition to reminding the community about practical applications such as monitoring drought, crop yields, fires, and air quality, the Aqua 2017 Senior Review proposal highlighted numerous recent scientific accomplishments made possible by Aqua measurements, including: (1) identification of discrepancies between modeled and observed surface radiation budgets in the Arctic; (2) identification of a positive solar radiation feedback from tropical low clouds; (3) creation in conjunction with earlier satellite datasets of a consistent 36-year sea surface temperature record extending back to 1981 and a consistent 18-year ocean chlorophyll concentration record extending back to 1998; (4) generation of the first global maps of convectively-generated concentric gravity waves, showing that they are far more frequent than previously realized. The completion of the 2017 Senior Review process found the Aqua mission ranked very highly by the panel and with a recommendation for continuation thanks to its high-quality climate data records, its critical role in the continuity of many geophysical time series, and the high utilization of its datasets by government agencies and the international operational user community.

For further information, please contact Lazaros Oreopoulos (Lazaros.Oreopoulos@nasa.gov).

3.1.3.3 Aura

On July 15, 2004, the Aura spacecraft was launched with four instruments to study the composition of Earth's atmosphere. The Ozone Monitoring Instrument (OMI), Microwave Limb Sounder (MLS), High-Resolution Dynamics Limb Sounder (HIRDLS), and Tropospheric Emission Spectrometer (TES) make measurements of aerosols, clouds, and ozone (O_3) and constituents related to O_3 in the stratosphere and troposphere. With these measurements the science team has addressed questions concerning the Antarctic Ozone Hole and the stratosphere's protective O_3 layer (OMI, MLS), and tropospheric composition and air pollution (OMI, TES). Thirteen years have passed since launch, and two of the instruments (OMI, MLS) continue to make daily measurements. HIRDLS suffered an anomaly in 2008 and is no longer operational. The present TES observing strategy is designed to make good use of the limited remaining life of the instrument, focusing on air pollution in "megacities" such as Mexico City, Mexico, and Lagos, Nigeria.

OMI data continue to be used to monitor global air pollution trends, determine the efficacy of mitigation control strategies, and estimate emissions. In 2017, they showed intriguing trends in air pollution in many world regions. For instance, one analysis found that pollutant levels of sulfur dioxide (SO_2), which contributes to acid rain and haze, have decreased dramatically in China with the installation of emission control devices on coal-burning power plants, the primary source of SO_2. In fact, the study found that

India is now overtaking China as the world's largest emitter. These trends will likely continue in 2018 as India continues to build new power plants. Additionally, the data are being increasingly used for studies of the impact of poor air quality on human health since the spatial coverage afforded by satellite data offers increased statistical power that strengthens inference of the relation between pollutants and health outcomes. OMI total column O_3 data are used to assess the health impact of ultraviolet radiation exposure and OMI nitrogen dioxide (NO_2) data for NO_2 exposure. NO_2 is a pollutant that causes respiratory distress and is emitted from the tailpipes of cars and the smokestacks of power plants. It contributes to the formation of unhealthy O_3 levels at Earth's surface. In 2017, OMI data of formaldehyde (HCHO), an air toxic, were used to estimate that 6,600–13,200 people in the United States will develop cancer over their lifetimes by exposure to outdoor HCHO. The primary source of HCHO is from the chemical oxidation of volatile organic compounds emitted naturally from trees.

In 2017, the long data record of Aura observations is central to understanding atmospheric composition in the upper troposphere and lower stratosphere. For example, long-term observations are necessary to show that the Ozone Hole is slowly recovering. Observations of O_3, hydrochloric acid (HCl) and nitrous oxide (N_2O) show that reactive chlorine (Cly) within the Antarctic polar vortex (responsible for the annual formation of the Antarctic Ozone Hole) has decreased since Aura's launch in response to the cessation of production of chlorofluorocarbons (source gases for Cly) as mandated by the Montreal Protocol and its amendments. A novel analysis capitalizes on the rapid conversion of all Cly to HCl once O_3 falls to very low values and uses the N_2O to account for dynamic variability. It links the Cly level to the amount of O_3 destroyed during July and August as determined from MLS O_3. A second example that requires the long data record obtained from MLS focuses on the Asian summer monsoon. This analysis exploits (1) the insensitivity of MLS to aerosol and most clouds, and (2) the spatial and temporal variations in tropospheric gases (H_2O, CO, CH_3Cl, CH_3CN, CH_3OH) and stratospheric gases (O_3, HNO_3, HCl) to produce the first climatology of the composition of the Asian summer monsoon throughout its lifecycle.

More information on Aura science highlights can be found at http://aura.gsfc.nasa.gov/ or contact Aura's Project Scientist, Bryan Duncan (bryan.n.duncan@nasa.gov).

3.1.3.4 DSCOVR

Deep Space Climate Observatory (DSCOVR) is a NOAA Earth observation and space weather satellite launched by SpaceX on February 11, 2015, from Cape Canaveral. The mission is a partnership between NOAA, NASA and the U.S. Air Force. NOAA operates the DSCOVR mission, to provide advanced warning of approaching solar storms with the potential to cripple electrical grids, communications, GPS navigation, air travel, satellite operations and human spaceflight. DSCOVR is positioned at the Sun-Earth first Lagrangian point (L1), about 1,500,000 km from Earth with the primary goal of monitoring variable solar wind condition and providing early warning of approaching coronal mass ejections. The satellite orbits the L1 point in a six-month Lissajous orbit, with a spacecraft-Earth-Sun angle varying from 4 to 12 degrees (Fig. 3.1). While the primary science objectives of DSCOVR are to make unique space weather measurements, the secondary goal of DSCOVR is to provide unique Earth and surface measurements.

There are two NASA Earth Science Instruments onboard the DSCOVR satellite: the Earth Polychromatic Imaging Camera (EPIC) (see https://epic.gsfc.nasa.gov/epic) and the National Institute of Standards and Technology Advanced Radiometer (NISTAR) (see, https://www.nasa.gov/content/goddard/noaas-dscovr-nistar-instrument-watches-earths-budget/). EPIC provides spatially resolved radiances from the sunlit face of the Earth on a 2048 x 2048-pixel CCD in 10 narrowband channels between UV (317 nm), and near-IR (780 nm) with a nadir sampling field-of-view of approximately 8 km at the center of the image with an effective resolution of 10 x 10 km2 for the 443 nm channel and 18 x 18 km2 for the other 9 filter channels.

The time cadence of these spectral band images is provided on a best effort basis given existing ground system and network capabilities and is no faster than one set of 10 spectral-band images approximately every hour (from mid-April to mid-October) or every two hours (during the rest of the year). The DSCOVR project provides raw instrument data, EPIC Level-1 images in CCD counts/second (C/s) that are geolocated on a common grid, and corrected for both dark-current and stray-light. Calibration conversions from C/s to reflectance are given based on the most recent in-flight calibration data. True-color (RGB) images are generated daily and are available at http://epic.gsfc.nasa.gov. As an example, Fig. 3.2 provides two images: the famous Apollo 17 "blue marble" image and the EPIC image taken on the same day 44 years apart.

Major Activities NISTAR measures the absolute "irradiance" as a single pixel integrated over the entire sunlit face of the Earth in four broadband channels: (i) visible to far IR (0.2 to 100 mm); (ii) solar (0.2 to 4 mm); (iii) near-IR (0.7 to 4 mm); and (iv) photodiode (0.3 to 1 mm) used for validation.

The Level-1 EPIC and NISTAR products are publicly available from the NASA Langley Atmospheric Science Data Center (ASDC). The Earth Science instruments onboard DSCOVR provide sunrise to sunset observations of global ozone levels, amount and distribution of aerosols, dust and volcanic sulfur dioxide (SO_2) and ash, cloud height over land and ocean, spectral surface reflectance and vegetation cover; the instruments will monitor effects that indicate changes in climate including Earth radiation budget.

The first release of some Level 2 data products has been done in late 2017. Examples of such products (ozone, UV reflectivity, clouds, atmospherically corrected surface reflectance, aerosols and volcanic sulfur dioxide) are shown in Figures 3.3–3.7.

For further information, please contact Alexander Marshak (alexander.marshak-1@nasa.gov).

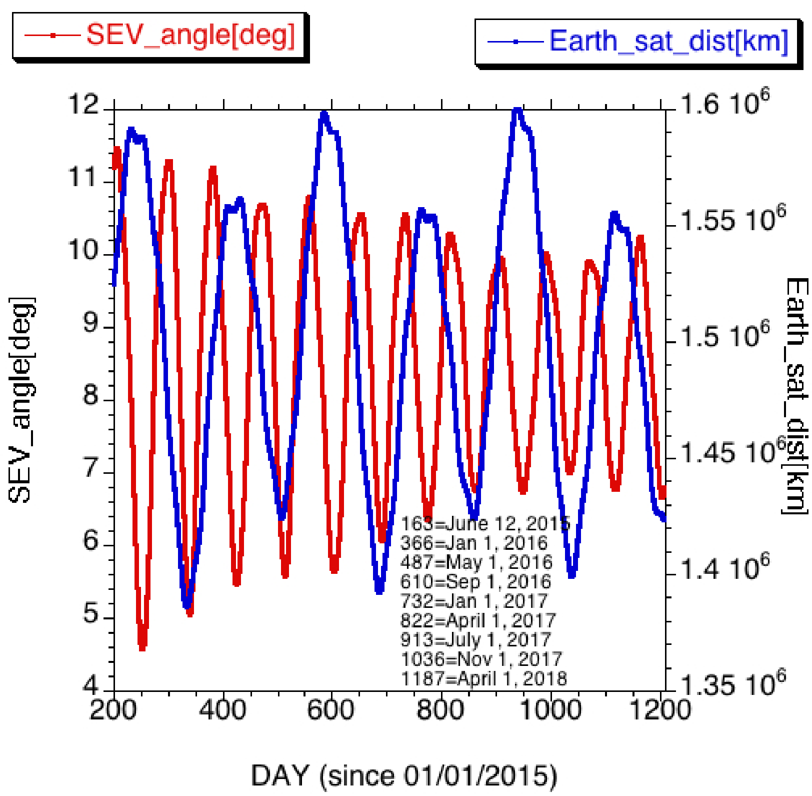


Figure 3.1: Sun Earth Vehicle (SEV) angle (left axis, red curve) and the distance between DSCOVR and Earth (right axis, blue curve) are plotted versus the day since January 1, 2015. Note that SEV = 180° minus the scattering angle between solar and viewing directions.

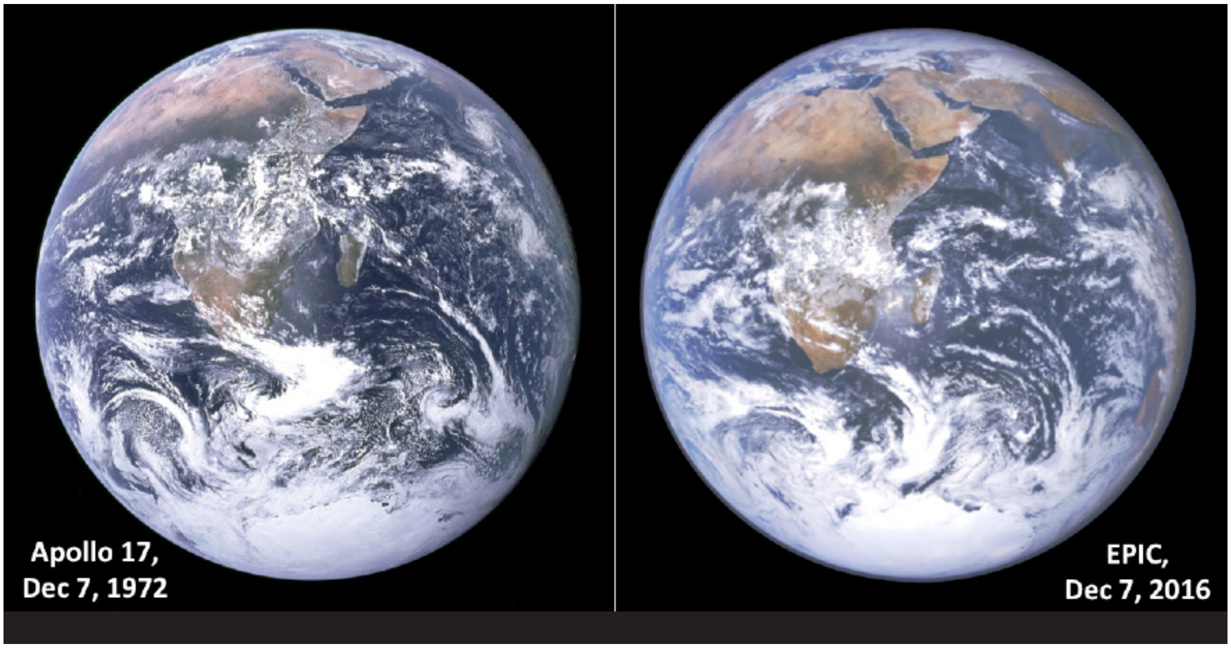


Figure 3.2: Apollo 17 ("blue marble") and DSCOVR EPIC images acquired on December 7, 1972 and 2016, 44 years apart.

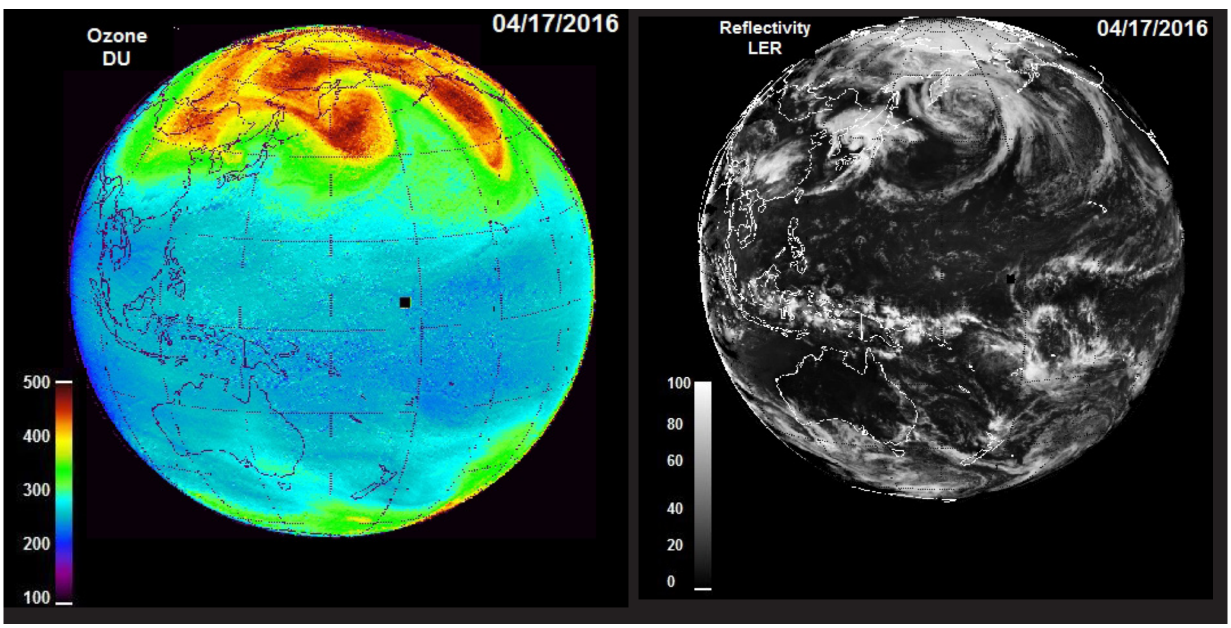


Figure 3.3: The ozone (left) and scene reflectivity (right) products obtained at 00:34 GMT on April 17, 2016. Local time varies across the image with sunrise on the left (west) and sunset on the right (east). The reflectivity gives the cloud transmission of UV radiation permitting a calculation of the amount of UV radiation reaching the ground when combined with ozone absorption. Notice the large ozone plumes flowing from the Arctic to lower latitudes. (Courtesy of Jay Herman).

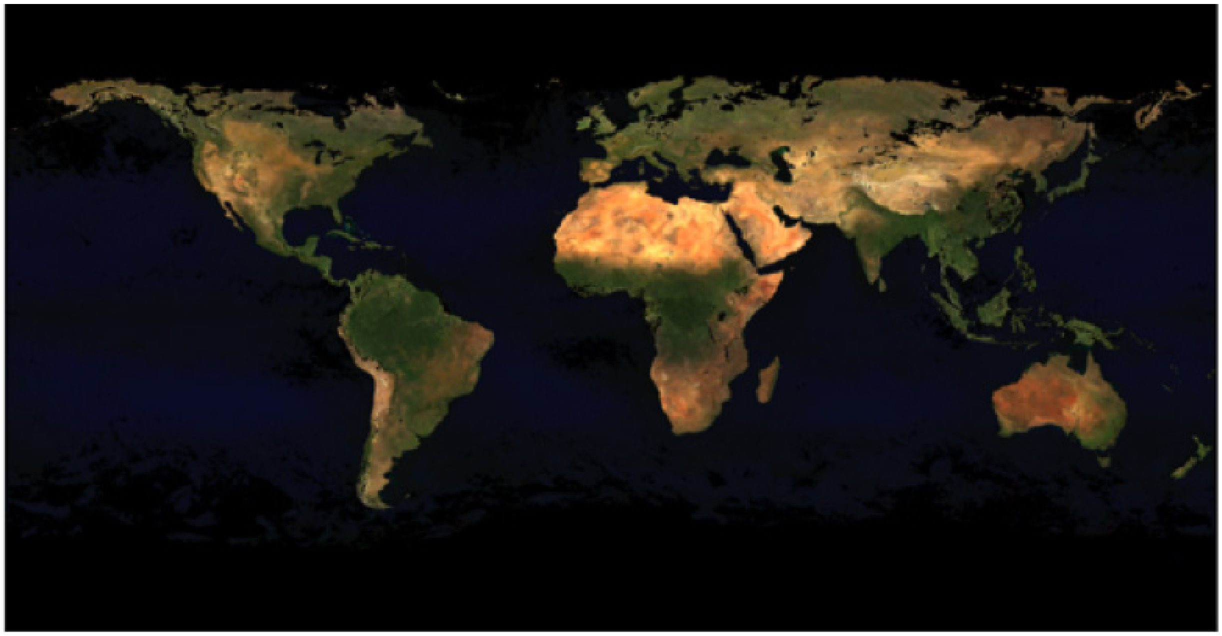


Figure 3.4: Sample EPIC cloud products for the observations at 14:57 GMT on June 23, 2016: (a) EPIC RGB image. (b) EPIC cloud mask 1: High-confidence clear, 2: Low-confidence clear, 3: Low-confidence cloudy, and 4: High-confidence cloudy. (c) O_2 A-band cloud effective pressure. (d) Cloud optical thickness assuming liquid phase. (e) Cloud optical thickness assuming ice phase. (f) Most likely cloud phase. (Courtesy of Yuekui Yang).

