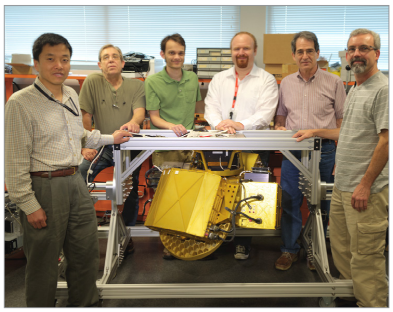
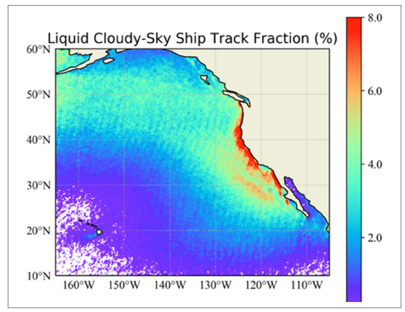
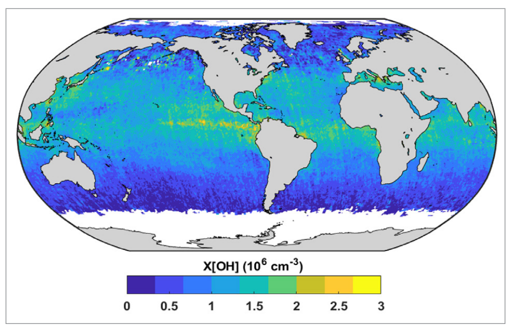
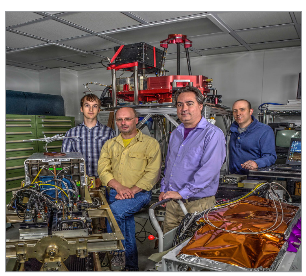
NASA/TM–20210013331

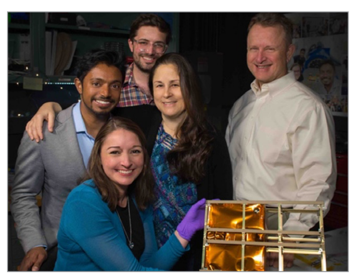
Atmospheric Research 2019 Technical Highlights

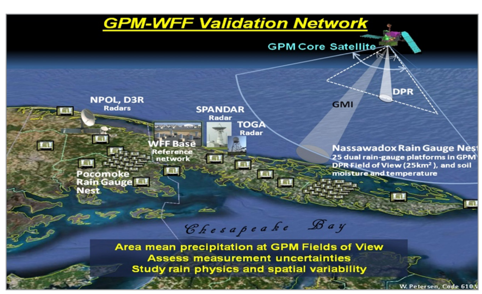












June 2021

On the Cover

Top left: *HIWRAP (High-altitude Imaging Wind and Rain Airborne Profiler)*
The HIWRAP scanner shown on test stand with Lihua Li, Gerald McIntire, Michael Coon, Matthew McLinden, Gerald Heymsfield, and Martin Perrine. Wind measurements are crucial for understanding and forecasting tropical storms since they are closely tied to the overall dynamics of the storm. HIWRAP is a dualfrequency (Ka- and Ku-band), dual-beam (300 and 400 incidence angle), conical scan, solid-state transmitter-based system, designed for operation on the high-altitude (20 km) Global Hawk UAV. HIWRAP has also flown on the WB-57 aircraft, and in a nadir scanning configuration on the ER-2.

Top right: *Finding the World's Ship-tracks with a Deep Learning Model*
A deep learning model was developed to identify in satellite images marine clouds modified by ship emissions, also known as ship-tracks. This paves the way for routine automatic detection of ship-tracks worldwide and the creation of a unique dataset for detailed aerosol-cloud interactions studies. They can also be used to identify shipping activities around the world.

Middle: *Mapping the Oxidizing Capacity of the Global Remote Troposphere*
August 2016 column-average tropospheric OH concentrations (X[OH]) derived from a combination of ATom insights, OMI retrievals, and additional parameters from GSFC's GMI model. Median uncertainty in individual grid cells is 0.35×106 molecules cm^{-3}. This is the first ever satellite-derived estimate of the near-global distribution of OH. Note, it is currently only possible to apply this technique in remote regions (over water).The hydroxyl radical (OH) destroys methane and is central to the chemistry of the lower atmosphere.

Lower Left: *CATS (The Cloud-Aerosol-Transport System)*
The CATS instrument team (from left to right)—Andrew Kuphock (engineer), Matt McGill (PI), Stan Scott (Instrument Manager), John Yorks (Science Lead), and many others (not pictured) - developed the path-finding CATS instrument, which operated from the International Space Station (ISS) for 33 months (Feb. 2015 to Oct. 2017) and fired over 200 billion laser shots. In addition to demonstrating new lidar technologies, CATS showcased how affordable spaceborne experiments can take advantage of existing platforms, such as the ISS, paving the way for less costly experiments on smaller missions with more rapid access to space.