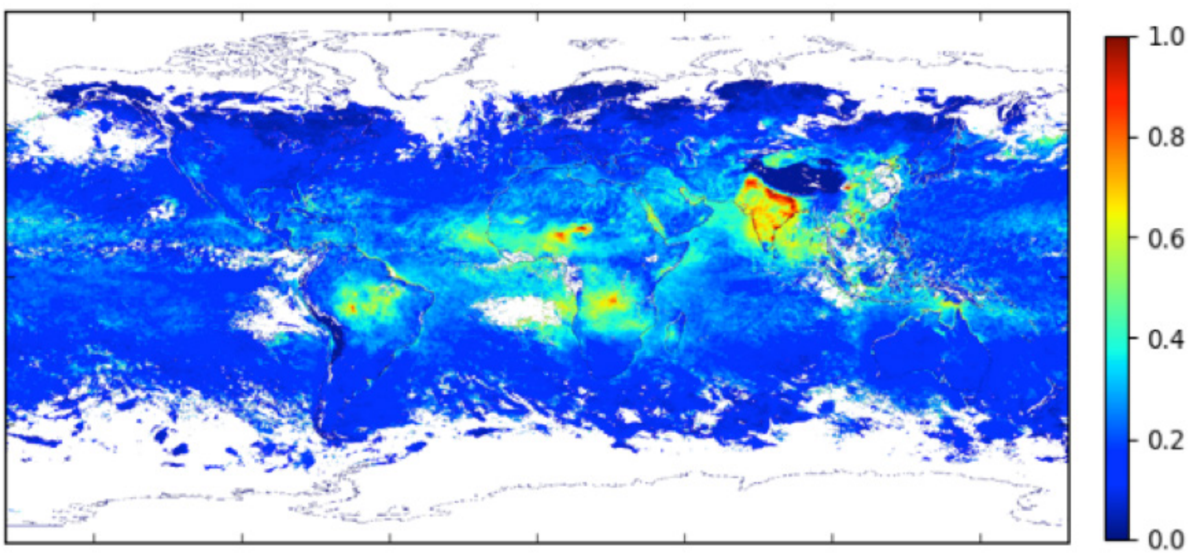


Figure 3.5: Atmospheric correction for EPIC observations in October 2016. Shown in rows are monthly composites of: atmospherically corrected RGB surface reflectance (BRF), aerosol optical thickness (AOT) at 443 nm, and normalized difference vegetation index (NDVI). Color scale for RGB BRF was reduced to emphasize accuracy of atmospheric correction over dark vegetation. (Courtesy of Alexei Lyapustin and Dong Huang).

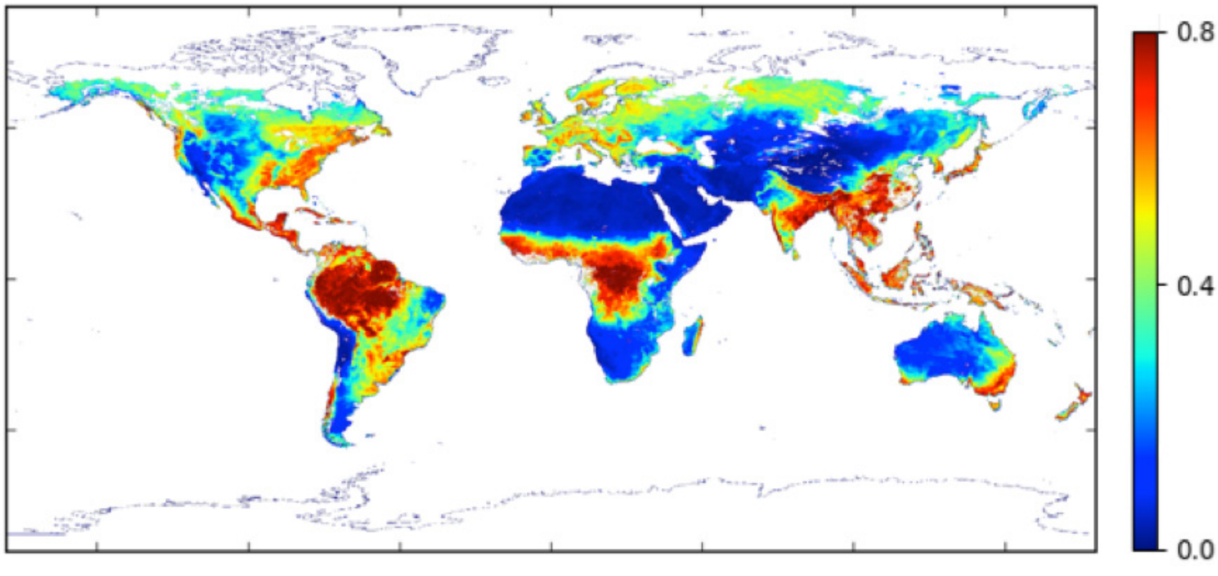


Figure 3.6: EPIC-DSCOVR view, in terms of UV Aerosol Index, (UVAI) of an unprecedented PYROCB cloud from fires in Western Canada in August 2017. The UVAI is calculated from EPIC observations at 340 nm and 388 nm. The carbonaceous aerosol layer reached the stratosphere and was observed for several months after injection. The EPIC three-day sequence shows the aerosol layer mobilization a few days after formation. The unusually high UVAI values are a combination altitude (above 14 km) and very high optical depth (larger than 3.0) (Courtesy of Omar Torres).

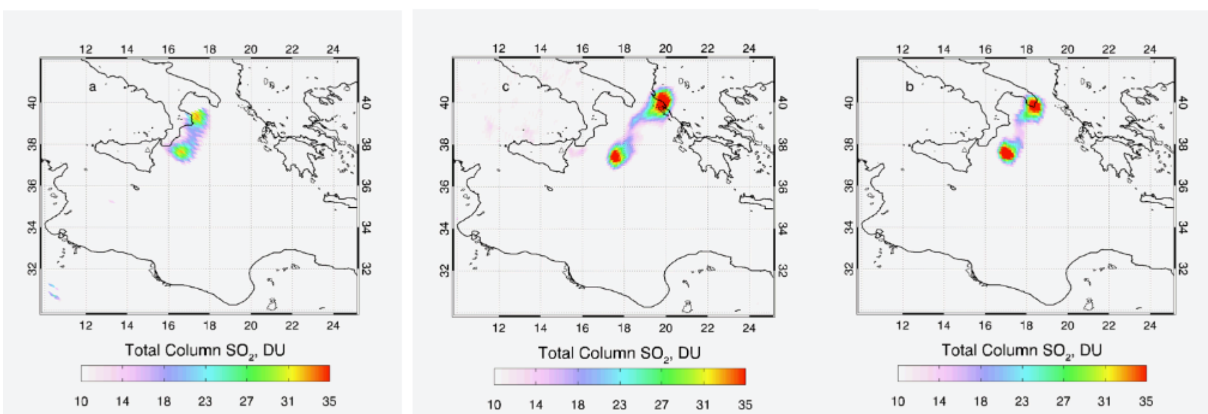


Figure 3.7: EPIC volcanic sulfur dioxide (SO_2) maps for the December 3, 2015 eruption of Etna volcano (Sicily, Italy; triangle). SO_2 in the Etna volcanic cloud was detected in three consecutive EPIC exposures at (a) 08:16 UTC; (b) 10:04 UTC; (c) 11:52 UTC showing volcanic SO_2 cloud movement with eastward wind toward Greece. EPIC measures total column amount of SO_2 gas above surface (or underlying clouds) in Dobson Units (Courtesy of Nick Krotkov).

3.1.3.5 GOES

NOAA's Geostationary Operational Environmental Satellites (GOES) are built, launched, and initialized by Goddard's GOES Flight Project Office under an interagency program hosted at Goddard (http://www.goes-r.gov/). The GOES series of satellites carry sensors that continuously monitor the Earth's atmosphere for developing planetary weather events, the magnetosphere for space weather events, and the Sun for energetic outbursts. The flight project scientist at Goddard assures the scientific integrity of the GOES sensors throughout the mission definition, design, development, testing, and post-launch data-analysis phases of each decade-long satellite series. The first satellite in the latest GOES-R series launched in November 2016. Five new and improved instruments were operated during 2017 at the post-launch test location above the Gulf of Mexico at 89.5°W. The satellite was moved to 75.2°W in December 2017, where it became operational as NOAA's GOES-East satellite.

A NOAA GOES-R validation campaign was conducted from March 13 to May 18, 2017, using the NASA ER2 aircraft and Goddard's ER2 Doppler radar (EXRAD), Cloud Radar System (CRS), and Cloud Profiling Lidar (CPL), along with other instruments. The first four weeks focused primarily on validation of the Advanced Baseline Imager (ABI) reflective solar band channels using measurements of the surface over the Sonoran Desert, while the latter portion of the campaign focused on validation of the Geostationary Lightning Mapper (GLM) within severe thunderstorms at various locations in the eastern half of the United States.

For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

3.1.3.6 SORCE

SORCE has been making daily measurements of Total Solar Irradiance (TSI) and Solar Spectral Irradiance (SSI) since March 2003. On July 30, 2013, SORCE went into its safe hold mode, which temporarily ceases science operations including the collection of TSI measurements. SORCE satellite's battery power declined to a level too low to maintain instrument power for solar observations. Following a five-month gap (August 2013–February 2014) in SORCE daily solar measurements, new flight software was developed by Orbital Sciences Corporation (OSC) and CULASP. The software was installed via uplink radio commands in time for a special campaign in the last week of December 2013 to ensure overlapping measurements between SORCE and TSI Calibration Transfer Experiment (TCTE)/ Total Irradiance Monitor (TIMs) launched in November 2013 on the Air Force's Operationally Responsive Space (ORS) Space Test Program Satellite3. Additional SORCE flight software, deployed in February 2014, enabled a "Day-Only Operations" (DOOp) mode to stabilize the battery substantially. There have not been any additional battery cell failures since July 2013, and the battery has been stable for more than two years. The DO-Op mode allows SORCE to make the solar observations during the daylight part of the orbit and then put itself into safe-hold every eclipse. Further improved flight software has been developed with the goal for SORCE to survive through the eclipse without battery power. It is expected that SORCE could operate in its DO-Op mode for several more years, to overlap with the Total and Spectral Solar Irradiance Sensor-1 (TSIS-1), which is currently scheduled to launch in December 2017 for operation on the International Space Station (ISS).

For further information, please contact the SORCE project scientist Dong Wu (dong.l.wu@nasa.gov).

3.1.3.7 Suomi NPP

The Suomi National Polar-orbiting Partnership (NPP) satellite was launched on October 28, 2011. NPP's advanced visible, infrared, and microwave imagers and sounders are designed to improve the accuracy of climate observations and enhance weather forecasting capabilities for the Nation's civil and military users of satellite data. Suomi NPP instruments include the Advanced Technology Microwave Sounder (ATMS), the Cross-track Infrared Sounder (CrIS), the Ozone Mapping and Profiler Suite (OMPS), the Cloud and Earth Radiant Energy System (CERES), and the Visible Infrared Imaging Radiometer Suite (VIIRS). The five sensors onboard Suomi NPP operate routinely, and the products are publicly available from the NOAA CLASS archive: http://www.class.noaa.gov/.

Suomi NPP is on track to extend and improve upon the Earth system data records established by NASA's Earth Observing System (EOS) fleet of satellites, whichhave provided critical insights into the dynamics of the entire Earth system: cloud, oceans, vegetation, ice, solid Earth, and atmosphere. Data from the Suomi NPP mission will continue the EOS record of climate-quality observations after EOS Terra, Aqua, and Aura. Since launch, Suomi NPP's instruments have been in nominal operations. Suomi NPP's Level-1 instrument data and all the higher-level data products have been publicly released and are available from the archive.

The current Suomi NPP Science Team members have the mandate to create NASA data products from Suomi NPP mission that continue the data record from the EOS missions. Science Team members from Earth Science/Atmospheres include: N. Christina Hsu, VIIRS aerosol products using the Deep Blue algorithm; Robert Levy, VIIRS aerosol products using the Dark Target algorithm; Steven Platnick, cloud properties using only the channels available on both MODIS and VIIRS; Richard McPeters, total ozone continuing OMI with OMPS; P.K. Bhartia, OMPS Limb Team Leader; Alexei Lyapustin, VIIRS aerosol and surface reflectance products using MAIAC; and Joel Susskind, continuing temperature and water vapor profiles using CrIS and ATMS. The Suomi NPP Science Team was re-competed in 2017.

For further information, please contact James Gleason (james.f.gleason@nasa.gov).

3.1.3.8 GPM

The Global Precipitation Measurement (GPM) is an international satellite mission that provides next-generation observations of rain and snow, worldwide. NASA and the Japan Aerospace Exploration Agency (JAXA) launched the GPM Core Observatory (GPM-CO) satellite on February 27, 2014. The GPM-CO data are used to unify merged precipitation measurements made by an international network of satellites provided by partners from the European Community, France, India, Japan, and the United States and to quantify when, where, and how much it rains or snows around the world. The GPM mission will advance our understanding of the water and energy cycles, and extend the use of precipitation data to directly benefit society. FY2017 was a key year for GPM in that the GPM-CO completed its three-year Prime mission lifetime and moved into extended operations. GPM has been conducting a series of field campaigns with international and domestic partners. The last one hosted by GPM was the Olympic Mountain Experiment (OLYMPEX) field campaign from November 2015 to January 2016. GPM's field campaign instrumentation is mostly designed to be portable for operations supporting other needs for precipitation observations. As such during FY17 and FY18, GPM is partnering with the Korean Meteorological Administration (KMA)-led International Collaborative Experiment–PyeongChang Olympics Paralympics (ICE-POP) field campaign, which will coincide with and support the 2018 Winter Olympics. The data collected from these field campaign instruments provides crucial information to improve the GPM mission's measurements of light rain and snow, hydrological impacts of precipitation, directly validate the satellite data products, as well as help researchers understand how precipitation changes across land and ocean.

Significant milestones and activities were met in 2017 including:

- GPM's Version 05 products were reprocessed by the Precipitation Processing System (PPS) in Spring 2016.
- The GPM team is recalibrating TRMM merged products back to the start of TRMM with expected reprocessing to start in mid 2018.
- GPM underwent the NASA HQ Senior Review process in the spring of 2017 and received passing approval for continued funding in December 2017. Funding and operations are approved through FY20 (assuming no other instrument or funding changes).

- GPM successfully completed its End-of-Prime Review in June 2017 and entered into its extended operations period.
- GPM sent equipment to South Korea for ICE-POP pre-field campaign set-up and testing.
- In October 2017, the science team met in San Diego, California, to review algorithm development and plan future activities, including a retrieval algorithm product reprocessing to occur in 2018.
- GPM's vigorous outreach and education efforts continue and included numerous video and online features, website updates for all big weather events, presentations to educators and students, and more.

For further information, please contact Gail Skofronick Jackson (gail.s.jackson@nasa.gov) or visit the GPM home page at http://gpm.nasa.gov.

3.1.3.9 ISS/JEM-EF (CATS)

The Cloud-Aerosol Transport System (CATS) is a laser remote-sensing instrument designed to provide vertical profiles of clouds and aerosols (tiny airborne particles) while also demonstrating new space-based technologies for future Earth Science missions. On January 22, 2015, flight controllers successfully installed CATS aboard the on the Japanese Experiment Module–Exposed Facility (JEM-EF) of the International Space Station (ISS) through a robotic handoff—the first time one robotic arm on-station has worked in concert with a second robotic arm. CATS began operations on the ISS two weeks later (early February 2015) and operated near-continuously until Oct. 2017, well beyond its 6-month designed lifetime. The ISS orbit provides comprehensive coverage of the tropics and mid-latitudes, where primary aerosol transport tracks and clouds from mid-latitude storm tracks and tropical convection are located.

During the 33 months of operation, CATS provided several benefits to society and the science community. CATS extended and improved the global climate record of cloud and aerosol vertical profiles that are critical to understanding the Earth's changing climate. CATS also demonstrated several new technologies in space for future Earth Science missions, such as high-repetition rate lasers and highly sensitive detectors. Finally, CATS provided information about the vertical structure of hazardous volcanic, dust, and smoke plumes that can cause poor air quality and respiratory illnesses. The CATS data is still being used by aerosol and air quality modeling groups around the world to improve forecasts of hazardous plume transport. The CATS data and analysis team includes Laboratory members Dennis Hlavka, Andrew Kupchock, Edward Nowottnick, Scott Ozog, Steve Palm, Rebecca Pauly, and Patrick Selmer.

For further information, please contact Matt McGill (matthew.j.mcgill@nasa.gov) or John Yorks (john.e.yorks@nasa.gov).

3.1.3.10 Earth IceCube

NASA's Science Mission Directorate (SMD) has chosen a team at Goddard Space Flight Center to build its first Earth cloud observing CubeSat to demonstrate a compact, commercially-available radiometer technology (http://www.nasa.gov/cubesat/). The IceCube team is led by Dong Wu who serves as the project Principal Investigator, with a Greenbelt team responsible for payload development and a Wallops team for CubeSat and ground system development. The 1.3-kg payload in 1.2 U CubeSat units (1 U=10´10´10 cm^3) will demonstrate and validate a new 883-Gigahertz submillimeter-wave receiver to advance cloud-ice remote sensing and help scientists to better understand the role of ice clouds in the Earth's climate system. Global distribution and microphysical properties of ice clouds remain highly uncertain, which is one of the leading error sources in determining Earth's radiation budget and cloud-precipitation processes. IceCube was launched to the International Space Station (ISS) in April 2017 and subsequently released from ISS in May 2017. It obtained the first light data on June 6, 2017 and completed its nominal tech-demo mission by the end of August 2017. The IceCube 883-Gigahertz cloud radiometer had experienced a large (10°–35°C) orbital temperature variation but achieved 3K radiometric calibration stability. It produced the first cloud ice map ever taken at 883-Gigahertz frequency, and raised the receiver technology readiness level from 5 to 7.