Lower Right: *MiniCarb (Miniaturized Carbon Observer)*
A CubeSat built in partnership with Lawrence Livermore National Laboratory (LLNL) that featured a laser heterodyne radiometer (LHR) payload developed at NASA/GSFC for passively observing CH_4, CO_2 and H_2O in the Earth's atmosphere. MiniCarb was transported to the ISS via SpaceX in December 2019 for launch into orbit in January 2020. The GSFC team with the LHR: Jennifer Young (front), Guru Ramu (left), A.J. DiGregorio (back), Emily Wilson (PI) (middle), and Paul Cleveland (right). Credit: NASA/W. Hrybyk.

Bottom: *GPM-WFF Validation Network*
The Global Precipitation Measurement (GPM) Ground Validation (GV) program is based at GPM Precipitation Research Facility (PRF) which is located at NASA Wallops Flight Facility (WFF). The GV team obtains measurements of precipitation from a variety of instruments including multi-frequency radars, disdrometers and rain gauges. The flagship instrument is NASA's S-band dual-polarimetric radar (NPOL) which provides high-resolution estimates of precipitation rates as well as types.

NASA/TM–20210013331

Atmospheric Research 2019 Technical Highlights

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

June 2021

NASA STI Program Report Series

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at http://www.sti.nasa.gov

- E-mail your question to help@sti.nasa.gov

- Phone the NASA STI Information Desk at 757-864-9658

- Write to:
  NASA STI Information Desk
  Mail Stop 148
  NASA Langley Research Center
  Hampton, VA 23681-2199

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Reader,

Welcome to the 2019 Atmospheres Highlights report. Here, we summarize research and communication/outreach accomplishments from the portion of atmospheric science activities at NASA's Goddard Space Flight Center (GSFC) that comprises the Earth Science Division's Atmospheres organization. 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 (610AT), which is within Earth Sciences Division (Code 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, the 301 personnel in Code 610AT consist of 57 civil servants and 244 cooperative agreement associates, postdoctoral fellows, as well as contractor scientific and technical staff.

While the report provides a comprehensive summary of 610AT 2019 activities, below are a few highlights.

Satellite Observations: The Earth Observing System (EOS) Terra satellite celebrated 20 years in orbit this past December. 610AT scientists have long been active in the Terra mission (and the sister EOS Aqua and Aura missions), serving as project scientists, algorithm product developers, and data users. Terra's long lifetime, vantage point from space, and robust suite of sensors combine to provide a unique source of climate and environmental data records not available from any other platform. During 2019 alone, the Terra project distributed over 10,000 TB of data to hundreds of thousands of domestic and international users. For comparison, the entire text holdings of the Library of Congress are estimated to be about 10 TB. In addition to scientific research, multiple agencies use Terra's land and atmosphere products for monitoring volcanic ash, forest fires, air quality, crops as well as for weather forecasting, and carbon management.

GPM celebrated its 5-year anniversary in February. The GPM Core Observatory and an international network of satellites provided by partners from the European Community, France, India, Japan, and the United States quantify when, where, and how much it rains or snows around the world. The GPM mission is advancing our understanding of the water and energy cycles and is extending the use of precipitation data to directly benefit society.

Two other satellite missions of special note in 610AT are DSCOVR/EPIC and Suomi NPP. EPIC is completing its fourth year in orbit; NPP, with an instrument suite designed to provide continuity with many of the EOS data records, celebrated eight years of operation in October 2019. 610AT scientists developed many of the atmospheric algorithms used for generating scientific data products from these satellite sensors, as well as the EOS sensors, and are actively involved in analysis and interpretation of these datasets.

Kudos: As in previous years, 610AT scientists garnered professional honors and other recognition during 2019.

- Anne Douglass (614 emeritus) received the 2020 AMS Joanne Simpson Mentorship Award. As Jim Irons (Director of the Earth Science Division) stated: "I find it entirely fitting that Anne is receiving an award named after Joanne Simpson as Anne has carried forward Joanne's legacy of mentorship at GSFC."

- The Ozone Monitoring Instrument (OMI) International team won the prestigious 2018 NASA-USGS Pecora Group award (belatedly presented in 2019) for "For fifteen+ years of sustained team innovation and international collaboration to produce daily global satellite data that revolutionize urban air quality and health research."

- The Terra Team team received the prestigious 2019 Pecora Group Award for significant contributions in all areas of Earth science, with scientific impacts and a legacy that make it one of the most successful missions in NASA's long line of Earth Observing System satellites.

- Scott Braun (612) and George Huffman (612) were named 2019 AMS Fellows.

- Ralph Kahn (613) won the 2019 William Nordberg Memorial Award, the highest Earth Science honor at Goddard. He has conducted pioneering work to advance our understanding of aerosol interactions with their environment and to influence relevant research directions of GSFC, NASA, and the Earth science community as a whole.

A special credit to Paul Newman (610 Senior Scientist and 614 alumnus), the co-chair of the Scientific Assessment Panel (SAP) to the Montreal Protocol. Paul attended the November Meeting of the Parties to the Montreal Protocol Substances that Deplete the Ozone Layers at the Food and Agriculture Organization of the United Nations in Rome, Italy. He presented information on the recent increases of CFC-11 emissions observed from eastern China shown in the Scientific Assessment Panels quadrennial report, and also discussed recently observed trace chemicals that have implications for both climate and ozone depletion issues.

Civil Servant Personnel: Effective January 2019, George Huffman, became Lab Chief for Code 612, Mesoscale Atmospheric Processes Laboratory. George, who became a Goddard Civil Servant in 2012, is a recognized world-class scientist in the analysis of global satellite precipitation data and the development of highly valued multi-sensor global precipitation data sets used across the international scientific community.

I was pleased to welcome Emily Wilson in December as the new Associate Deputy Director for Atmospheres replacing Karen Mohr who transferred to Code 610. Emily is a Research Physical Scientist who obtained a Ph.D. in physical chemistry from George Washington University in 2002. She joined NASA in 2005 after working here as an NRC Postdoc. She brings a great deal of experience in physical chemistry, spectroscopy, and measurements of atmospheric trace gases. Before transferring to Code 614 in 2016, Emily was the chief of the Laser Remote Sensing Laboratory in the Solar System Science Division.

I was also pleased to welcome Reed Espinosa (613) who became a new civil servant in August 2019. Reed received a Ph.D. from the University of Maryland in 2017 and will be performing research specializing in polarized radiative transfer and aerosol and cloud remote sensing.

Transitions: As previously mentioned, Karen Mohr transitioned in September to her new position as the 610 Associate Director for Institution Planning and Operations (replacing Dot Zukor and Jack Richards). She performed five years of exceptional service supporting management operations in Code AT, including close coordination with other division and center organizations. Her performance and positive attitude across many areas have been an asset to the organization and she will be missed.

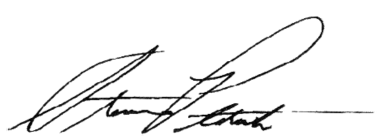
Pawan Bhartia (610) entered phased retirement following a long and distinguished career as a manager and research scientist. He is among the leading experts on ultraviolet-visible instruments and retrievals in the world. Among his accomplishments were his satellite discovery of the Antarctic ozone hole, his guidance and vision in algorithm development, measurement calibration, and the success of the Suomi National Polar-Orbiting Environmental Satellite System Preparatory Project Ozone Mapping and Profiler Suite Limb Profiler (OMPS-LP) and the Ozone Monitoring Instrument (OMI) System on the Aura satellite, and the Nimbus 7 and Earth Probe Total Ozone Mapping Spectrometer (TOMS).

Anne Douglass (614) transitioned to Emeritus status in January following her retirement in December 2018. During her 31-year association with the chemistry laboratory (614), 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 Modeling project (SGCCM) starting in the early 1990's.

Randy Kawa (614) transitioned to Emeritus status on October 26, following 24 years of civil service. Randy has achieved important results across a scientific landscape from Earth's surface to the stratosphere. His original research and publications on stratospheric ozone demonstrated confirmed loss processes expected from theory and observations. He developed numerical modeling tools for chemistry-along-trajectories, efficient photolysis calculation, and carbon species transport that are in wide use within the community and led a major NASA research program to detail the atmospheric effects of aircraft emissions as project manager and project scientist.

William (Bill) Ridgway retired from SSAI (613), but will continue to work on an as-need basis. During his career, he devoted many years of quality service in the planning and monitoring the implementation of IT security requirements in the Climate and Radiation Laboratory (613). He became known as the "wise elder" that defined actions to keep the lab compliant with all IT security requirements. He was a trusted voice that could filter signal from noise with regard to all IT matters. In addition, Bill served as the technical liaison between the MODIS Atmosphere Discipline Team and the MODIS production team for many years, and so was critical to the success of MODIS atmospheric products.

This report is being published in two media: a printed version and an electronic version on our Atmospheric Science Research Portal site, https://science.gsfc.nasa.gov/earth/reports. We continue to develop the site to be more useful for our scientists, colleagues, and the public. We welcome comments on this report and on the material displayed on our website.



Steven Platnick
Deputy Director for Atmospheres
Earth Sciences Division, Code 610

September 2020

Table of Contents

1. INTRODUCTION 1

2. SCIENCE HIGHLIGHTS 4
- 2.1. Satellite Data Utilization Group.. 4
- 2.2. Mesosale Atmospheric Process Laboratory 5
- 2.3. Climate and Radiation Laboratory.. 17
- 2.4. Atmospheric Chemistry and Dynamics Laboratory....................................... 29

3. Major Activities 37
- 3.1. Missions... 37
- 3.1. Project Scientists 49

4. Field Campaigns 52
- 4.1. MPLNET 52
- 4.2. SHADOZ... 53
- 4.3. eMAS/Oracles/FIREX-AQ 55
- 4.4. TROLIX'19 56
- 4.5. NDACC... 56
- 4.6. SEAS 57
- 4.7. RAJO-MEGHA.. 58
- 4.8. Pandora 59
- 4.9. SCOAPE 61
- 4.10. IMPACTS 63

5. Code 610 Web Development Team 65

6. Awards and Special Recognition 66
- 6.1. Agency Honor Awards 66
- 6.2. Robert H. Goddard Awards 67
- 6.3. Sciences and Exploration Directorate 67
- 6.4. External awards and recognition 67
- 6.5. William Nordberg Award.. 68
- 6.6. American Meteorological Society 70
- 6.7. American Geophysical Union 71