For further information, please contact Dong Wu (dong.l.wu@nasa.gov).

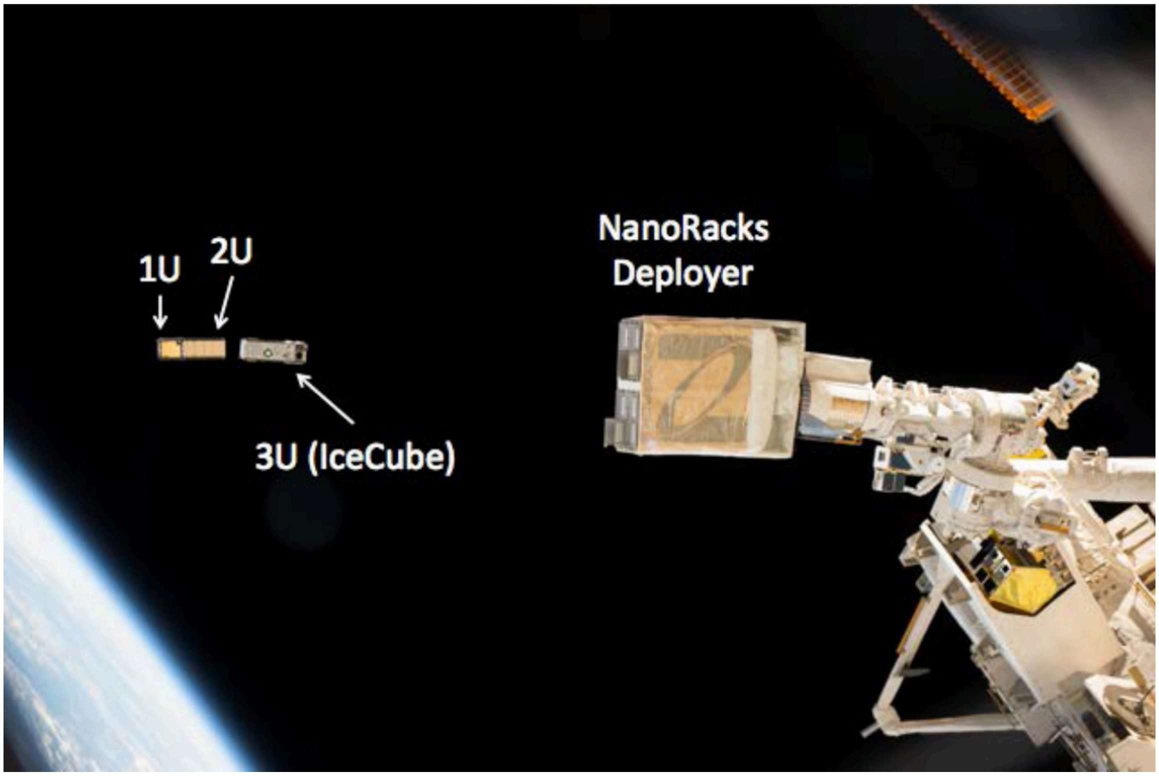


Figure 3.8: IceCube released from ISS on May 16, 2017

3.2. Project Scientist

Project scientists serve as advocates, communicators, and advisors in the liaison between the project manager and the community of scientific investigators on each mission. The position is one of the highest operational roles to which a scientist can aspire at NASA. Table 3.2 lists project and deputy scientists for current and planned missions. Table 3.3 lists the validation and mission scientists and major participants in field campaigns.

Table 3.2: 610AT Project and Deputy Project Scientist

Project Scientists		Deputy Project Scientists	
Name	Project	Name	Project
Anne Douglass	Aura	Bryan Duncan	Aura
Steven Platnick	EOS	Joanna Joiner	Aura

Project Scientists		Deputy Project Scientists	
Name	Project	Name	Project
Dennis Chesters	GOES	Lazaros Oreopoulos	Aqua
Gail Skofronick Jackson	GPM	Alexander Marshak	DSCOVR
James Gleason	JPSS	Scott Braun	GOES-R
Joanna Joiner	OMI	George Huffman	GPM
Pawan K. Bhartia	OMI	Si-Chee Tsay	Terra
James Gleason	SNPP	Christina Hsu	SNPP
Dong Wu	SORCE		
Dong Wu	TSIS		
Scott Braun	TROPICS		
Dong Wu	Earth-ICECube		

Table 3.3: 610AT Validation, Instrument, and Mission Scientists

Validation Scientists	
Name	Mission
Ralph Kahn	EOS/MISR
Matthew McGill	ISS/JEM-EF/CATS

Instrument Scientists/Managers		
Name	Instrument System	2017 Campaigns
Ellsworth Welton	MPLNET	SEALS-sA, ORACLES
Amber Emory/David Wolff	XBADGER	Wallops Facility Operations
Si-Chee Tsay/David Wolff	ACHIEVE	Wallops Facility Operations
David Wolff	NPOL, D3R	Wallops Facility Operations
Gerald Heymsfield	HIWRAP	SHOUT
Thomas McGee	TROPOZ	KORUS-AQ
Anne Thompson	SO3 Sondes/SHADOZ	KORUS-AQ
James Gleason	Pandora	KORUS-AQ
Anne Thompson	SO3 Sondes/SHADOZ	Ascension Island Sondes
Paul Newman/Tom Hanisco	ISAF	ATom
Steven Platnick	eMAS	ORACLES

4. FIELD CAMPAIGNS

Field campaigns use the resources of NASA, other agencies, and other countries to carry out scientific experiments, to validate satellite instruments, or to conduct environmental impact assessments from bases throughout the world. Research aircraft, such as the NASA Global Hawks, ER-2, DC-8, and WB-57F, serve as platforms from which remote-sensing and *in situ* observations are made. Ground-based systems are also used for soundings, remote sensing, and other radiometric measurements. In 2017, atmospheric research personnel supported activities in the planning and coordination phases as scientific investigators or as mission participants.

4.1. ASCENDS

During July and August 2017 Goddard's CO_2 Sounder team completed 8 flights on the NASA DC-8 from Palmdale, CA, and Fairbanks, AK, in support of precursor instruments designed for the Active Sensing of CO_2 Emissions over Nights, Days, & Seasons (ASCENDS) mission-in-development. The objectives of the campaign were, first, to gather data with which to critically assess the accuracy of IPDA lidar measurements of CO_2 column concentrations, and then to measure atmospheric CO_2 over Alaska and North West Territories Canada in coordination with the Arctic Boreal Vulnerability Experiment (ABoVE) intensive field campaign. In addition to the CO_2 laser remote-sensing instruments, the aircraft carried a set of in situ sensors to provide ancillary data for the laser XCO_2 data retrieval and validation, as well as to establish the airborne measurement context.

The DC-8 covered a wide range of Arctic/Boreal locations in 4 flights from Fairbanks plus incoming and outgoing transits. Approximately 40 hours of flight data are available at high latitudes including 30 spiral profiles from 10000 ft to the surface. These data form a unique observational resource for the ABoVE 2017 intensive campaign.

The CO_2 Sounder investigation is led by James Abshire (690) with team members Haris Riris (614), Graham Allan (614/SIGMA), William Hasselbrack (614/SIGMA), Jeffrey Chen (554), Jianping Mao (614/ESSIC), and Stephen Kawa (614).

For further information, please contact S. Randolph Kawa (stephan.r.kawa@nasa.gov).

4.2. ATom

The Atmospheric Tomography Mission (ATom) is studying the impact of human-produced air pollution on greenhouse gases and on chemically reactive gases in the atmosphere. Reductions of atmospheric concentrations of methane (CH_4), tropospheric ozone (O_3) and black carbon (BC) aerosols are effective measures to slow global warming and to improve air quality. Airborne instruments are providing data on how atmospheric chemistry is transformed by various air pollutants and their impact on CH_4 and O_3. Mitigation of these short-lived climate forcers is a major component of current international policy discussions.

ATom has conducted 3 global scale deployments in August 2016 (northern summer), February 2017 (winter), October 2017 (fall). The final ATom deployment will happen in May 2018 (spring). These deployments are identifying seasonal patterns in chemical reactivity and the integrated impact of anthropogenic emissions from the major continents. Each deployment will be comprised of ~11 flights in a circuit transecting the Pacific and Atlantic basins from nearly pole-to-pole. In the coming years, the science team will use these observations from around the world to better understand chemical processes in the atmosphere that control the short-lived greenhouse gases—methane and ozone, the latter of which is also a health-damaging air pollutant.

In a repeat of the previous deployments, the ATom suite of instruments aboard NASA's DC-8 flying laboratory will be hopping down the Pacific Ocean from Alaska to Antarctica, then north up the Atlantic to Greenland and the Arctic in May 2018. ATom measures more than 300 gases and particles in the air and studies their interactions around the world.

For further information please contact Thomas Hanisco (thomas.hanisco@nasa.gov) or Paul Newman (paul.a.newman@nasa.gov).

4.3. CARAFE

The CARbon Airborne Flux Experiment (CARAFE) completed its second set of flight measurements in May 2017. CARAFE flies on the NASA Wallops C-23 Sherpa aircraft, and flights have been made across a variety of biomes in the U.S.mid-Atlantic region based from WFF. Nine science and one test flights were successfully completed and a great cache of data has been acquired.

The objective of CARAFE is to demonstrate and exercise a versatile system for direct measurement of vertical fluxes to/from the Earth surface via the airborne eddy covariance technique. The scientific aim is to quantify greenhouse gas sources and sinks over diverse ecosystem states and land-use regions in order to improve top-down and bottom-up source/sink estimation, evaluate biophysical process models, and validate top-level flux products from OCO-2 and other space borne missions. CARAFE 2017 flights were funded by the NASA Carbon Monitoring System Program. Results from CARAFE 2017 in May will be compared to corresponding data and models taken in September 2016 over many of the same surfaces to examine how the uptake of CO_2 and emissions of CH_4 by vegetation vary with phenology (seasonal cycles with respect to climate conditions) for crops and different forest types. CARAFE also added a N_2O/CO sensor to the payload for 2017.

CARAFE investigators are: PI S. R. Kawa (614) and co-Is P. A. Newman (610), G. Wolfe (614/UMD), T. Hanisco (614), G. Diskin, K. L. Thornhill, J. Barrick (LaRC), G. Hurtt (UMD), G. Bland (610.W), and S. Pusede (UVA).

For further information, please contact S. Randolph Kawa (stephan.r.kawa@nasa.gov).

4.4. ECLIPSE

During late August, two 610AT teams were stationed across the path of totality during the Great American Eclipse: Jay Herman (614), Nader Abuhassan (614/UMBC), and Alexander Marshak (613) **in Casper, WY; and** Si-Chee Tsay (613), Ukkyo Jeong (613/UMD) and Peter Pantina (613/SSAI) in Columbia, MO. At each site, teams deployed two Pandora spectrometers (one pointing at the Sun for direct radiation measurements and one pointing vertically for diffuse radiation measurements) and a set of SEBRA radiometers (thermal-dome-corrected pyranometer and pyrgeometer). The purpose of the deployment was to collect ground-based solar radiation data to help to better understand the performance and behavior of a 3D, global radiative transfer model (RTM).

More details are provided at https://www.nasa.gov/feature/goddard/2017/nasa-looks-to-the-solar-eclipse-to-help-understand-the-earth-s-energy-system.

For further information, please contact Alexander Marshak, (alexander.marshak-1@nasa.gov)

Figure 4.1: Sherpa-eye-view during flux measurements over forest and agricultural fields in the Delmarva Peninsula, May 18, 2017

4.5. eMAS and ORACLES

Several 610 scientists traveled to Namibia to participate in the ObseRvations of Aerosols above CLouds and their intEractionS (ORACLES) campaign. ORACLES is an Earth Venture Suborbital Project focusing on the interaction of African biomass-burning aerosol with the extensive marine boundary layer clouds off the coasts of Namibia and Angola. To date, Goddard researchers that have been in the field include: Steven Platnick (610), Kerry Meyer (613), and Thomas Arnold (613/SSAI) with the Enhanced MODIS Airborne Simulator (eMAS) imager on the ER-2; Brian Cairns (611), Jacek Chowdhary (611/CU), Kirk Knobelspiesse (616) and Ken Sinclair (graduate student with 611/CU) operating the RSP polarimeter on the ER-2 and the P-3; Brent Holben (618) installing and supporting AERONET sun photometers throughout the country; Arlindo da Silva and Karla Longo (610.1) providing GEOS-5 model support; and Andrew Ackerman (611) and Ann Fridlind (611) attending as part of the theory team. Steve Platnick was the principal investigator for the eMAS imager flown on the NASA ER-2 high-altitude research aircraft during the campaign. Flight missions were conducted with the ER-2 and/or the NASA WFF P-3B from September 3 to September 27 out of Walvis Bay, Namibia.

ORACLES is a five-year investigation with three intensive observation periods (IOP) designed to study key processes that determine the climate impacts of biomass burning aerosols in Southern Africa. Southern Africa produces almost a third of the Earth's biomass-burning aerosol particles, yet the fate of these particles and their influence on regional and global climate is poorly understood. The overall scientific goal of ORACLES is to understand the processes that control the radiation balance and cloud properties over the Southeast Atlantic, which impact the regional and global distribution of surface temperatures and precipitation. The eMAS 38-channel scanning-spectrometer acquires high spatial resolution imagery of cloud, aerosol, and surface features from its ER-2 vantage point of about 20 km. In addition to providing essential data for ORACLES science, eMAS observations will also help to develop, test, and refine algorithms for the MODIS and VIIRS, key NASA sensors used for cloud process and climate studies Oracles.

For further information please, contact Steve Platnick (steven.e.platnick@nasa.gov).

4.6. GOES-R Calibration/Validation flights on the ER-2.

A NOAA GOES-R validation campaign was conducted from March 13 to May 18, 2017, using the NASA ER-2 aircraft and Goddard's ER-2 Doppler radar (EXRAD), Cloud Radar System (CRS), and Cloud Profiling Lidar (CPL), along with other instruments. The first four weeks focused primarily on validation of the Advanced Baseline Imager (ABI) reflective solar-band channels using measurements of the surface over the Sonoran Desert, while the latter portion of the campaign focused on validation of the Geostationary Lightning Mapper (GLM) within severe thunderstorms at various locations in the eastern half of the United States.

For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

4.7. ICE-POP

NASA's GPM Ground Validation program will assist the Korean Meteorological Administration (KMA) with the execution of the International Collaborative Experiment for the Pyeongchang Olympics and Paralympics (ICE-POP) 2018 field campaign. GPM is providing ground-based instruments for forecast and research studies before, during and after the planned 2018 Winter Olympic Games (February 9–25, 2018), to be held in Pyeongchang, South Korea. Preparations for ICE-POP 2018 began in November 2016 when a Letter of Agreement (LOA) was established between NASA and KMA. ICE-POP is expected to provide GPM ground validation with valuable data for researching frozen and mixed-phase precipitation in complex terrain. GPM radars and ground instruments will be used for both nowcasting and forecasting support during Olympics operations.

An initial suite of GPM ground validation equipment arrived at the Daegwallyeong Weather Station, South Korea, in early May 2017. Two precipitation imaging package (PIP) instruments and two micro rain radars (MRR) were shipped in July 2017. The NASA Dual-polarization, Dual-Frequency, Doppler Radar (D3R) was shipped from NASA's Wallops Flight Facility in September 2017. In October, an internet-accessible GPM overpass prediction site (https://gpm-gv.gsfc.nasa.gov/Tier1/) was set up for the domain of the campaign. GPM rain gauges, MRRs, and PIPs are currently operating at numerous locations in the domain. GSFC and Colorado State University successfully deployed the D3R on the roof of the Daegwallyeong Weather Station in South Korea in October. KMA has funded the transportation and installation of the D3R as well as the operations staff during the campaign.

In December KMA requested that Michael Watson (610.W), a Wallops-based radar engineer, visit to help deploy an X-band dual-polarization radar (TREx) on loan from Spain. This radar was loaned to Wallops for about 1.5 years, so a Wallops engineer has the requisite experience to assist. Michael's visit is scheduled for January 2–9, 2018.

For further information, please contact David B. Wolff (david.b.wolff@nasa.gov).

4.8. MPLNET

The MPLNET project added a number of new sites to the network during 2017. Two sites were added in Taiwan—Banqiao and Douliu—in partnership with the country's National Central University (NCU) and the Taiwanese EPA. A new site in Spain was added at El Arenosillo along the Atlantic coast, in partnership with the Spanish National Institute of Aerospace Technology (INTA). A new site at NASA Langley Research Center was also established; this moved the pre-existing site from the Langley's COVE research station to a new location named Chemistry and Physics Atmospheric Boundary Layer Experiment (CAPABLE). An additional site was added in Singapore, in partnership with the National University of Singapore. Another site was added at Sigma Space Corporation, the manufacturer of the micro-pulse lidar instruments used within MPLNET.

MPLNET is also developing new calibration facilities within the network to reduce the calibration work currently required at its home facility at Goddard. The work on new calibration facilities has begun in Taiwan at NCU and at the Sigma Space Corporation in Lanham, MD. An additional calibration facility in Barcelona will be added in 2018 in conjunction with partners at the University Politecnica de Catalunya (UPC).

Finally, MPLNET supported the Aerosols, Radiation, and Clouds in Southern Africa (AEROCLO-SA) field campaign in Namibia during August and September 2017. In addition to the existing site at Windpoort, near Etosha National Park, MPLNET installed an additional lidar at Henties Bay, on the coast of Namibia, to support related surface measurements for the campaign.

For further information, please contact Ellsworth Welton (ellsworth.j.welton@nasa.gov).

4.9. NDACC

The Stratospheric Ozone Lidar is currently deployed at the Observatoire de Haute Provence, in southern France, for the purpose of participating in a Network for the Detection of Atmospheric Composition Change (NDACC) ozone profiling validation campaign. These campaigns are a regular part of the NDACC Validation Protocol, for instrumentation at different sites around the globe. PI Thomas McGee (614), and new civil servant, John Sullivan (614) will participate in the next deployment, scheduled for February 2018.

For further information, please contact Thomas McGee (thomas.j.mcgee@nasa.gov).

4.10. OWLETS

The monitoring of ozone (O_3) in the troposphere is of pronounced interest due to its known toxicity and health hazard as a photochemically generated pollutant. One of the major difficulties for the air quality modeling, forecasting and satellite communities is the validation of O_3 levels in sharp transition regions, as well as near-surface vertical gradients. Significant land-water gradients in coastal regions can occur due to differences in emissions, surface deposition, boundary layer height, and cloud coverage. Therefore, vertical, horizontal, and temporal (4D) measurements are needed to describe complex scenes to improve forecast models and air quality satellite retrievals.