7. Communication 73
- 7.1. Introduction 73
- 7.2. University and K-12 Interactions 73
- 7.3. Lectures and Seminars... 87
- 7.4. Public Outreach... 94

8. Atmospheric Sciences in the News 104

ACRONYMS AND ABBREVIATIONS.. 105

APPENDIX 1: REFEREED ARTICLES 110

1. INTRODUCTION

A broad and vigorous program of atmospheric research is carried out in the Earth Science Division as shown in Figure 1.1. The atmospheres organization (Code AT) is shown in relation to other organizations performing research in atmospheric sciences; scientific interactions within the organizations are carried out across many areas. Research within the atmospheres organization (610AT) 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 laboratories and office that comprise the organization improve our understanding of the dynamics and physical properties of precipitation, clouds, and aerosols; atmospheric

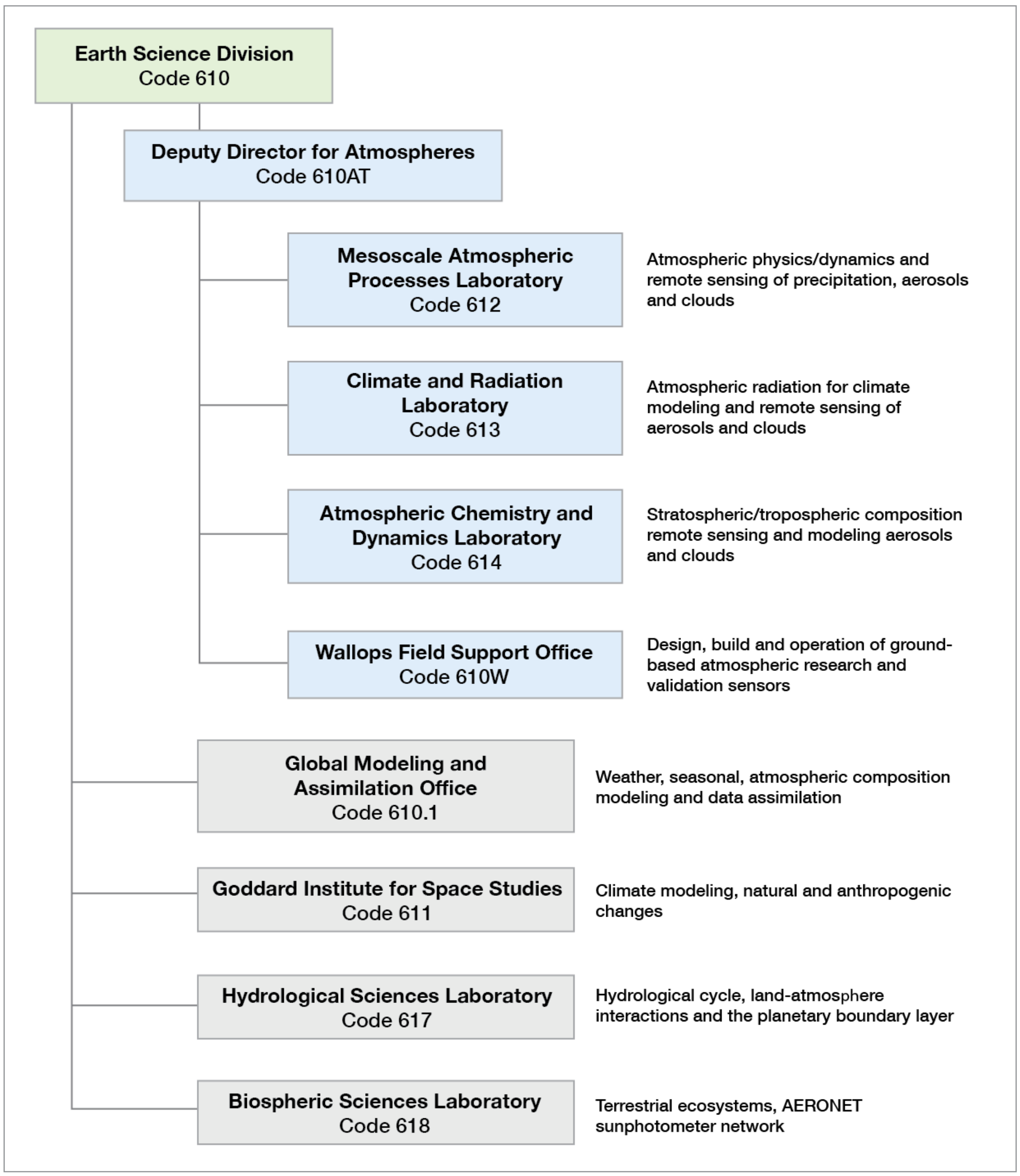


Figure 1.1: *Relationship of 610AT organization to other 610 laboratories and offices performing atmospheric research, and their primary activities.*

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 Earth's climate. The overall scope of the research in the organization covers end-to-end activities, starting with the identification of scientific problems; leading to observational requirements for remote-sensing instruments/platforms, technology and retrieval algorithm development along with related model development; followed by satellite and suborbital observations; and eventually, data processing, analyses of measurements, and dissemination to the scientific community and the public. The offices and laboratories of the total Earth Sciences Division can be seen at https://science.gsfc.nasa.gov/earth/orgchart.