The Ozone Water-Land Environmental Transition Study (OWLETS) field campaign was conducted in Summer 2017 in the Tidewater Virginia region to better characterize O_3 across the coastal boundary. This began as a NASA 2017 Science Innovation Fund Award and was further supported by the GeoTASO project, the Student Airborne Research Program–East (SARP-E), the Pandora project, the Tropospheric Ozone Lidar Network (TOLNet), and NASA HQ. OWLETS utilized a unique combination of two TOLNet lidars, UAV/mobile units equipped with O_3 and surface sensors, ozonesondes, and surface sensors to characterize the water-land differences in O_3.

Goddard's (614/618) ground-based networks (e.g. TOLNet, Pandora, AERONET) were used to provide a framework for future collaborative investigations and provide a novel validation platform. The 614 lidar was deployed to NASA's Langley Research Center (LaRC) to provide profiles of ozone from the boundary layer into the free troposphere. Pandora and AERONET instruments were also deployed to sample column amounts of trace gases and aerosols. The LaRC Code E304 TOLNet Lidar, as well as Pandora and AERONET, were deployed on the Chesapeake Bay Bridge Tunnel (CBBT) 7–8 miles offshore. The NASA Student Airborne Research Program-East (SARP-E, Co-I and support from 614) and GeoTASO (PI and support from 614) flights provided additional chemical information regarding vertical and horizontal gradients between the land-water interfaces. Ship-borne measurements of additional trace gases were provided by the Smithsonian Environmental Research Center (SERC, support from 614) vessel supported Pandora instruments and provided shipborne measurements of additional trace gases. This combination of observations provided a unique characterization of O_3 and other pollutants to help provide feedback to air quality forecast models as well as future satellite remote-sensing systems, such as NASA's TEMPO and GeoCAPE missions.

Participants in the OWLETS campaign include: John Sullivan, Laurence Twigg, Thomas Mcgee, and Robert Swap from the 614 lidar group; Joe Robinson and Nader Abuhassan from Pandora; Matt Kowaleski and Scott Janz from the GeoTASO group; Maria Tzortziu and Ryan Stauffer from the SERC cruise; and Glenn Wolfe, Thomas Hansico, Reem Hannum, and Jason St Clair from the SARP-E team. Participation from LaRC was also extensive, with support from Timothy Berkoff, Travis Knepp, Jay Al-Saadi, and Margaret Pippin as well as many student interns.

For further information, please contact John Sullivan (john.t.sullivan@nasa.gov).

4.11. Pandora

The Lake Michigan Ozone Study (LMOS) occurred in June 2017 in an attempt to quantify chemistry gradients at the lakeshore. In support of this campaign, five Pandora systems were sited and co-located with additional platforms for air quality observations. The LMOS campaign was a concerted effort to evaluate chemistry transport models in complex environments, such as at the lake-land interface and near urban centers.

Previous studies, including LMOS, showed complex chemical gradients at the land-water interface that required a more complete dataset of co-located observations (e.g. Martins et al., 2012; Goldberg et al., 2014; Loughner et al., 2011, 2014; Stauffer et al., 2015). To accomplish this, the Ozone Water-Land Environmental Transition Study (OWLETS; figure 4.2) established a land supersite at NASA's Langley Research Center (LaRC) and an over-water supersite on the Chesapeake Bay Bridge Tunnel (CBBT). In July–August 2017, OWLETS created a network of seven Pandora systems sited at five strategic locations around the southern Chesapeake Bay, including the Smithsonian Environmental Research Center (SERC) vessel which supported Pandora instruments and provided shipborne measurements of additional trace gases. While not an overarching goal of the campaign, Pandora and ozone lidar systems were also used synergistically to capture high-resolution observations that showed the effects of large maritime ship emissions on local chemistry in the Chesapeake Bay (Gronoff et al. submitted; Figure 4.3).

Due to the results and successes of these campaigns, a number of Pandora systems involved were left permanently at field sites to continue long-term, uninterrupted observations. Additional information can be found on Pandora's website: https://acd-ext.gsfc.nasa.gov/Projects/Pandora/index.html.

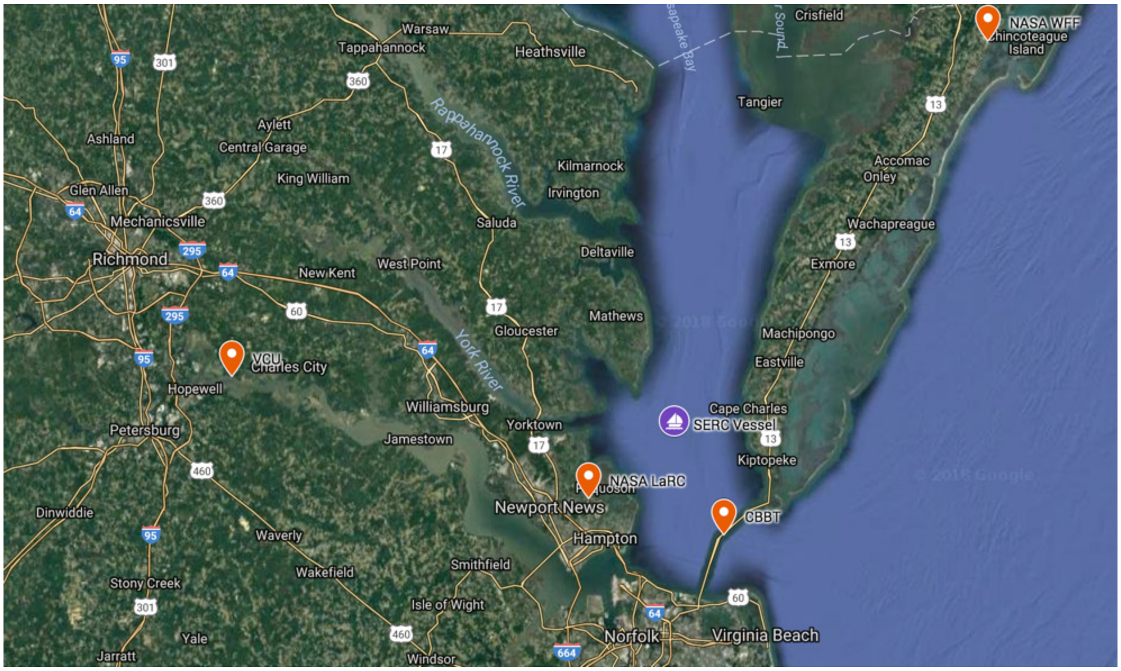


Figure 4.2: Five field sites for the OWLETS 2017 campaign. Two Pandora systems were sited at both LaRC and CBBT, for a total of seven systems. The SERC Vessel sailed for two days along the length of the Bay.

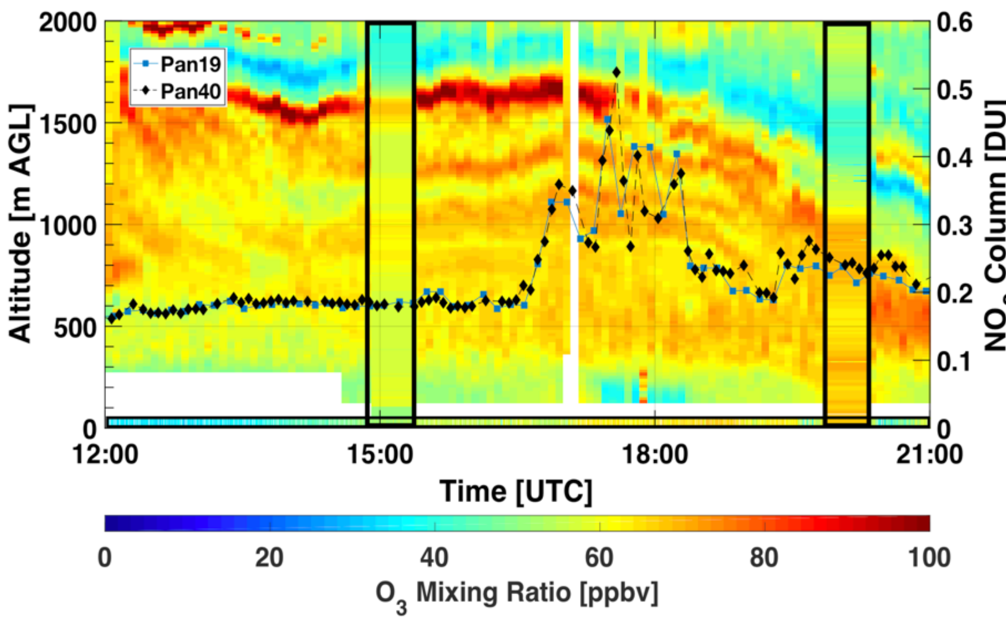


Figure 4.3: Coincident Pandora NO_2 and ozone lidar observations at CBBT from August 01, 2017. Inserts with black rectangles represent ozone observations from surface in situ monitors and ozonesonde launches. During the time from 12 to 17 UTC, the background for both gases is relatively consistent. However, as a large freight vessel passes by at 17:30 UTC, the exhaust caused a marked local increase in NO_2 and decrease in O_3 as a result of chemistry within the exhaust plume. Both instruments show these interactions between 17:30 and just after 18 UTC.

4.12. SHADOZ

There were three major activities for SHADOZ: (i) Visits by PI Anne Thompson (610) to two South American countries (March 2017) that host SHADOZ ozonesonde stations; (ii) The WMO-sponsored JOSIE-SHADOZ-2017 experiment in Germany, held October 9 through November 2017; (iii) The first major reprocessing of the 19-year SHADOZ data archive.

The South American countries visited were Suriname (Meteorological Dept. of Suriname in Paramaribo) and Ecuador. In Suriname, Thompson was accompanied by NPP Post-doc Ryan Stauffer (USRA/614) and Senior Scientist Dr. Ankie Piters of KNMI (Royal Dutch Meteorological Institute), the agency that sponsors weekly Paramaribo soundings. On March 8, visitors observed the preparation and calibration of a sonde launch (Figure 4.4) that measured ozone to 34 km.

Figure 4.4: SHADOZ ozonesonde launch, Paramaribo, Suriname, March 2017. Credit: A. Thompson

The Jülich Ozonesonde Intercomparison Experiment (JOSIE)–SHADOZ campaign was held in Germany at the World Centre for Calibration of Ozonesondes, a specially designed facility that allows multiple sondes to be tested in a simulation chamber (Figure 4.5). Hosted by PI Herman Smit of the Forschungszentrum-Jülich, this was the first JOSIE to compare ozonesonde performance under exclusively tropical conditions. The sondes were prepared by operators from eight SHADOZ stations including Suriname, Brazil, Kenya, South Africa, Malaysia, Vietnam. Teams from both Greenbelt Code 614 (Anne Thompson, Jacquie Witte [SSAI], Ryan Stauffer [USRA NPP]) and Wallops Code 610.W (participated in the first 2-week session of JOSIE-SHADOZ. Capacity-building activities included lectures on sonde quality-assurance and data-processing from sponsoring organizations (e.g., NASA/GSFC; NOAA/GMD; KNMI (Netherlands); KMI (Belgium); Meteoswiss; Finnish Meteorological Institute). Financial support for the tropical operators came from the UNEP-sponsored Vienna Convention Trust Fund, administered by WMO. It is expected that JOSIE-SHADOZ will lead to new standards for 100 sonde stations worldwide because all the instrument types and preparation techniques used by the community were represented at event.

SHADOZ continues to launch ozonesondes biweekly at thirteen stations in the network. At present, there are ~7000 sets of archived SHADOZ ozone and radiosonde profiles at the website: https://tropo.gsfc.nasa.gov/shadoz. These data are widely used for analysis of lower stratospheric ozone trends, where satellites alone often do a poor job.

Figure 4.5: Code 614 and 610.W sonde teams, JOSIE PI, and technical team with SHADOZ operators in front of the ozonesonde Environmental Simulation Chamber in Jülich, Germany, during JOSIE-SHADOZ. Photo Credit: Forschungscentrum-Jülich.

However, over the 19 years of SHADOZ, biases at various stations or discontinuities in profile time-series due to instrument changes have been observed. Thus, the global sonde community has undertaken reprocessing of sonde data. SHADOZ data reprocessing has been conducted in a GSFC-NOAA collaboration (*Sterling et al.,* 2017; *Thompson et al.,* 2017; *Witte et al.,* 2017).

The typically two-percent agreement between SHADOZ and satellite total ozone (Figure 4.6) represents a marked improvement in sonde quality since the 1990s, enabling more precise predictions of ozone and climate in the tropics.[1]

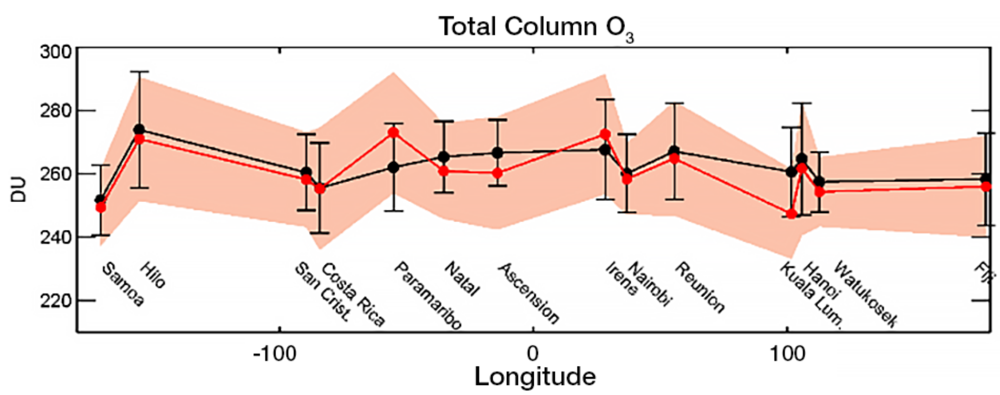


Figure 4.6: Longitudinal cross-section of 1998–2016 SHADOZ sonde total column O3 (red circles with ±1 light red shading) and the collective mean overpass columns from the TOMS-OMI-OMPS satellite instruments (black with ±1σ black bars). From Thompson et al., 2017.

For further information please, contact Anne Thompson (anne.m.thompson@nasa.gov).

[1]Thompson, A. M., Witte, J. C., Sterling, C., Jordan, A., Johnson, B. J., Oltmans, S. J., Thiongo, K. (2017). First reprocessing of Southern Hemisphere Additional Ozonesondes (SHADOZ) ozone profiles (1998–2016): 2. Comparisons with satellites and ground-based instruments. *Journal of Geophysical Research: Atmospheres*, 122. https://doi.org/10.1002/2017JD027406

5. AWARDS AND SPECIAL RECOGNITION

This year many deserving employees were recognized for outstanding accomplishments, leadership, or service. Notable achievements were recognized by Goddard, NASA, and by national, international, or professional organizations. Such accomplishments were achieved through individual dedication and perseverance as well as through close cooperation with co-workers and associations and collaborations with the outside community.

5.1. Agency Honor Awards

In 2017, NASA identified the following people for special recognition.

Honor Award	Recipient	Citation
NASA Distinguished Service Medal	Paul A. Newman (610)	*For sustained leadership strengthening the scientific basis of the Montreal Protocol resulting in the 2016 Kigali Amendment controlling hydro-fluorocarbon emissions*
Ames Honor Award	Geoffrey Bland (610.W)	*For the Volcanic Emissions Retrieval Experiment (VEREX) for excellence in the category of group/team.*
NASA Blue Marble Award	Kevin Ward (613/SSAI)	*In recognition of excellence in environmental and energy management, presented at the 2017 NASA Environmental Conference.*
NASA Team Excellence Award	George J. Huffman (612)	*As part of the Satellite Needs Assessment Team "for outstanding teamwork in developing solutions to the Earth observation needs of the federal government in response to the Satellite Needs Working Group".*

5.2. Robert H. Goddard Awards

Atmospheric Research team members received the following individual awards.

Robert H. Goddard Award	Recipient	Citation
Award of Merit	Dennis Chesters (612)	*For exceptional and sustained leadership of Goddard's role in the NOAA GOES satellite series missions.*

Atmospheric Research scientists also received the following Robert H. Goddard Team Award.

Robert H. Goddard Award	Recipient	Citation
Earth Sciences Field Support Office Team	Michael Watson (610.W/Orbital/ATK), Matt Wingo (610.W/Univ. Alabama-Huntsville), Gary King (610.W/ ASRC), David Marks (610.W/SSAI), Jason Pippitt (612/SSAI), Jason Bashor (610.W/ASRC), Jianxin Wang (612/SSAI), Shaena Rausch (610.W/ASRC), Brandon Jameson (610.W/ASRC)	*For outstanding technical and field support for the Global Precipitation Measurement (GPM) Ground Validation program.*

5.3. External Awards and Recognition

Paul Newman (610) received the Scientific Leadership Award during the Montreal Protocol 30th Anniversary Awards Honour Ozone Heroes on November 24. The awards ceremony was co-hosted by

United Nations Environment Champion of the Earth for 2017, Leyla Acaroglu; award-winning CEO of PCI Media Impact, Sean Southey; and Grammy Awards nominee Rocky Dawuni, a Goodwill Ambassador of the Global Alliance for Clean Cookstoves, who also delivered a musical performance at the event. The awardees were nominated for their awards and selected by an international jury comprising eminent environmental leaders based on the recommendations of a technical screening committee made up of experienced ozone experts from around the world.

Sergey Korkin (613/USRA) received the 2017 Richard M. Goody Award for Atmospheric Radiation & Remote Sensing. This prestigious Elsevier *Journal of Quantitative Spectroscopy and Radiative Transfer* Young-Scientist Award is named after Richard M. Goody, whose pioneering research has had a profound and long-lasting impact on the disciplines of atmospheric radiation, remote sensing, and climate change. The award was presented at the 16th Electromagnetic and Light Scattering Conference.

Manisha Ganeshan (613/USRA) was awarded the International Arctic Science Committee (IASC) fellowship to join their Atmosphere Working Group (AWG). This fellowship is an opportunity for early career Arctic researchers to engage in leading-edge international scientific activities and also to develop management skills by participating in the working group activities. http://iasc.info/capacity-building/fellowship.

Matthew McGill (610) has been selected as the recipient of the 2017 National Organization of Gay and Lesbian Scientists and Technical Professionals' GLBT Scientist award for his outstanding achievements in the application of lidar technology in the study of atmospheric conditions to better understand climate change impacts on Earth.

Brian Campbell (610W/GST) is the recipient of the 2017 Albert Nelson Marquis Achievement Award as "an honor reserved for Marquis Biographees who have achieved career longevity and demonstrated unwavering excellence in their chosen fields." This award is through The Marquis Who's Who Publications Board.

Ali Tokay (612/UMD) is a 2017 recipient of an American Meteorological Society Editor's Award for his work in the Journal of Applied Meteorology and Climatology for his frequent and in-depth reviews of manuscripts related to precipitation microphysics and estimation, and remote sensing using radar.

5.4. William Nordberg Award

The William Nordberg award for Earth Sciences is given annually to an employee of the Goddard Space Flight Center who best exhibits those qualities of broad scientific perspective, enthusiastic and technical leadership on the national and international levels, wide recognition by peers, and substantial research accomplishments in understanding Earth system processes which exemplified Dr. Nordberg's own career. The first award was presented to Dr. Joanne Simpson on November 4, 1994. All current and past atmospheric science recipients of this award are listed below.

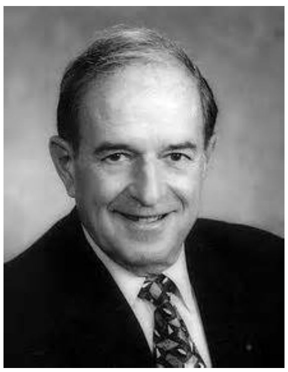
Recipient	Year		Recipient	Year
Joanne Simpson	1994		P. K. Bhartia	2003
Mark Schoeberl	1998		Robert Adler	2007
William K. M. Lau	1999		Wei-Kuo Tao	2008
Yoram J. Kaufman	2000		Paul Newman	2011
Michael D. King	2001		Anne Douglass	2013

5.5. American Meteorological Society

Founded in 1919, the American Meteorological Society (AMS) is the nation's premier scientific and professional organization promoting and disseminating information about the atmospheric, oceanic, hydrologic sciences.

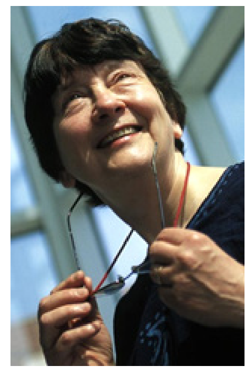
5.5.1. Honorary Members

Honorary AMS Members are persons of acknowledged preeminence in the atmospheric or related oceanic or hydrologic sciences, either through their own contributions to the sciences or their application or through furtherance of the advance of those sciences in some other way. The following current and former Goddard atmospheric scientists have achieved this award.



David Atlas

Joanne Simpson



Eugenia Kalnay

Figure 5.1: Honorary AMS members David Atlas, Joanne Simpson, and Eugenia Kalnay

5.5.2. Fellows

Fellows shall have made outstanding contributions to the atmospheric or related oceanic or hydrologic sciences or their applications during a substantial period of years." The following current and former Goddard atmospheric scientists have achieved this award.

Recipient	Recipient	Recipient
Robert F. Adler	Eugenia Kalnay	Mark R. Schoeberl
Dave Atlas	Jack A. Kaye	Siegried D. Schubert
Robert M. Atlas	Michael D. King	J. Marshall Shepherd
Wayman E. Baker	Steven E. Koch	Jagadish Shukla
John R. Bates	Christian Kummerow	Joanne Simpson
Antonio J. Busalacchi	William K. Lau	Eric A. Smith
Robert F. Cahalan	Paul A. Newman	Wei-kuo Tao
Anne R. Douglass	Gerald R. North	Anne M. Thompson
Franco Einaudi	Steve Platnick	Louis W. Uccellni
Donald F. Heath	David A. Randall	Thomas T. Wilheit
Arthur Hou	Richard R. Rood	Warren Wiscombe

5.6. American Geophysical Union

Established in 1919 by the National Research Council, the American Geophysical Union (AGU) is an international non-profit scientific association with more than 62,000 members.Roger Revelle Medal: Anne Thompson, 2015 Award Recipient.

5.6.1. Union Fellows

A Union Fellow is a tribute to those AGU members who have made exceptional contributions to Earth and space sciences as valued by their peers and vetted by section and focus group committees. Eligible Fellows nominees must have attained acknowledged eminence in the Earth and space sciences. Primary criteria for evaluation in scientific eminence are: (1) major breakthrough, (2) major discovery, (3) paradigm shift, or (4) sustained impact. The following current and former Goddard atmospheric scientists have received this distinguished honor.

Recipient	Year
David Atlas	1972
Joanne Simpson	1994
Mark R. Schoeberl	1995
Richard S. Stolarski	1996
David A. Randall	2002
Anne M. Thompson	2003
Marvin A. Geller	2004
Gerald R. North	2004
Eugenia Kalnay	2005
Michael D. King	2006
William K.-M. Lau	2007
Anne R. Douglass	2007
Paul Newman	2010
Warren Wiscombe	2013
Lorraine Remer	2015

5.6.2. Yoram J. Kaufman Unselfish Cooperation in Research Award

The Atmospheric Sciences Section of the American Geophysical Union established the Yoram J. Kaufman Unselfish Cooperation in Research Award in 2009. This award is named in honor of Yoram J. Kaufman, an outstanding atmospheric scientist, mentor, and creator of international collaborations who worked on atmospheric aerosols and their influence on the Earth's climate for his entire 30-year career. The following Goddard atmospheric scientists have been honored with this award.

Recipient	Year
Ralph Kahn	2009
Pawan Bhartia	2012

6. COMMUNICATION

6.1. Introduction

Atmospheric Scientists in the Earth Sciences Division actively participate in NASA's efforts to serve the education community at all levels and to reach out to the general public. Scientists seek to make their discoveries and advances broadly accessible to all members of the public, and they to increase the public's understanding of why and how such advances affect their lives through formal and informal education as well as public outreach avenues. This year's activities included: continuing and establishing collaborative ventures and cooperative agreements; providing resources for lectures, classes, and seminars at educational institutions; and mentoring or academically-advising all levels of students. The following sections summarize many such activities.

6.2. University and K-12 Interactions

Dorian Janney (612/ADNET), Kristen Weaver (612/SSAI), and Brian Campbell (610W/GST) implemented the sixth webinar for Phase II of the GLOBE ENSO Student Research Campaign on Tuesday, February 21. In this webinar, information was presented about the current ENSO patterns from NASA JPL scientist, Veronica Nieves. Specific ENSO phenomenon characteristics were explained, such as why an El Niño event that is followed by a La Niña event and an explanation of the data that is used to determine which phase of the ENSO cycle we are in. Some highlights included how we know that we did not end up having a La Niña event and explain why it is so important to continue to collect measurements during all phases of ENSO patterns, including the La Nada. A presentation from Harry Koad, a graduate student in Thailand, discussed the impact of the ENSO on the 2016–2017 drought and flooding in his region. The GLOBE GIO showed participants how to use the GLOBE Visualization Tool and the Advanced Data Access Tool as ways to view and retrieve GLOBE data from around the world. The webinar culminated with a call for water stories for our ENSO Campaign partner, the H2yOu Project.

On March 9, Anne Thompson (610) visited the Deputy Ambassador G. Webster and two staff at the U.S. Embassy in Suriname to discuss activities in the South American country; this is the first time a NASA scientist had visited the capital, Paramaribo. Thompson delivered a lecture on March 9 to the Anton de Kom University on "Environmental Success Stories: A View from Space." On March 13, Thompson gave a similar presentation to an all-day Environmental Symposium in Quito, Ecuador, attended by 70 students, faculty, and Ecuadorian government personnel at the University San Francisco-Quito (USFQ). Thompson met with the Executive Director J. Olmedo and several senior staff at INAHMI (Institute for Hydrology and Meteorology) in Quito on March 14 to work out resumption of SHADOZ sonde launches at San Cristóbal, Galapagos, which have been suspended for a year. In the afternoon of March 14, Thompson gave a lecture to a Women in Science and Engineering Group at USFQ and visited the roof-top atmospheric lab of host Prof Maria Cazorla, a former GSFC NPP post-doc.

Dorian Janney (612/ADNET), Kristen Weaver (612/SSAI), and Brian Campbell (610W/GST) implemented the seventh webinar for Phase II of the GLOBE ENSO Student Research Campaign on Tuesday, March 14. In this webinar, information about how and why NASA missions study Earth's systems. Brian gave the webinar introduction and data summary, followed by Dorian focusing on NASA's Earth Science "Big Questions." Participants learned about the Global Precipitation Measurement mission from Dalia Kirschbaum (617). Dalia described how she uses data from GPM to help her develop worldwide

Figure 6.1: Anne Thompson and Prof. M. Cazorla in the rooftop atmospheric lab of USFQ, Quito, Ecuador.

landslide modeling and warning systems. Peter Falcon from NASA JPL shared a few user-friendly online resources to enable participants to easily access and personalize NASA Earth science data sets to meet participant needs, and Kristen Weaver shared an example of how participants can access and use GLOBE data sets matched to the NASA data. The webinar finished up with a bedtime story or two from Laura Schetter with H2yOu Project.

Dorian W. Janney (612/ADNET) ran a table at the Anne Arundel County Boy Scout Jamboree attended by about 300 scouts and 150 adult leaders. The science and technology behind the GPM mission were featured.

Gala Wind (613/SSAI) participated in “Be Excited About Math (BEAM) Week” at the Bollman Bridge Elementary School of the Howard County Public School System, March 13–17. She gave a astrophysics talk to first graders entitled “When Space Things Go KABOOM!”. The talk covered the lifecycle of stars from proto-stars to main sequence to final stages of red giants and the (super)novae remnants such as white dwarfs, neutron stars and black holes. For third graders, she taught the Midpoint Method for Numerical Integration in an interactive lesson which fit into their curriculum as they just started material on finding areas of objects. The general idea was how to make what looks impossible, possible. The nine-year-old children were excited to see that they could do college math with nothing more than some basic addition.

Brian Campbell (610W/GST) was inducted into the Wilson High School Academic Hall of Fame on March 21, 2017. The ceremony took place during the high school’s National Honor Society Induction Ceremony in West Lawn, Pennsylvania. During the induction, Brian gave a speech on the importance of not fearing failure, among other words of inspiration and encouragement.

Brian Campbell (610W/GST) has been working with GLOBE schools from around the world in creating student research videos that complement the NASA GLOBE ENSO Student Research Campaign and the protocol measurements the students are collection. Videos from the United States, Suriname, and Croatia were among the first few to be created in April.

Brian Campbell (610W/GST) has collaborated with several teachers, internationally, to develop GLOBE ENSO Student Research Campaign videos that showcase their students taking measurements using the six protocols (max/min air temperature, soil temperature, soil moisture, surface temperature, precipitation, and biometry tree and canopy cover) that are part of the GLOBE ENSO Student Research Campaign, which Brian leads. These videos will be showcases during future campaign webinars and in GLOBE blogs.

During the week of April 17-21, Dorian Janney (612/ADNET) went to the Maret School in Washington, DC, to work with their 8th grade students as they prepare for their Climate Conference in May. She showed them how to access and use various NASA resources, and explained the science and technology behind the GPM mission. In addition, she shared information on STEM-related careers with NASA. She will continue to serve as a resource for these 84 students and their five teachers as they conduct research and prepare for the May 12 conference. She will attend their conference as well.

During the week of May 5–12, Dorian Janney (612/ADNET)) held a 2.5-hour “First Things First” workshop for Montgomery County Public School teachers who were enrolled in an Outdoor Environmental Education course at the Lathrop E. Smith Center in Rockville, MD. She showed the 36 participants how to use the GLOBE Observer Cloud app, and shared information on the upcoming Mosquito app. These teachers ranged from teaching preschool special education to high school AP biology.

Between May 1–4, Dorian Janney (612/ADNET)) reviewed five secondary school GLOBE International Science Symposium projects for the GLOBE Program.

Women of the Dark Target Aerosol Group—Yaping Zhou (613/MSU), Virginia Sawyer (613/SSAI), Yingxi Shi (613/USRA), Falguni Patadia (613/MSU), and Lorraine Remer (UMBC)—visited Maryvale Elementary School and engaged with thirty 3rd, 4th, and 5th grade girls attending the after-school girls’ STEM club. They talked. They showed pictures. They had the girls participate in hands-on activities that illustrated different properties of light and air.

As a follow-up to the several presentations presented in February 2017, Brian Campbell (610W/GST) gave a virtual presentation to 55 students in Sunyani, Ghana, on May 12. These presentations focused on several of the NASA GLOBE ENSO Student Research campaigns in hopes that students in Ghana will continue to take GLOBE protocol measurements.

Dorian Janney (612/ADNET), Kristen Weaver (612/SSAI), and Brian Campbell (610W/GST) held their ninth webinar as part of Phase II for the NASA GLOBE ENSO Student Research Campaign on May 16. During this webinar, GLOBE scientists, teachers, and students who have used various instruments to collect data (and enjoyed using technology) shared and reported their data to the participants. The ENSO team shared engineering challenges that can be easily incorporated into classrooms and other settings. The webinar introduced two ways in which the participants can BYOD—“Bring Your Own Device” and engage in the GLOBE Observer Citizen Science efforts. Combining the measurements for Phase I and Phase II of the campaign, there have been almost three-million measurements taken using the selected suite of protocols.

On May 15, Dorian Janney (612/ADNET) presented information on the GPM mission and shared information on the differences between weather and climate for 20 elementary school educators via webinar through the GSFC Digital Learning Network. The teachers are part of a group of educators from New Jersey who had requested training through the GSFC Office of Education.

On May 10, Dorian Janney (612/ADNET) was an invited guest speaker for the Maret School's "Climate Conference" in Washington, DC. She shared information about how the GPM mission is able to measure precipitation from space and listened to the 85 eighth-grade student's speeches. At the end of the conference, she met with small groups and showed them how to download and use the GLOBE Observer Cloud app. After working with the eighth-grade students, she met with the fifth-grade classes (56 students and two teachers) and gave them a presentation about the efforts of NASA Earth Science missions to learn about freshwater resources.

On May 17, Dorian Janney (612/ADNET) presented information on the GPM mission and shared information about freshwater resources to 17 elementary school educators via webinar through the GSFC Digital Learning Network. The teachers are part of a group of educators from New Jersey who had requested training through the GSFC Office of Education.

On May 18, Dorian Janney (612/ADNET) presented information on the GPM mission and shared information about Earth's freshwater resources to 27 secondary school educators via webinar through the GSFC Digital Learning Network. The teachers are part of a group of educators from New Jersey who had requested training through the GSFC Office of Education.

On May 24–27, at the Odyssey of the Mind World Finals, Dorian Janney (612/ADNET) delivered fourteen NASA classroom presentations that focused on teaching participants about the new GLOBE Observer Mosquito Habitat Mapper app to approximately 500 adults and children as well as eight GLOBE Observer Cloud app presentations and hands on activities to demonstrate the GLOBE Observer Cloud app to approximately 300 adults and children. She also gave two large group presentations about the science, technology, and applications of the GPM mission to approximately 200 participants as well as two large group presentations about the new GLOBE Observer Mosquito Habitat Mapper app to approximately 200 participants.

Joe Munchak (612) and Kristen Weaver (612/SSAI) attended the Thomas Jefferson High School for Science and Technology's Symposium to Advance Research in Alexandria, VA, on June 6. They demonstrated live 3D printing of various storm structures measured by the DPR instrument on the GPM satellite, explaining the science behind each storm structure and answering general questions about GPM and NASA earth science.

On June 13, Dorian Janney (612/ADNET) presented on the GPM mission's science and technology to a group of 51 pre-service teachers and their faculty advisors from minority-serving institutions (MSI) in Maryland, New Jersey, and New York. These participants have been selected to participate and continue in a long-term collaboration through the Institutional Engagement line of business.

Brian Campbell (610W/GST) presented at a NASA STEM Education and Accountability Projects (SEAP) workshop at the NASA Wallops Flight Facility's Educator Resource Center on Thursday, June 29, to 35 educators and NASA education staff. Brian presented on the ICESat-2 Missions science and technology and highlighted an educational activity he developed to showcase ICESat-2 photon-counting as part of its laser altimeter.

Brian Campbell (610W/GST) and Valerie Casasanto (610/UMBC) participated in a STEM teacher professional development workshop organized by the Goddard Educator Resource Center entitled "ICESat-2 (Ice, Cloud, and Land Elevation Satellite): A Laser Takes Aim," Thursday, July 6, at the Goddard Visitor Center for middle school and high school teachers. Presentations were given on the ICESat-2 mission and hands-on were performed including a GLOBE clinometer-measuring tree heights activity, and water density experiments related to the global thermohaline circulation system and sea ice.

The NASA Student Airborne Research Program (SARP) recently completed a series of flights over southern California targeting the atmospheric composition impacts of urban pollution, fossil fuel extraction, and wild fires. SARP is an 8-week summer program, operated by NSRC, that immersed 32 rising undergraduate seniors in all aspects of airborne science. GSFC scientists Glenn Wolfe (614/JCET) and Matthew Kowalewski (614/USRA) traveled to Armstrong Flight Research Center to interact with students and facilitate instrument operations on the WFF C-23 Sherpa, and LaRC UC-12B. Jason St. Clair (614/JCET) and Thomas Hanisco (614) also assisted in the effort.

On July 12, Ian Adams (612), David Bolvin (612/SSAI), Dorian Janney (612/ADNET), Joseph Munchak (612), Eric Nelkin (612/SSAI) and Kristen Weaver (612/SSAI) staffed a table about GPM and the work of the Mesoscale Atmospheric Processes Lab at the Goddard Science Jamboree.

Geoffrey Bland (610W) participated in the Worcester County, MD, middle school summer program's full-day workshop, "Reach for the Stars" on July 18. Brian Campbell (610W/GST) led a student discussion and hands-on workshops. This event featured kite building in the Wallops Educator Resource Center and flying on Wallops Island. An introduction to the NASA CANS AEROKATS and ROVER Education Network (AREN) project was also outlined, including a flight demonstration of a camera-carrying Aeropod. The workshop was supported by Code 610.W AREN team members Kay Rufty (615/GST), Brian Campbell (610W/GST), and Ted Miles (610W/Zinger) and was attended by twenty-two students and three educator advisors.