Instrument scientists in the organization 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 1.2 shows the 20-year record of peer-reviewed publications and proposals among the various laboratories.

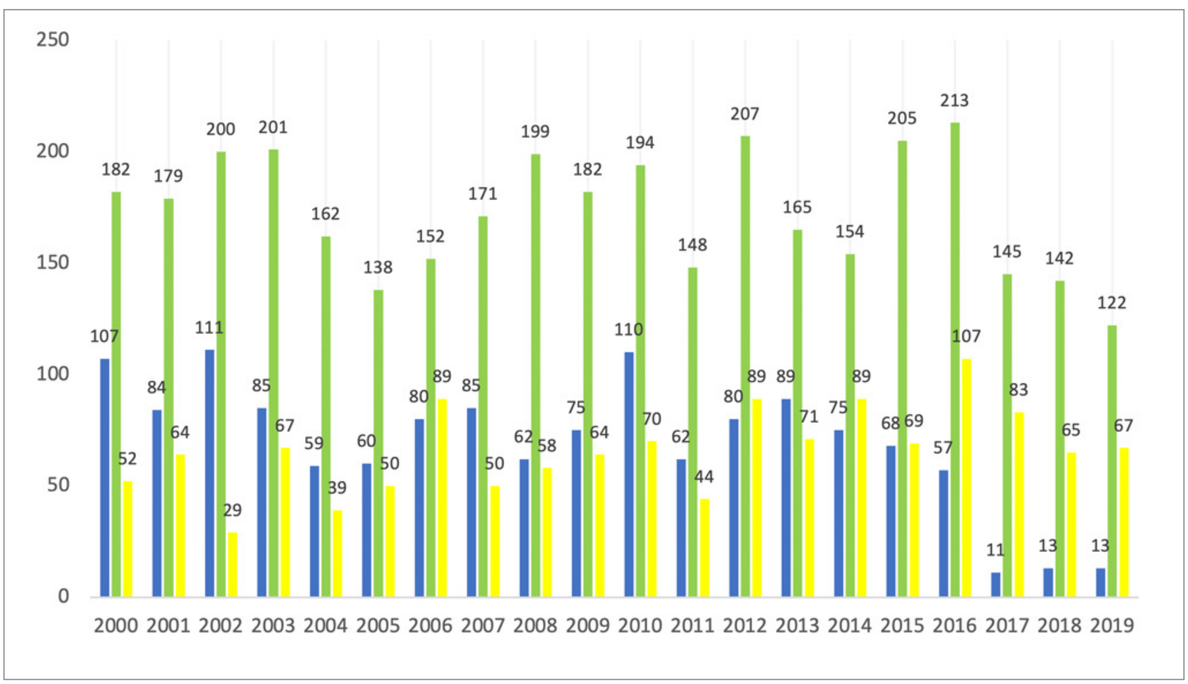


Figure 1.2: *Number of proposals and refereed publications by atmospheric sciences members over the years. The green bars are the total number of publications and the blue bars the number of publications where a laboratory member is first author. Proposals submitted are shown in yellow.*

610AT strives to maintain the organization's productivity by promoting quality while emphasizing coordination and integration among atmospheric disciplines. Being in a NASA center, it is important to achieve an appropriate balance between our scientists' involvement in large collaborative projects and missions vs. active research. Such a balance across the workforce is essential for members of 610AT to develop scientific credentials that are needed to complement mission development and leadership.

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. 610AT has made substantial efforts to attract and recruit new scientists through cooperative agreements that often include academic partners (associate scientist), contracts, and the NASA Postdoctoral Program (NPP). We strongly promote societal application of our science products, often making use of partnerships with federal and state agencies that have operational responsibilities.

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 2019. The composition of the organization is shown in Figure 1.3 for each organization code. This report is published in a printed version with an electronic version on our atmospheres website https://science.gsfc.nasa.gov/earth/reports.

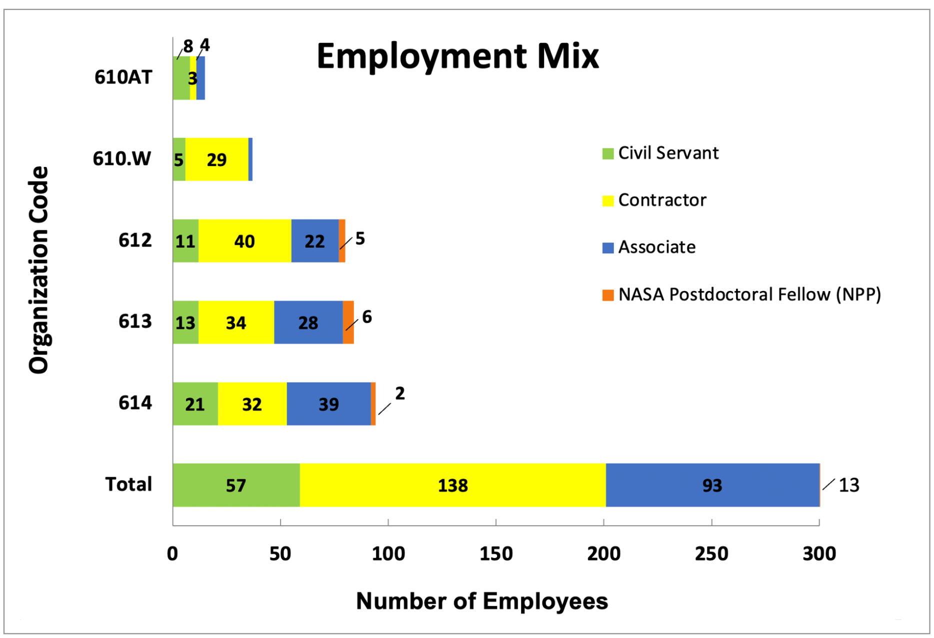


Figure 1.3: *Breakdown of the organizational employee mix.*

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 (1960's-1970's) 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 the 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 are 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 recent *Decadal Survey* by the National Academy of Sciences in 2007 (http://www.nap.edu/catalog/11820.html.) The Earth Science and Applications from Space (ESAS) 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 2019. The individual contributor(s) are named at the end of each summary. Additional highlights and other information may be found at the website https://earth.gsfc.nasa.gov/.

2.1. Satellite Data Utilization Group

The group develops techniques to infer surface and atmospheric parameters from meteorological satellite observations for use in weather and climate studies. Quantitative assessments of the potential impact of proposed observing systems through simulation experiments are also carried out.

2.1.1. Recent global warming as confirmed by AIRS

The GISTEMP (GISS Surface Temperature product) data set and the totally independent satellite-based AIRS surface skin temperature data set are very consistent with each over the past 15 years. Both data sets demonstrate that the Earth's surface has been warming globally over this time period, and that 2016, 2017, and 2015 have been the warmest years in the instrumental record, in that order. In addition to being an independent data set, AIRS products complement those of GISTEMP, because they are at a higher spatial resolution have more complete spatial coverage, but with a shorter record. Differences in the products (and lower temporal correlations) mostly reflect areas without much directly observed station data (the Arctic, Southern Ocean, sub-Saharan Africa) suggesting that the fault lies in the station-based products rather than with the AIRS data. Notably, surface-based data sets may be underestimating the changes in the Arctic. Complementary satellite-based surface temperature analyses serve as an important validation of surface-based estimates, and they may point the way to make improvements in surface-based products that can perhaps be extended back many decades.

Contributors: J. Susskind (610), et al.

Reference: Susskind, J., G.A. Schmidt, J.N. Lee, and L. Iredell, 2019: Recent global warming as confirmed by AIRS. *Environ. Res. Lett.*, **14**, no. 4, 044030, doi:10.1088/1748-9326/aafd4e.

2.2. Mesosale 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.

2.2.1. The Diurnal Cycle of Cloud Profiles as Seen by CATS

Studies using Cloud Aerosol Transport System (CATS) data directly support 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. Clouds are one of the largest uncertainties in predicting climate change, because they are a key regulator of the planet's average temperature. Even small changes in the abundance or location of clouds could change the climate more than the anticipated changes caused by greenhouse gases, human-produced aerosols, or other factors associated with global change. From 33 months of CATS data we documented, for the first time, the diurnal cycle of the vertical distribution of clouds. Over the summer tropical ocean, high clouds are limited during daytime (hours 10-14), but become more frequent at night. Over land during the summer, low-level clouds develop vertically, up to 2.5 km, and cloud fractions (CF) reach a maximum occurrence around hour 15. CATS provided measurements at different local times for each overpass. Other lidars observe clouds at the same two local times for any location, capturing only a snapshot of the diurnal variability seen by CATS. The CATS data advance the space-based lidar record that is vital to understanding the Earth's climate system by providing, for the first time ever, diurnally varying vertical profiles of clouds on a near-global scale (up to 51° latitude). The diurnally varying vertical profiles determine the cloud radiative effects, a key uncertainty in predicting the Earth's radiation balance.

Contributors: J. Yorks (612), V. Noel (CNRS), et al.

References: Noel, V., Chepfer, H., Chiriaco, M., and Yorks, J. E., 2018: The diurnal cycle of cloud profiles over land and ocean between 51° S and 51° N, seen by the CATS spaceborne lidar from the International Space Station, *Atmos. Chem. Phys. Discuss.*, https://doi.org/10.5194/acp-2018-214.

Yorks, J. E., M. J. McGill, S. P. Palm, D. L. Hlavka, P. A. Selmer, E. Nowottnick, M. A. Vaughan, S. Rodier, and W. D. Hart, 2016: An Overview of the CATS Level 1 Data Products and Processing Algorithms. *Geophys. Res. Let.*, **43**, doi:10.1002/2016GL068006.