Brian Campbell (610W/GST) gave an online presentation on GLOBE Observer Cloud App on Thursday, July 20. This online presentation was attended by 15 educators from the Delmarva Region. The presentation consisted of cloud identification and current environmental conditions and the importance of satellite measurements.

Dorian Janney (612/ADNET) gave a presentation on the various resources related to the GPM mission that might prove useful for formal and informal educators. She presented this information to the 36 in-service educators who were involved in the GSFC Office of Education Pennsylvania Teacher's Summer Institute. This presentation was given in the GEWA Recreation Center on July 17.

The Pandora Project's Robert Swap (614)—along with the project's large cohort of summer, junior research analysts—presented on their summer activities at GSFC at NASA HQ, the culmination of their 8-week student engagement. JCET and ESSIC assisted with onboarding this interdisciplinary cohort of 15 students from six different universities: American U, MIT, UMD, UMBC, VCU and VT. Students helped to describe the current state of project operations with the intent to move the Pandora project towards an operational network while being exposed to training and team building activities involving personnel from GSFC, Howard, UMBC, UC Irvine, VCU and UVA. The students shared their interests, experiences and contributions especially related to this summer's OWLETS field campaign and the deployment and maintenance of the Pandoras and ancillary instrumentation in support of multi-agency ground-, air- (SARP-E Sherpa), and water-based (SERC Research Vessel) operations.

Anne Thompson (610) was a PhD committee member at the thesis defense of Kenny Christian in the Meteorology and Atmospheric Sciences Department at Pennsylvania State University, held on August 11. Professor William Brune is Christian's advisor. Funded by NASA's ACCDAM ROSES (2013), the title of the thesis was "Global Sensitivity Analysis of the GEOS-Chem Chemical Transport Model for Six NASA Field Campaigns." For model comparisons, the missions provided DC-8 data from east Asia, CONUS, and southern and northern tropics. Generally model and measurements agree well. Global NOx and CO sources are major sources of computed O_3 and OH uncertainties (1–5 km). The photochemical rates to which oxidants are most sensitive, eg the rate of NO + HO_2 reaction, O_3 and NO_2 photolysis, aerosol radical scavenging, are the same as identified in ground-based studies using regional observations in Texas and Denver.

On August 15, in conjunction with Goddard's Office of Education, Gala Wind (613/SSAI) had two high school students from Fairfax County Public Schools shadowing her during a morning session to see what a scientist's day is like. A number of topics were discussed including career choices, what it is really like to do science, and how to continue being successful in the world where there are no longer answers in the back of a textbook (a difficult transition for some). The students visited a flight hardware laboratory, saw the CAR instrument, and discussed instrument calibration, science software development, and general topics of interest.

Santiago Gassó (613/MSU) visited the Colegio Nacional de Buenos Aires, a high school affiliated with the national university. He gave a presentation to the senior class (STEM track) highlighting the research activities carried out at GSFC and NASA.

On September 15, Phase III of the NASA GLOBE ENSO Student Research Campaign commenced. Phase III, entitled, "Water in Our Environment" strives to bring together GLOBE students, educators, researchers, and scientists, for the purpose of taking measurements, in local places, in order to understand water's global impact on our environment. The campaign is led by Brian Campbell (610W/GST) with campaign team members, Dorian Janney (612/ADNET) and Kristen Weaver (612/SSAI). Other team members include those at several NASA centers and partnering programs, including the H2yOu Project. The campaign is based upon students and educators focusing on several campaign guiding investigative questions, which will structure their ground-based measurements and further the ability to use the data collected as data for designing and implementing student research projects. Phase III of the campaign was approved by NASA HQ and the GLOBE Implementation Office and will run from September 2017 through June 2018.

Brian Campbell (610W/GST) gave four virtual presentations to Shumate Middle School in Gibraltar, MI, on September 29. The presentations focused on NASA Earth-observing satellite, the GLOBE Program, and the NASA GLOBE Observer Citizen Science app. Shumate Middle School is a champion in taking GLOBE protocol measurements, doing satellite data/GLOBE data comparisons, and developing research projects using NASA and GLOBE Program science. There were eight classrooms consisting of 260 students and four educators presented to.

Dorian Janney (612/ADNET) presented a webinar to share information about NASA, and educational and career opportunities through NASA to the fifth-grade students at the Maret School on September 29. She used the GPM mission to provide examples of some of the ways in which NASA studies Earth, and included videos giving information about some GPM scientists and engineers. There were 4 staff members and 46 fifth grade students in attendance.

Brian Campbell (610W/GST) gave a virtual presentation about the GLOBE Program and the ENSO Student Research Campaign to 25 graduate students and educators at the Bowling Green State University in Bowling Green, OH, on October 9. The presentation consisted of discussions on the SMAP Mission and the GLOBE SMAP Block Pattern Soil Moisture protocol, the ICESat-2 Mission, the GLOBE Biometry Tree Height Protocol, and many of the protocols that are part of the GLOBE ENSO Student Research Campaign. Participants became part of the ENSO Student Research Campaign and also serve as beta-testers for the new GLOBE Program – ICESat-2 Collaboration.

Holli Riebeek Kohl (610/SSAI) assembled and staffed a table in the NASA booth at the International Balloon Fiesta in Albuquerque, NM, on October 7–15. The table theme was NASA Earth science and included two demos about clouds and aerosols, GLOBE Observer (citizen science), and the Landsat poster/game from the Earth Science Week educator kit. Brent Holben (618) also supported the booth on October 7–9 with a table about aerosols.

Brian Campbell (610W/GST) gave a live seminar to undergraduate students, graduate students, and faculty at the University of Maryland Eastern Shore on October 12. This seminar was part of the School of Agriculture and Natural Sciences Seminar Series. Approximately 50 participants were taught about several NASA missions, including the GPM Mission, SMAP Mission, ICESat-2 Mission, Operation IceBridge Airborne Campaign, AEROKATS Project, and the GLOBE Program. Participants learned the importance of comparing satellite and airborne data with ground-based, in-situ data for satellite data validation and building a robust dataset.

One hundred students from Hansung Science High School (Seoul, South Korea) and 82 students from the Jeon-nam Science High School (Jeon-nam, South Korea) were given official tours of GSFC on October 10 and 13, repectively. Tours included a stop at the James Webb Space Telescope. During the visits, DongMin Lee (613/MSU), DoHyuk King (617/UMD), Ruth C. Carter (401), EunJee Lee (610.1/USRA) and SukBin Kang (673/USRA) volunteered to support NASA's official guide, and Daeho Jin (613/USRA), EunJee Lee (610.1/USRA), JeeWoo Park (672/USRA), and Wonsik Yoon (662/AS&D) gave presentations introducing the students to science and the life of a scientist at NASA.

Brian Campbell (610W/GST) gave a live presentation to 15 pre-service teaching students at the Salisbury University in Salisbury, MD, on Monday, October 9. This presentation focused on NASA's Earth-observing mission, teacher and student resources, and the GLOBE Program. This presentation was part of a teaching methods course.

Peter Colarco (614) was invited to the Department Chemical and Biochemical Engineering at the University of Iowa and presented a seminar, entitled “Aerosol Modeling Capabilities and Applications in the NASA GEOS-5 Earth System Model,” on October 19.

Kristen Weaver (612/SSAI) gave virtual presentations about NASA Earth science and GPM to about 60 4th and 5th graders at St. Paul School in Fenton, MO, on October 19.

Gala Wind (613/SSAI) was one of two Code 600 participants in an event organized by the George Washington (GW) Women in Science and Engineering that hosted students from GW University. The students had a busy day visiting various areas at Goddard and attended a networking lunch where they were given the opportunity to ask scientists and engineers questions on a variety of topics. The visit was led by Blanche Meeson (600) and Tamra Goldstein (580) with the participation of a GSFC team of scientists and engineers.

Brian Campbell (610W/GST) had discussions with educators from Trinidad and Tobago about future GLOBE Program collaboration and measurements aligning to the NASA GLOBE ENSO Student Research Campaign. This campaign is in Phase III: Water in Our Environment. Students and educators from Trinidad and Tobago are active GLOBE members. The ENSO Campaign is led by Brian Campbell.

Brian Campbell (610W/GST) planned and implemented the first Short Observation & Data Analysis (SODA) webinar for the NASA GLOBE ENSO Student Research Campaign on November 6. This webinar featured Shumate Middle School teacher Jeff Bouwman and his students' GLOBE protocol research. The monthly SODA webinars focused on the data collected during the SODA event. Several schools (teachers and students) presented their data collection and what the data revealed about water in our environment.

Each school presenting at a SODA webinar collaborated with another school or schools to take some of the same measurements and answer the same questions.

Graham R. Allan (614/Sigma) gave a talk to approximately 30 high school students from the Delaware Science Olympiad at Goddard's Visitor Center on November 17. The talk was entitled "CO_2 Sounder Development at NASA-GSFC for the ASCENDS Mission," and it highlighted the work of various disciplines required to develop laser sensors to measure trace gases in the atmosphere.

On November 21, Dorian Janney (612/ADNET) ran the NIH Children's Inn Family Night Program in Bethesda, MD. She focused on the formation and structure of stars and helped the 16 children and 14 adults make solar cookies.

Brian Campbell (610W/GST) held the second informational webinar for the NASA ICESat-2 and GLOBE collaboration's Educator Beta-Testers Group on November 13. The group is composed of educators and students from around the world who are taking tree height measurements that will eventually complement the ICESat-2 sensor-based tree height data. This beta-testing group began measurements one-year prior to the ICESat-2 launch, scheduled in September 2018.

On November 14, Dorian Janney (612/ADNET) planned and implemented the third NASA GLOBE ENSO Student Research Campaign Monthly Science and Research Webinar for Phase III: Water in Our Environment. This webinar focused on water quality in Europe and Eurasia. Guest speakers were educators and researchers from Croatia, Poland, and Switzerland. Dorian presented on the remote sensing of NASA satellites and Brian Campbell (610W/GST) presented on the past and upcoming campaign Short Observation & Data Analysis (SODA) webinars. There were approximately 30 participants from across the globe.

Over the past year, Kristen Weaver (612/SSAI) and Brian Campbell (610W/GST) gave virtual distance learning presentations on the GPM and SMAP missions, respectively, to educators, through the Goddard Education Office's Distance Learning Program. With this information, one group of teachers and students participated in the First Lego League Competition in Noble, OK, in November 2017. The teams were challenged how to find, use, transport, and dispose of water in the human water cycle. This included looking at precipitation and soil moisture data. The students took measurements and also research data from other students on the GLOBE Programs web site. The team, Warrior Cats First Lego League Robotics Team, came in second in the qualifier, and are now headed to the First Lego League Oklahoma State Finals on December 9 in Norman, OK, by focusing on trees and soil as part of their solution to their human water cycle investigation.

Brian Campbell (610W/GST) gave a virtual presentation on November 27 about the GLOBE ENSO Student Research Campaign to students and teachers at two schools in Croatia: the Osnovne Škole Varaždin and the Medicinska Škola Varaždin. Students and teachers from both schools would be presenting on December 4 at the next Short Observation & Data Analysis (SODA) webinar as part of the ENSO Campaign's Phase III: Water in Our Environment. These presentations would be a collaborative effort between the schools and their research on the Plitvica River in Croatia.

Dorian Janney (612/ADNET) had an online training with the assistant principal of Suncrest Elementary School in Morgantown, WV, on November 27, to assist him in setting up the GLOBE atmosphere site in order to get their staff prepared for an online meeting this week in which they will learn how to input their GLOBE daily atmosphere data.

Brian Campbell (610W/GST) gave a virtual lesson on how to do the GLOBE SMAP Block Pattern Soil Moisture Protocol to students from the Brazil School in Trinidad and Tobago, on December 7. The students will be taking SMAP soil moisture measurements and uploading their data to GLOBE as part of the NASA GLOBE ENSO Student Research Campaign.

Brian Campbell (610W/GST) held the second NASA GLOBE ENSO Student Research Campaign's Shot Observation and Data Analysis (SODA) webinar on December 4, entitled "Live from Croatia." There were presentations from students from the Osnovne Skole Varazdin and Medicinska Skola Varazdin. The webinar was attended by over 20 educators and students from 5 countries, including, Croatia, Netherlands, Switzerland, Trinidad and Tobago, and the United States (including Puerto Rico).

Brian Campbell (610W/GST) gave a virtual presentation to the Brazil School's Environmental Club from Trinidad and Tobago on December 8. This presentation focused on NASA Earth Science and related GLOBE protocol measurements. The environmental club will begin taking a suite of measurements that explore several of the NASA GLOBE ENSO Student Research Campaign's "Guiding Investigative Questions." There were 35 students and 3 teachers present.

Dorian Janney (612/ADNET) led the fourth NASA GLOBE ENSO Student Research Campaign's Monthly Science & Research webinar on December 7. The webinar, entitled "Making Sense of the Impacts of Water in our Environment by Measuring Earth's Water from Space," featured Matt Rodell (617). Matt discussed Earth's water cycle, the importance of being able to collect measurements during each phase of the water cycle, and how and why some NASA Earth observing satellites measure water both above and below ground. He also shared some of the ways in which NASA Earth-observing satellite data is used in real-world applications; such as agriculture, landslides, flooding, and drought response and monitoring. A demonstration of NASA's Wavelength Tool was provided, allowing participants to see lists of good teaching resources related to floods, erosion and landslides, and agriculture.

6.3. Lectures and Seminars

One aspect of public outreach includes the seminars and lectures held each year and announced to all our colleagues in the area. Most of the lecturers come from outside NASA, and this series gives them a chance to visit with our scientists and discuss their latest ideas with experts. The following lectures were presented in 2017 among the various laboratories.

Table 6.1: Atmospheric Sciences Distinguished Lecture Series

Seminar Series Coordinators: Luke Oman

Date	Speaker	Title
February 16	Diego Loyola Code 614, German Aerospace Center (DLR)	*Computational Intelligence Techniques in Remote Sensing*
March 16	Kirk Knobelspiesse Code 616, Ocean Ecology Laboratory	*Multi-angle polarimetry: the once and future king (of aerosol remote sensing)*
May 9	David J. Diner Jet Propulsion Laboratory, Caltech	*Techniques and applications of multiangle spectropolarimetric imaging*
May 18	Steven J. Goodman NOAA/NESDIS GOES-R Program Office	*GOES-R (GOES-16): Introduction and First Results*
June 15	Sid A. Boukabara NOAA/NESDIS STAR	*Environmental Data Fusion: Combining Satellite Remote Sensing and Data Assimilation Techniques for NWP and Situational Awareness Applications. Assessment Using OSSE CGOP Testbed.*

Date	Speaker	Title
August 17	Christopher Ruf Climate and Space Department, University of Michigan	*Early On-Orbit Results for the NASA Cyclone Global Navigation Satellite System*
September 19	Harshvardhan Dept. of Earth, Atmospheric and Planetary Sciences, Purdue University	*Aerosols: Smoke and Mirrors of the Climate System*
September 21	Jerry Harrington The Pennsylvania State University	*Predicting Ice Particle Properties in Bulk Microphysical Models: Informed with Measurements, Impacts on Cloud Systems*
December 20	Christian Frankenberg Jet Propulsion Laboratory, California Institute of Technology	*Solar Induced Chlorophyll Fluorescence: Past success stories and challenges ahead*

Table 6.2: Climate and Radiation

Seminar Series Coordinators: Robert Levy, Yaping Zhou, Hongbin Yu and Lauren Zamora

Date	Speaker	Title
January 4	Frank Werner UMBC	*Quantifying the impact of subpixel reflectance variability on cloud property retrievals using high-resolution ASTER observations*
January 18	Stephen Nicholls Code 612, UMBC	*Out of this world: An evaluation of infrared and microwave sounding data for characterizing the dynamics and evolution of the Saharan Air Layer in North Africa*
February 1	Jae N. Lee Code 613, UMBC	*The Role of the Sun in Climate*
February 15	David D. Turner Earth System Research Laboratory/NOAA	*Improving Longwave Radiative Transfer Models via Field Experiments and Its Impact on a GCM*
February 21	Stephen Warren University of Washington, Seattle	*Bubbles in ice: radiative transfer on the tropical ocean of Snowball Earth*
March 1	Katrina Virts USRA-NPP, Marshall Space Flight Center	*Intraseasonal Variability in the Structure and Lightning Production of Tropical MCSs*
March 15	Sergey Korkin Code 613, USRA	*Radiative Transfer in the Atmosphere: Some Numerical Methods and Native Vector RT Codes*
March 29	Adrian Loftus Code 613, UMD	*Observational and modeling efforts to better quantify aerosol-cloud-precipitation processes and interactions*
April 5	Eric Wilcox Desert Research Institute	*Dynamics of cumulus clouds in the presence of black carbon aerosol*
April 12	Jackson Tan Code 613, USRA	*Evaluating Rainfall Errors in Global Climate Models through Cloud Regimes*
May 3	Anton Darmenov Code 610.1, GMAO	*A study of the 2016 post-monsoon air pollution event over India using the GMAO GEOS system*
May 17	Steve Palm Code 612, SSAI	*New Perspectives on Blowing Snow Transport, Sublimation, and Layer Thermodynamic Structure over Antarctica*
June 21	Tao Wang Code 613, UMD	*Cloud regime evolution in the Indian monsoon intraseasonal oscillation: Connection to large-scale dynamical conditions and the atmospheric water budget*

September 20	Jie Gong Code 613, USRA	*What Ice Microphysical Characteristics Can We Tell from Passive Microwave Polarimetric Measurements?*
October 5	Verity J. Flower Code 613, USRA/NPP	*Volcanology from space: Characterizing eruptions and their corresponding geological implications using space-borne remote sensing data*
October 18	Jianjun Liu UMD/ESSIC	*Aerosol Indirect Effects: Uncertainties and Influential Factors as Inferred from Ample Measurements by Different Platforms*
November 1	Antonia Gambacorta NOAA-NESDIS	*Converting satellite based hyperspectral measurements into climate data records: from theory to algorithm implementation*
November 15	Chenxi Wang Code 613, UMD/ESSIC	*Infrared, a shy spectral region that always tells us the truth indirectly: Advantages and Challenges of Using Infrared Observations in Cloud Remote Sensing Applications*
November 29	Gala Wind Code 613, SSAI	*Multi-sensor Cloud and Aerosol Retrieval Simulator and Its Applications*

6.4. Maniac Talks

Maniac Talks are about what inspired people to do what they are doing now in their career. They are about the driving forces and motivators. What keeps them going? How have they overcome obstacles?