2.2.2. An Advanced Bin Microphysics Scheme Explains Improvements in Simulated Radar and Radiometer Signals and Sensitivities to Ice Nucleation

Improving model representation of cloud and precipitation processes are critical for advancing weather predictions and satellite data assimilation. NASA satellites provide important observation for model evaluation and validation. On the other hand, advanced models enable tests of complicated microphysical processes that will benefit improving understanding of satellite observations and retrievals. This research compares the performance of two advanced microphysics schemes, a bulk (Thompson) and an explicit bin (Hebrew University Cloud Model, HUCM), in WRF model, which can be applied by the research and operational communities to understand the uncertainties of the microphysics schemes. The explicit bin scheme enables a novel test of the redistribution of snow mass through particle breakup and the increase snow total mass as a result of an increased number of ice nuclei. Enhanced snow breakup shifts the snow PSD and the dominant snow mass from ~4 to ~2 mm in radius, and these changes are reflected in simulated Z and Tb. Future work will involve investigations of the scattering signature of the very small snow particles with the high-frequency GPM radiometer channels and the application of GPM observations to improve understanding of cloud/precipitation processes. The ability to model snow processes, and then link those processes to remote sensing observables, is a necessary component of a robust and comprehensive Earth observing system that can inform the Aerosol and Cloud, Convection, and Precipitation targeted observables as described in the *2017-2027 Earth Science and Applications from Space Decadal Survey*.

Contributors: M. Han (612, MSU), S. Braun (612), T. Matsui (612, UMD), T. Iguchi (612, UMD)

Reference: Han, M., S. A. Braun, T. Matsui, and T. Iguchi, 2018: Comparisons of bin and bulk microphysics schemes in simulations of topographic winter precipitation with radar and radiometer measurements. *Q. J. R. Meteorol. Soc.*, **144**, 1926-1946. doi: 10.1002/qj.3393.

2.2.3. Inclusion of Non-spherical Ice Particles Improves GPM Precipitation Retrievals

Improving estimates of global precipitation is of fundamental importance for countless applications, ranging from real-time hazard monitoring to numerical weather prediction and global energy budgets. This has once again been highlighted in the *2017 Decadal Survey*. There is much to be learned from GPM for designing the next generation of observing systems that will begin looking into precipitation processes. GPM's use of physically-based methods is fundamental to linking retrievals to physical processes. A physically-based Bayesian passive microwave precipitation retrieval requires an accurate forward radiative transfer model along with realistic database representation of hydrometeors, atmospheric properties, and surface emission. In this study, the Goddard Profiling Algorithm (GPROF), used operationally for the Global Precipitation Measurement (GPM) constellation retrievals, depends heavily on simulated brightness temperatures (Tbs) for consistent retrievals across all platforms. Substituting more realistic non-spherical ice particles for the previously used spherical approximations significantly improves Tb agreement with observations, and consequently improves rain rate retrieval bias, RMSE, and correlation. Simulated brightness temperature agreement with observations is shown to be significantly improved across the high frequencies, appreciably decreasing biases and increasing correlations to observed Tb.

Contributors: S. Ringerud (612, UMD), M. S. Kulie (MTU), D. L. Randel and C. D. Kummerow (CSU), G. S. Skofronick-Jackson (NASA/HQ)

Reference: Ringerud, S., M. S. Kulie, D. L. Randel, G. M. Skofronick-Jackson and C. D. Kummerow: 2019: Effects of Ice Particle Representation on Passive Microwave Precipitation Retrieval in a Bayesian Scheme. *IEEE Trans. Geosci. Remote Sens.*, doi: 10.1109/TGRS.2018.2886063.

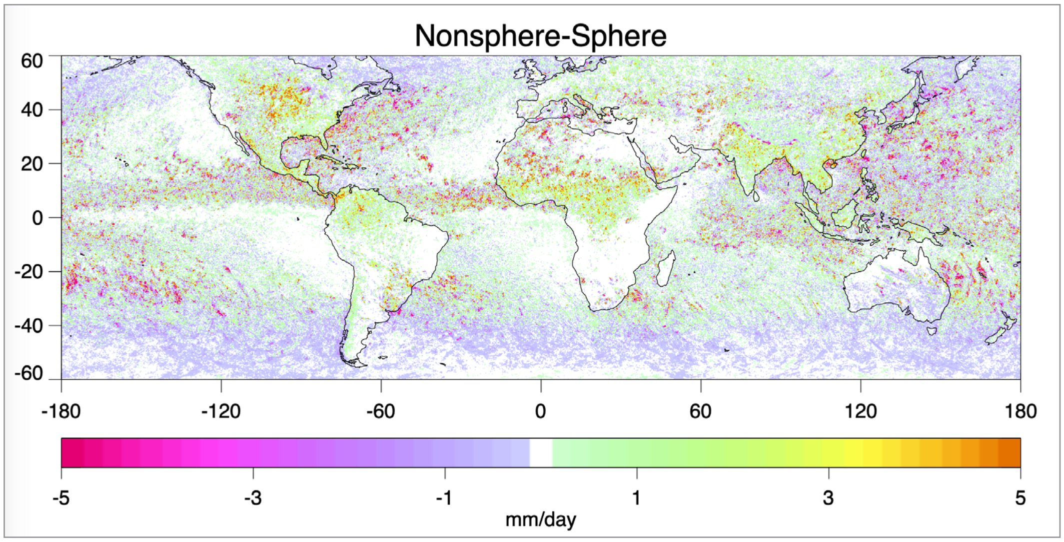


Figure 2.2.3: *Change in retrieved GPROF precipitation rate for the period June, July, August 2016, using the non-spherical particle database in place of the previously used spheres.*