Table 6.3: Maniac Talks

Maniac Talk POC: Charles Gatebe, GESTAR-USRA, Climate and Radiation Laboratory

Date	Speaker	Title
February 22	Arlin Krueger NASA GSFC,Atmospheric Chemistry & Dynamics Laboratory, Emeritus	*Why don't you measure ozone?*
March 22	Michelle Thaller NASA GSFC: Assistant Director of Science for Communications	*Emotional Science*
April 20	Sara Tangren University of Maryland, College Park	*NASA's Meadow Garden*
April 5	J. Vanderlei Martins University of Maryland, Baltimore County	*From the atom to the atmosphere and beyond*
May 24	Peter Pilewskie University of Colorado Boulder	*Better to be Lucky than Good …*
June 28	Arthur Frederick “Fritz” Hasler 610, Emeritus	*50 years of looking at Earth, on the 50th anniversary of ATS-1 and the Suomi Spin Scan Camera*
July 26	Belay Demoz UMBC	*My Journey from the Horn of Africa to NASA!*
August 16	Antonio Busalacchi University Corporation for Atmospheric Research (UCAR)	*From Here to Boulder: With Apologies to Burt Lancaster*
October 13	J. Marcos Sirota Sigma Space Corporation	*Can introvert scientists become good entrepreneurs?*
November 1	Michael H. Freilich NASA Headquarters	*From Beaches to Bureaucracy -- Evolution(?!) of a Career(?)*

Table 6.4: Atmospheric Chemistry and Dynamics

Date	Speaker	Title
January 12	Anne Douglass NASA/GSFC, Atmospheric Chemistry and Dynamics Laboratory, Code 614	*Nominations! What I learned on the AGU and AMS Fellows Committees*
January 19	Rebecca Wilson University of Edinburgh	*Measurements of isoprene mole fraction above an Australian rainforest*
February 23	Haris Riris NASA/GSFC, Atmospheric Chemistry and Dynamics Laboratory, Code 614	*Methane measurements from space: technical challenges and status*
March 2	P.K. Bhartia NASA GSFC, Earth Sciences Division-Atmospheres, Code 610	*Successes and challenges in Space-based measurement of trace gas and aerosol pollutants*
March 9	Susan Strode and Jerry Ziemke Code 614, USRA and Code 614, MSU	*Ozone in Deep Convective Clouds: satellite Observations and Application to Chemistry Climate Models*
March 30	Earnest Nyaku Hampton University	*Stratospheric Aerosol Phase function and its Importance on Extinction Retrievals from Limb Scatter Radiance*
April 6	Can Li Code 614, UMD	*Principle Component analysis technique for satellite trace gas retrievals: Recent progresses and next steps*
May 11	P.K. Bhartia NASA GSFC, Earth Sciences Division-Atmospheres, Code 610	*50th anniversary of first paper on BUV total ozone algorithm and its impact on ozone research at NASA*
May 18	Julie Nicely Code 614, UMD	*Quantifying the drivers of CH_4 lifetime differences between the CCMI models*
May 25	Clara Orbe USRA	*Comparison of Large-Scale Tropospheric Transport among the Chemistry Climate Model Initiative (CCMI) Simulation*
June 1	Ryan Stauffer USRA	*Informed Ozone Profile Climatologies using Ozonesondes and MERRA-2 Reanalyses*
June 8	Daniele Visioni University of L'Aquila, Italy	*Sulfate geoengineering: factors controlling the needed injection of sulfur dioxide*
June 15	Diego G. Loyola Rodriguez Code 614, UMBC	*The operational L2 retrieval algorithms for Sentinel-5 Precursor and Sentinel 4*
June 29	Jay Herman Code 614, UMBC	*Pandora NO_2, O_3 and Validation*
July 13	Luke Oman NASA GSFC, Atmospheric Chemistry and Dynamics Laboratory, Code 614	*MERRA-2 GMI simulation*
August 31	Pandora Project Students	*Pandora Project*
September 7	Anne Thompson and Jacquie Witte NASA GSFC, Atmospheric Chemistry and Dynamics Laboratory, Code 614 and Code 614, SSAI	*What's New in SHADOZ? Data Collection, JOSIE-2017, and Sonde Reprocessing*

Date	Speaker	Title
October 26	Haris Riris NASA GSFC, Atmospheric Chemistry and Dynamics Laboratory, Code 614	*The CO_2 Sounder and the ASCENDS mission*
November 16	Olga Tweedy JHU	*Transport processes and variability of the tropical lower stratosphere composition*
December 7	Julie Nicely Code 614, UMD	*Ongoing adventures with hydroxyl radical*

6.5. AeroCenter Seminars

Aerosol research is one of the nine crosscutting themes of the Earth Sciences Division at NASA's Goddard Space Flight Center. AeroCenter is an interdisciplinary union of researchers at Goddard and other organizations in the Washington, D.C., metropolitan area (including NOAA, NIST, universities, and other institutions) who are interested in many facets of atmospheric aerosols. Interests include aerosol effects on radiative transfer, clouds and precipitation, climate, the biosphere, and atmospheric chemistry the aerosol role in air quality and human health; as well as the atmospheric correction of aerosol that blur satellite images of the ground. Our regular activities include strong collaborations among aerosol community, bi-weekly AeroCenter seminars, annual poster session, and annual AeroCenter updates.

6.6. NASA Cloud-Precipitation Center Annual Report

Cloud and precipitation processes and feedback remain among the largest uncertainties for predicting Earth's energy and water cycle and budget, as well as their socio-economic impacts such as agricultural harvest, water resource management, and even power generation. In order to increase knowledge and understanding of these processes, the NASA GSFC Cloud-Precipitation Center (CPC), was established in 2016 as a cross-laboratory union for cloud-precipitation researchers primarily at GSFC. CPC offers discussions and collaborations across NASA laboratories through an interactive seminar series.

In the 2016–2017 season, CPC hosted 13 seminars, and the current CPC membership stands at 75. Main seminar topics include (1) cloud-precipitation processes and interactions with surface process, aerosols, mesoscale dynamics, and large-scale circulations, (2) remote sensing, radiative transfer, and scattering theory of cloud and precipitation particles, (3) cloud microphysics and convection measurements and parameterizations, and (4) satellite missions and field campaigns associated with cloud and precipitation processes.

6.7. Public Outreach

Brian Campbell (610W/GST) gave the introductory talk, to 38 public participants, at the "STEM Saturdays: Engineering Challenge–Satellite" event at the NASA Wallops Visitors Center on Saturday, March 18. Brian presented the engineering of the GLAS instrument onboard the ICESat satellite versus the ATLAS instrument onboard the ICESat-2 satellite. The Wallops region debut of ICESat-2's new animated short, called "Photon Jump" was a huge hit with the crowd.

Dorian Janney (612/ADNET) presented information about NASA and the exciting new discoveries that NASA scientists are making. She also had a hands-on activities for the 36 participants, which included NIH Children's Inn staff and visiting families.

Communication

Dorian Janney (612/ADNET) has been working with the World Bank to assist with helping some of their advisors to understand and utilize GPM data to inform their decision-making process. She created the outline for an e-book (see http://www.appsolutelydigital.com/Nasa/index.html) and assisted with the development and presentation of the face to face training for World Bank managers on World Water Day, March 22, in Washington, D.C. She is continuing to assist with managing a collaborative process between NASA Earth Scientists, ARSET trainers, and the World Bank end-users.

Brian Campbell (610W/GST) and Dorian Janney (612/ADNET) presented at the virtual NASA Beginning Engineering, Science, and Technology (BEST) Earth Right Now Workshop on March 27. The BEST Workshop was cohosted by the NASA Education Offices at the Goddard Space Flight Center and the Goddard Institute for Space Studies. Brian presented on the NASA Soil Moisture Active Passive (SMAP) Mission, the GLOBE Program and the GLOBE ENSO Student Research Campaign. Dorian presented on the NASA Global Precipitation Measurement (GPM) Mission and the many NASA precipitation education resources available to educators. This virtual workshop was attended by 101 educators from nineteen states and multiple countries.

Dorian Janney (612/ADNET) did a webinar for the HBCU NASA STEM Professional Development consortium. This group included pre-service educators from the following universities: Bowie State, Morgan State, University of Maryland Eastern Shore, and Coppin State University. She described many aspects of NASA's current Earth Science mission science related to Earth's water cycle and featured the science and technology behind the GPM mission. She also showed the 62 participants how to access, become trained, and use the GLOBE Program.

Dorian Janney (612/ADNET) presented a talk about GPM's ground validation campaigns at the NSTA annual conference. She shared many ways that teachers and curriculum developers could use the real world applications of these ground validation campaigns when teaching the NGSS to students in secondary school as well as in-service and pre-service teachers. She had 57 participants for this presentation.

Dorian Janney (612/ADNET) gave a presentation at the NSTA annual convention on the science behind watershed regions and how they are being studied by different NASA Earth observing missions. She shared examples of data collected on watershed regions around the world using different satellites and gave some examples of way in which teachers and curriculum developers could use these real-world examples to teach the NGSS across all grade levels, as well as with in-service and pre-service teachers. There were over 70 participants at this presentation.

On April 15, Kristen Weaver (612/SSAI) staffed a table at the Greenbelt Maker Festival featuring the GPM mission and showcasing easy-to-make models of the satellite and a visualization of precipitation data using plastic bricks and 3D-printed components.

Dorian Janney (612/ADNET) assisted with the NIH Children's Inn visit which took place at the GSFC Visitor's Center from 4 to 6 p.m. She showed the 21 children and 18 adult participants how and why NASA's GPM Core Observatory is studying precipitation from space.

Brian Campbell (610W/GST), Dorian Janney (612/ADNET), and Kristen Weaver (612/SSAI) held the eighth webinar for Phase II of the NASA GLOBE ENSO Student Research Campaign on April 25. This webinar focused on the various ways all citizens can be engaged in helping make our home planet a better place. Participants learned how this is possible through both the GLOBE Program and the GLOBE Observer app. The webinar also looked at the current status of Earth's "vital signs" from NASA's Global Climate Change web site and heard about the efforts that are currently underway within many federal agencies to enable individuals to become involved as citizen scientists. Guest speakers from SciStarter and The H2yOu Project highlighted education and citizen science efforts from their programs.

On April 28, Bryan Duncan (614), Steven Pawson (610.1/GMAO) and Danielle Wood (610) met with UNICEF representatives (Toby Wicks, Nick Rees, and Mark Anthony and others) at UNICEF HQ in New York City. The purpose of the meeting was to coordinate the use of GMAO air quality forecasts by UNICEF to alert parents of children with respiratory diseases of impending poor air quality. This effort was initiated by Duncan and Lok Lamsal (614/USRA) through their NASA Health and Air Quality Applied Sciences Team (HAQAST) project, which has the focus to create a satellite-based, multi-pollutant health air quality index (HAQI). Duncan and Lamsal are working with Kevin Cromar (NYU) to formulate the HAQI, which will be based on the relationship of pollutant concentrations and health outcomes. Duncan identified UNICEF as a potential user of GMAO's air quality forecasts at the GSFC Applied Sciences Health and Air Quality Showcase on Nov. 17th, 2016. UNICEF's contribution to the project includes developing messaging for the air quality forecasts to reach communities in the countries where UNICEF serves. Ana Prados (614/UMBC) presented on the NASA ARSET training program.

May 5, 2017, Take Your Child to Work Day: Dorian Janney (612/ADNET) assisted with this year's activities at the State Department and gave a presentation on how to use the upcoming GLOBE Observer mosquito app, using microscopes and slides for the participants to identify the life cycle and types of mosquitos. The State Department had a speaker share information on how they assist countries in identifying and responding to mosquito-borne disease outbreaks. After working with four groups of children, ages 9 through 15, she worked with a small group of State Department employees who wanted to learn more about the GLOBE Program's mosquito protocol and the GLOBE Observer app. She worked with 60 children and 60 adults, as well as with four State Department employees throughout the day. Trena Ferrell (610) also assisted with solar eclipse activities.

Maurice Henderson (HGB) (613/ADNET) supported the Quick Deploy Science on a Sphere at the international Association for Research in Vision and Ophthalmology conference in Baltimore. The exhibit was titled "World Vision on a Sphere, with ARVO covering the logistics expense. The exhibit afforded us an opportunity to explain to a new audience the wide range of NASA data that is available to researchers. Visitors often learned of tools for accessing NASA data, and about programs that support emergency responses. Data that is contributed to the SERVIR collaboration such as AURA and AQUA aerosol and other atmospheric products was shared with the researchers. Specific visualizations for global blindness and vision impairment starting in 1990–2015 were built using GIS tools and data from the new Global Vision Database (GVD). The researcher that built the GVD Vision Atlas felt the exhibition was a very effective way to increase awareness and gain support for their work.

Brian Campbell (610W/GST) and Trena Ferrell (610) attended and presented at the 2017 Odyssey of the Mind World Finals in East Lansing, Michigan May 24–27. Brian gave two talks on the ICESat-2 Mission entitled, "ICESat-2 with Pho" and two talks on the NASA GLOBE ENSO Student Research Campaign entitled, "GLOBE ENSO Student Research Campaign." Brian also led eighteen, 30-minute workshops. Fourteen presentations on the "ICESat-2 Bouncy Ball Photon Counting Activity" and four presentations on the "GLOBE Observer Cloud App."

On May 18, Kristen Weaver (612/SSAI) presented a poster titled "GLOBE Observer: Bridging Students, Scientists, and Citizens" at the Citizen Science Association Conference in Saint Paul, Minnesota, as well as staffing tables with Sarah McCrea (LaRC) about GLOBE Observer at the public "Night in the Cloud" event at the convention center on May 19 and the Citizen Science Festival at the Science Museum of Minnesota on May 20.

GLOBE Northeast/Mid–Atlantic Student Research Symposium was held at Palmyra Cove Nature Center, NJ, May 19 and 20. Todd Toth (160/ADNET) sponsored students from Gettysburg, Pennsylvania, area schools. Larger than expected number of students involved. All went well. Todd also visited a number of Pennsylvania schools to help implement GLOBE into existing science/environmental curriculum areas.

On June 6, the GLOBE Observer team, including Kristen Weaver (612/SSAI), held a Facebook Live event that went behind the scenes with the app development team. The post had a reach of over 250,000 people, and the video has nearly 40,000 views. On June 6–7, webinars about the GLOBE Observer Mosquito Habitat Mapper were held as part of a collaboration between GLOBE and the Association of Science-Technology Centers and the Global Experiment they are planning through their annual International Science Center and Science Museum Day. The webinars were organized by Dorian Janney (612/ADNET) and supported by Kristen Weaver (612/SSAI) and Peter Falcon (JPL).

Brian Campbell (610W/GST) traveled to Poland, June 6–14, as part of a program organized by the United Nations Environment Programme's Global Resource Information Database (GRID) and funded by the United States Embassy in Warsaw, Poland. On June 8, Brian gave three presentations organized by the U.S. Embassy – Warsaw. From June 9–12, Brian attended the 2017 Poland GLOBE Games in the town of Ruciane-Nida, Poland. During the GLOBE games, Brian organized several research stations and gave several presentations regarding NASA Earth Science, the GLOBE Program, NASA satellite imagery. During the closing ceremonies, Brian received a plaque from the mayor of Ruciane-Nida that features the town emblem. On June 13, Brian traveled to XIX LO im. Powstańców Warszawy, a very active GLOBE high school for 11th and 12th graders, where he presented on NASA-GLOBE and students presented their research using GLOBE measurement protocols.

Brian Campbell (610W/GST) gave two workshops at the NASA Wallops Visitors Center's "STEM Saturday" event. In the first workshop, "NASA Wallops Paper Airplane Engineering Challenge," 65 participants built paper airplanes, flew them, then engineered them to fly better. A friendly completion included the calculation of flight distance versus flight time. The second workshop was the "GLOBE Observer Cloud Citizen Science Training" where 35 participants learned all about clouds, how to identify them, and why studying them is important. Following the presentation, Brian led participants in doing real-time cloud observation via the NASA GLOBE Observer App.

On June 26th, Dorian Janney (612/ADNET) was an invited presenter for the State Department's National Foreign Service Institute's Environment, Science, Engineering, and Technology Institute. In Arlington, VA. She shared information on the new GLOBE Observer Mosquito Habitat Mapper with the 32 Foreign Service officers as well as 5 State Department staff who attended the training. The participants learned how to use this app and had the opportunity to use live mosquito larvae to identify and photograph. This training was a joint Federal agency effort to assist embassies around the world to engage in a variety of U.S.-led efforts to improve environmental and health conditions in their regions.

On June 19th, Dorian Janney (612/ADNET), Brian Campbell (610W/GST) and Kristen Weaver (612/SSAI) held the tenth webinar for the GLOBE Program ENSO Student Research Field Campaign. The focus was on the new GO Mosquito Habitat Mapper, and the NASA SME guest presenter was Assaf Anyamba, who shared his research on using NASA satellite data to better understand the teleconnections between the ENSO patterns and Rift Valley Fever in parts of Africa.

Andrew Sayer (USRA/613) was featured in the "Conversations with Goddard" series, discussing his work and background, https://cms.nasa.gov/feature/goddard/2017/andrew-sayer-takes-a-world-view.

On July 17, Dorian Janney (612/ADNET) gave a presentation about GPM and related educational resources to a workshop held at Goddard for a group of teachers from Pennsylvania.

Earth Science participated in Artscape 2017, in Baltimore, MD, from July 21 to 23. The following people participated with hands on activities:

- Valerie Casasanto (610/UMBC)—IceSat 2
- Dorian Janney (612/ADNET)—GPM
- Kristen Weaver (612/SSAI)—GPM

Brian Campbell (610W/GST) traveled to Reading, Pennsylvania, and the Reading Museum's Neag Planetarium July 24–26. During his visit, Brian gave a presentation on the ICESat-2 Mission, a hands-on, interactive talk on the ICESat-2 Mission and a lecture on the ICESat-2 Mission in the Neag Planetarium, which was featured in the Reading Eagle newspaper and on WFMZ, Channel 69 News during the 10:30 p.m. broadcast on July 25.

The GPM team has been visualizing Hurricane Irma observations since it intensified in the Atlantic and subsequently made landfall in Florida. In addition, the team fielded several interviews including Rob Gutro for BBC London (Skype, 9/9), Scott Braun for MSNBC (instudio, 9/9), Dalia Kirschbaum for BBC London (Skype, 9/10) and CTV (Facetime, 9/10), and Owen Kelley for CNBC Asia (Skype, 9/11). Relevant Core Observatory overpasses and IMERG graphics are being posted at https://pmm.nasa.gov/.

Kristen Weaver (612/SSAI) and Trena Ferrell (610) organized and implemented Sunday Experiment at the Visitors Center on September 17 to kick of the new season. The theme was STEAM and Sound (with a live NASA DJ). There were over 50 that attended.

On October 27, Space.com picked up the GPM video of the rapid intensification of four Atlantic basin hurricanes in the 2017 season. https://www.space.com/38529-nasa-satellites-study-rapidlyintensifyinghurricanes.html. There was an audience of 1,893,469.

On November 30, Kristen Weaver (612/SSAI) hosted a table about GLOBE Observer at a Citizen Science Expo organized by the National Academy of Sciences and held at the National Academy of Science's Keck Center in Washington, D.C.

ATMOSPHERIC SCIENCE IN THE NEWS

The following pages contain summaries and links to articles and press releases that describe some of the Laboratory's activities that were covered by the news or science organizations during 2017.

1. NASA study finds a connection between wildfires and drought

Various factors influence African droughts, however the relationship between fire and the water in northern sub-Saharan Africa had never been comprehensively investigated until recently.

PHYS ORG
10 January 2017, by Samson Reiny
https://phys.org/news/2017-01-nasa-wildfires-drought.html

2. NASA makes an EPIC update to website for daily Earth pics

NASA has upgraded its website that provides daily views of the Earth from one million miles away using the Earth Polychromatic Imaging Camera (EPIC) camera.

PHYS ORG
3 February 2017, by Rob Gutro
Environmental Research Letters (2016). DOI: 10.1088/1748-9326/11/9/095005
https://phys.org/news/2017-02-nasa-epic-website-daily-earth.html
Source: Goddard Space Flight Center

3. From volcano's slope, NASA instrument looks sky high and to the future

An instrument called the miniaturized laser heterodyne radiometer, or mini-LHR, measures the total amount of methane and carbon dioxide in the atmospheric column.

PHYS ORG
26 April 2017, by Elizabeth Zubritsky
https://phys.org/news/2017-04-volcano-slope-nasa-instrument-sky.html
Source: Goddard Space Flight Center

4. Spotting Mysterious Twinkles on Earth From a Million Miles Away

An image from the DSCOVR satellite, taken on Dec. 3, 2015, shows a glint over central South America.

NY Times
19 May 2017, by Nicholas St. Fleur
https://www.nytimes.com/2017/05/19/science/dscovr-satellite-ice-glints-earth-atmosphere.html?_r=1
Source: Goddard Space Flight Center

5. NASA to measure greenhouse gases over the mid-Atlantic region in May
In May, a team of Goddard scientists, headed by Paul Newman and Randy Kawa, will begin measuring greenhouse gases over the Mid-Atlantic region that influences the exchange of carbon dioxide and methane between the Earth and the atmosphere.

PHYS ORG
2 May 2017, by Lori Keesey
https://phys.org/news/2017-05-nasa-greenhouse-gases-mid-atlantic-region.html
Source: Goddard Space Flight Center

6. Why The Right Side of a Hurricane is Particularly Dangerous
It is probably better understood that the storm surge and tornadoes threats are greater in the right-front quadrant of landfalling hurricanes.

Forbes
13 September 2017, by Marshall Shepherd
https://www.forbes.com/sites/marshallshepherd/2017/09/13/why-the-right-side-of-a-hurricane-is-particularly-dangerous/#5a72a13a6e16

7. The Earth's ozone hole is shrinking and is the smallest it has been since 1988
Weather conditions over Antarctica were a bit weaker and led to warmer temperatures, which slowed down ozone loss," in 1988.

The Washington Post
3 November 2017, by Marwa Eitagouri
https://www.washingtonpost.com/news/speaking-of-science/wp/2017/11/03/the-earths-ozone-hole-is-shrinking-and-is-the-smallest-its-been-since-1988/
Source: Goddard Space Flight Center

8. Concerns for ozone recovery
A concern exists for ozone layer recovery due to incomplete compliance with the Montreal Protocol, which will impact stratospheric ozone for many decades, as well as rising natural emissions as a result of climate change.

Science
8 December 2017
http://science.sciencemag.org/content/358/6368/1257
Source: Goddard Space Flight Center

9. Climate change mitigation and compliance with the Montreal Protocol are crucial for ozone layer recovery

The Montreal Protocol has been a huge success, nevertheless the long-lived controlled substances, the majority released before 1987, are projected to still comprise 56 percent of the total stratospheric chlorine and bromine in 2050.

Science Daily
15 December, 2017 Released by Goddard Space Flight Center
https://www.sciencedaily.com/releases/2017/12/171214144436.htm
Source: Goddard Space Flight Center

ACRONYMS

Acronyms defined and used only once in the text may not be included in this list. GMI has dual definitions. Its meaning will be clear from context in this report.

3D	Three Dimensional
7-SEAS	Seven SouthEast Asian Studies
AAAS	American Association for the Advancement of Science
ACATS	Airborne Cloud-Aerosol Transport System
ACE	Aerosols, Clouds, and Ecology
ACE	Aerosols-Clouds-Ecosystems
ACHIEVE	Aerosol, Cloud, Humidity, Interactions Exploring and Validating Enterprise
ACRIM	Active Cavity Radiometer Irradiance Monitor
ACRIMSAT	Active Cavity Radiometer Irradiance Monitor Satellite
ADM	Atmospheric Dynamics Mission
AEROKATS	Advancing Earth Research Observation Kites And Tether Systems
AERONET	Aerosol Robotic Network
AETD	Applied Engineering and Technology Directorate
AFI	American Film Institute
AGU	American Geophysical Union
AI	Aerosol Index
AirMSPI	Airborne Multi-angle Spectro-Polarimetric Imager
AIRS	Atmospheric InfraRed Sounder
ALVICE	Atmospheric Lindar for Validation, Interagency Collaboration and Education
AMA	Academy of Model Aeronautics
AMMA	African Monsoon Multidisciplinary Activities
AMS	American Meteorological Society
AMSR-E	Advanced Microwave Scanning Radiometer–Earth Observing System
AMSU	Advanced Microwave Sounding Unit
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
ARAMIS	Application Radar á la Météorologie Infra-Synoptique
ARC	Ames Research Center
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARI	Average Recurrence Interval
ARM	Atmospheric Radiation Measurement
ASCENDS	Active Sensing of CO_2 Emissions over Nights, Days, and Seasons
ASIF	Air Sea Interaction Facility

Acronyms

ASR	Atmospheric System Research
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AT	Atmospheres
ATM	Airborne Topographic Mapper
ATMS	Advanced Technology Microwave Sounder
AVHRR	Advanced Very High Resolution Radiometer
BC	Black Carbon
BESS	Beaufort and East Siberian Sea
BEST	Beginning Engineering Science and Technology
BMKG	Meteorological Climatological and Geophysical Agency
BRDF	Bidirectional Reflectance-Distribution Functions
CALIOP	Cloud-Aerosol LIdar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAR	Cloud Absorption Radiometer
CASI	Climate Adaptation Science Investigation
CATS	Cloud Aerosol Transport System
CCAVE	CALIPSO-CATS Airborne Validation Experiment
CCM	Chemistry-climate Model
CCMVal	Chemistry Climate Model Evaluation
CCNY	City College of New York
CERES	Cloud and Earth Radiant Energy System
CF	Central Facility
CFC	Chlorofluorocarbons
CFTD	Contoured frequency by temperature diagrams
CHIMAERA	Cross-platform High-resolution Multi-instrument AtmosphEric Retrieval Algorithms
CINDY	Cooperative Indian Ocean experiment on intraseasonal variability
CIRC	Continual Intercomparison of Radiation Codes
CLEO	Conference on Lasers and Electro-Optics
CO	Carbon Monoxide
COMMIT	Chemical, Optical, and Microphysical Measurements of In-situ Troposphere
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
COSP	CFMIP Observation Simulator Package
CPL	Cloud Physics Lidar
CPL	Cloud Physics Lidar
CR	Cloud regimes
CrIS	Cross-track Infrared Sounder

CRM	Cloud-resolving Models
CRM	Cloud-resolving models
CRS	Cloud Radar System
DB-SAR	Digital Beam-forming Synthetic Aperture Radar
DISC	Data and Information Services Center
DISCOVER-AQ	Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality
DLN	Digital Learning Network
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DOD	Department of Defense
DOE	Department of Energy
DOW	Doppler on Wheels
DPR	Dual-frequency Precipitation Radar
DSCOVR	Deep Space Climate Observatory
DT	Dark-target
DYNAMO	Dynamics of the Madden-Julian Oscillation
EC	Environment Canada
ECO-3D	Exploring the Third Dimension of Forest Carbon
ECS	Equilibrium Climate Sensitivity
EDOP	ER-2 Doppler Radar
EEMD	Ensemble Empirical Mode Decomposition
ENSO	El Niño Southern Oscillation
EO	Earth Observation
EOF	Empirical Orthogonal Function
EOS	Earth Observing System
EPIC	Earth Polychromatic Imaging Camera
ESA	European Space Agency
ESS	Earth and Space Sciences
ESSIC	Earth System Science Interdisciplinary Center
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FV	Finite Volume
G-IV	Gulfstream IV
GCE	Goddard Cumulus Ensemble
GCM	Global Climate Model
GCPEX	GPM Cold Season Precipitation Experiment
GEMS	Geostationary Environmental Monitoring Sensor

Acronyms

GEO-CAPE	Geostationary Coastal and Air Pollution Events
GEOS	Goddard Earth Observing System
GEOSCCM	Goddard Earth Observing System Chemistry-Climate Model
GES	Goddard Earth Sciences
GEST	Goddard Earth Sciences and Technology Center
GESTAR	Goddard Earth Sciences Technology Center and Research
GEV	Generalized Extreme Value
GHG	Greenhouse gases
GLOBE	Global Learning and Observations to Benefit the Environment
GLOPAC	Global Hawk Pacific Missions
GMAO	Goddard Modeling and Analysis Office
GMI	GPM Microwave Imager
GMI	Global Modeling Initiative
GOES	Geostationary Operational Environmental Satellites
GOES-R	Geostationary Operational Environmental Satellite – R Series
GOSAT	Greenhouse gases Observing Satellite
GPCEX	GPM Cold Season Precipitation Experiment
GPM	Global Precipitation Measurement
GRIP	Genesis and Rapid Intensification Processes
GRUAN	GCOS Reference Upper Air Network
GSFC	Goddard Space Flight Center
GUV	Global Ultraviolet
GV	Ground Validation
HAMSR	High Altitude Monolithic Microwave Integrated Circuit Sounding Radiometer
HBSSS	Hydrospheric and Biospheric Sciences Support Services
HIRDLS	High Resolution Dynamics Limb Sounder
HIWRAP	High-Altitude Imaging Wind and Rain Airborne Profiler
HIWRAP	High-altitude Imaging Wind and Rain Airborne Profiler
HOPE	Hyperspectral Ocean Phytoplankton Exploration
HS3	Hurricane and Severe Storm Sentinel
HSB	Humidity Sounder for Brazil
HSRL	High Spectral Resolution Lidar
HWLT	Hybrid Wind Lidar Transceiver
I3RC	Intercomparison of 3D Radiation Codes
IAMAS	International Association of Meteorology and Atmospheric Sciences
IASI	Infrared Atmospheric Sounding Interferometer
ICAP	International Cooperative for Aerosol Prediction

ICCARS	Investigating Climate Change and Remote Sensing
ICESat	Ice, Cloud, and land Elevation Satellite
IGAC	International Global Atmospheric Chemistry
IGP	Indo–Gangetic Plain
IIP	Instrument Incubator Program
INPE	National Institute for Space Research (Brazil)
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IRAD	Internal Research and Development
IRC	International Radiation Commission
ISAF	*In Situ* Airborne Formaldehyde
ISCCP	International Satellite Cloud Climatology Project
ISS	International Space Station
ITCZ	Intertropical Convergence Zone
IUGG	International Union of Geodesy and Geophysics
IWP	Ice Water Path
JAXA	Japanese Aerospace Exploration Agency
JAXA	Japan Aerospace Exploration Agency
JCET	Joint Center for Earth Systems Technology
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JSC	NASA's Johnson Space Center
JWST	James Webb Space Telescope
LaRC	Langley Research Center
LASP	Laboratory for Atmospheric and Space Physics
LDCM	Landsat Data Continuity Mission
LDSD	Low Density Sonic Decelerator program
LIS	Lightning Imaging Sensor
LIS	Land Information System
LPVEx	Light Precipitation Validation Experiment
LRRP	The Laser Risk Reduction Program
MABEL	Multiple Altimeter Beam Experimental Lidar
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MC3E	Mid-latitude Continental Convective Clouds Experiment
MCS	Mesoscale Convective System
MDE	Maryland Department of the Environment
MISR	Multi-angle Imaging Spectroradiometer

Acronyms

MJO	Madden-Julian Oscillation
MLS	Microwave Limb Sounder
MMF	Multi-scale Modeling Framework
MMF-LIS	Multi-scale Modeling Framework Land Information System
MOA	Memorandum of Agreement
MODIS	MODerate-resolution Imaging Spectrometer
MoE	Ministry of Environment
MOHAVE	Measurement of Humidity in the Atmosphere and Validation Experiment
MOPITT	Measurement of Pollution in the Troposphere
MPLNET	Micro Pulse Lidar Network
MSU	Morgan State University
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NCTAF	National Commission on Teaching and America's Future
NDVI	Normalized Difference Vegetation Index
NEO	NASA Earth Observations
NEXRAD	Next Generation Radar
NFOV	Narrow Field-of-View
NIH	National Institutes of Health
NIST	National Institute of Standards
NISTAR	National institute of Standards and Technology Advanced Radiometer
NLDAS-2	North American Land Data Assimilation System
NMVOC	Non-methane volatile organic compounds
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPOL	Naval Physical and Oceanographic Laboratory
NPP	National Polar-orbiting Partnership
NRC	National Research Council
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSTA	National Science Teachers Association
OASIS	Ocean Ambient Sound Instrument System
OCO-2	Orbiting Carbon Observatory
ODP	Ozone Depletion Potentials
ODS	Ozone Depleting Substances

OEI	Ozone ENSO Index
OLI	Operational Land Imager
OLYMPEX	Olympic Mountain Experiment
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapping and Profiler Suite
ORS	Operationally Responsive Space
OSC	Orbital Sciences Corporation
PACE	Pre-Aerosols, Clouds, and Ecology
PAO	Public Affairs Office
PARSIVEL	PARticle Size VELocity
PCA	Principal Component Analysis
PECAN	Plains Elevated Convection at Night
PI	Principal Investigator
PMM	Precipitation Measurement Missions
POC	Point of Contact
PODEX	Polarimeter Definition Experiment
POES	Polar-orbiting Operational Environmental Satellites
PR	Precipitation Radar
PSCs	Polar Stratospheric Clouds
PUMAS	Practical Uses of Math and Science
PVI	Perpendicular Vegetation Index
RADEX	Radar Definition Experiment
RESA	Regional Education Service Agency
RMSE	Root Mean Square Error
ROMS	Regional Ocean Modeling System
ROSES	Research Opportunities in Space and Earth Sciences
RSESTeP	Remote Sensing Earth Science Teacher Program
RSIF	Rain-Sea Interaction Facility
S-HIS	Scanning High-Resolution Interferometer Sounder
SAF	Satellite Application Facility
SAIC	Science Applications International Corporation
SC	Solar Cycle
SDC	Science Director's Council
SEAC4RS	Southeast Asia Composition, Cloud, Climate Coupling Regional Study
SeaWiFS	Sea-viewing Wide Field-of-View Sensor
SGP	South Great Plains
SHADOZ	Southern Hemisphere Additional Ozonesondes

Acronyms

SHOUT	Sensing Hazards with Operational Unmanned Technology
SIM	Spectral Irradiance Monitor
SIMPL	Swath Imaging Multi-polarization Photon-counting Lidar
SMAP	Soil Moisture Active Passive
SMART	Surface-sensing Measurements for Atmospheric Radiative Transfer
SMD	Science Mission Directorate
SNPP	Suomi National Polar-orbiting Partnership
SONGNEX	Shale Oil and Natural Gas Nexus
SORCE	Solar Radiation and Climate Experiment
SpaceX	Space Exploration Technologies Corp.
SPARRO	Self-Piloted Aircraft Rescuing Remotely Over Wilderness
SPE	Solar Proton Event
SSA	Single Scattering Albedo
SSA	Single scattering albedo
SSAI	Science Systems Applications, Inc.
SSI	Solar Spectral Irradiance
SST	Sea Surface Temperature
STEM	Science, Technology, Engineering, and Mathematics
SWG	Science Working Group
SWOT	Surface Water Ocean Topography
TCC	TRMM Composite Climatology
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TES	Tropospheric Emission Spectrometer
TIM	Total Irradiance Monitor
TIROS	Television Infrared Observation Satellite Program
TIRS	Thermal Infrared Sensor
TJSTAR	Thomas Jefferson Symposium To Advance Research
TMI	TRMM Microwave Imager
TMPA	TRMM Multi-satellite Precipitation Analysis
TOAR	Tropospheric Ozone Assessment Report
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TOPP	Tropospheric ozone pollution project
TRMM	Tropical Rainfall Measurement Mission
TROPOMI	Troposhere Ozone Monitoring Instrument
TSI	Total Solar Irradiance
TSIS	Total Spectral Solar Irradiance Sensor

TWiLiTE	Tropospheric Wind Lidar Technology Experiment
UARS	Upper Atmosphere Research Satellite
UAS	Unmanned Aircraft Systems
UAVs	Unmanned Aerial Vehicles
UMBC	University of Maryland, Baltimore County
UMSA	Universidad Mayor San Andres
UND	University of North Dakota
USAF	U.S. Air Force
USDA	U.S. Department of Agriculture
USGS	United States Geological Survey
USRA	Universities Space Research Associates
UTLS	Upper Troposphere and Lower Stratosphere
UV	Ultraviolet
VIIRS	Visible Infrared Imaging Radiometer Suite
VIRGAS	Volcano-Plume Investigation Readiness and Gas-phase and Aerosol Sulfur
VIRGO	Variability of solar IRradiance and Gravity Oscillations
VIRS	Visible and Infrared Scanner
VOC	Volatile Organic Compounds
WAVES	Water Vapor Validation Experiments Satellite and sondes
WFF	Wallops Flight Facility
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting

Acronyms

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