2.2.4. CALIPSO Offers New Insight into Antarctic Blowing Snow Properties

This work utilizes CALIPSO lidar measurements to directly detect the presence of blowing snow. We show that the snow occurs over 50% of the time over large areas of Antarctica in winter, and reaches heights as high as 500 m. A notable discovery is the existence of very large blowing snow "storms"—up to the size of the state of Texas—that act to transport huge quantities of snow from the continent to the surrounding ocean and sea ice. We have estimated that as much as 3.7 billion tons of snow is transported from continent to ocean by the wind each year. The transport and sublimation of blowing snow is an important component of the mass balance of the Antarctic ice sheet. Prior to space-borne lidar, the true extent and frequency of blowing snow in Antarctica was unknown. The only source of data were from models that could not be validated. Recent measurements have, for the first time, shown that blowing snow occurs more than 50% of the time over large areas of Antarctica with sublimation rates (Qs) considerably larger than estimated from models. Also for the first time, we have obtained temperature, moisture, and wind profiles through multiple blowing snow layers showing that the layer temperature almost uniformly mixed and does not reach saturation as commonly thought. The techniques developed for detecting blowing snow using CALIPSO data are now being used to analyze ICESat-2 data and the blowing snow retrievals will be part of the atmospheric data products. These results will extend the climate record of blowing snow, established by CALIPSO (2006-present), into the next decade. The CALIPSO blowing snow data have recently been made publicly available at the NASA Langley Atmospheric Science Data Center (ASDC) and ICESat-2 data will be available from the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, in May, 2019.

Contributors: S. P. Palm (612, SSAI), Y. Yang (613), and V. Kayetha (612, SSAI)

References: Palm, S.P., V. Kayetha, Y. Yang and R. Pauly, 2017: Blowing snow sublimation and transport over Antarctica from 11 years of CALIPSO observations. *The Cryosphere*. https://doi.org/10.5194/tc-11-2555-2017.

Palm, S. P., V. Kayetha and Y. Yang, 2018: Toward a satellite-derived climatology of blowing snow over Antarctica. *J. Geophys. Res. Atmos.*, **123**, https://doi.org/10.1029/2018JD028632.

Palm, S. P., Y. Yang, V. Kayetha and J. Nicolas, 2018: Insight into the thermodynamic structure of blowing snow layers in Antarctica from dropsonde and CALIPSO measurements. *J. Appl. Meteor Clim.*, doi: 10.1175/JAMC-D-18-0082.1.

2.2.5. Nonparametric Methodology to Estimate Precipitating Ice from Multiple-Frequency Radar Reflectivity Observations

Precipitating ice (i.e., snow) is an important component of the Earth's hydrological cycle. Over land, in some regions and seasons, precipitating ice reaching the ground may be the only form of precipitation, and therefore, it is very important for water resources management and planning. Also, over land, precipitating ice may be associated with severe weather that impacts human lives. Over land or oceans, precipitating ice is important, because it influences the atmosphere's thermal structure through release of latent heating and radiative cooling.

A precipitating ice estimation algorithm has been developed from in situ Particle Size Distributions collected during the NASA OLYMPEX and IPHEX field experiments. Its application to coincident triple frequency airborne radar observations produced ice estimates in very good agreement with in situ estimates. The algorithm is applicable to observations from future satellite missions such as Aerosol, Clouds, Convection and Precipitation (ACCP) Mission.

Contributors: M. Grecu (612, MSU), L. Tian (612, MSU), G.M. Heymsfield (612), A. Tokay (612, UMBC), W.S. Olson (612, UMBC), A.J. Heymsfield (NCAR), and A. Bansemer (NCAR)

Reference: Grecu, M., L. Tian, G.M. Heymsfield, A. Tokay, W.S. Olson, A.J. Heymsfield, and A. Bansemer, 2018: Nonparametric Methodology to Estimate Precipitating Ice from Multiple-Frequency Radar Reflectivity Observations. *J. Appl. Meteorol. Clim.*, **57**, 2605-2622, https://doi.org/10.1175/JAMC-D-18-0036.1.

2.2.6. Modified Dual-Wavelength Technique for Ku- and Ka-band Radar Improves Rain Retrievals

Global Precipitation Measurement (GPM) core satellite, is to derive rain rate and raindrop size distribution (DSD). Several dual-wavelength radar retrieval techniques have been developed which are based on uses the differential frequency ratio (DFR), i.e., the ratio (or difference in dB) of radar reflectivities between two wavelengths, to first infer the DSD parameters, correct attenuation, and then derive the rain rate profile gate by gate either stepping forward or backward along the radar beam. To overcome a deficiency in the standard Ku- and Ka-band dual-wavelength radar technique, a modified version of the method is introduced. The deficiency arises from ambiguities in the estimate of the mass-weighted diameter (Dm) of the raindrop size distribution derived from DFR. In particular, for DFR values less than zero, there are two possible solutions of Dm, leading to ambiguities in the retrieved DSD parameters. To overcome the deficiency in the standard Ku- and Ka-band dual-wavelength radar technique, a modified version of the method is introduced. Its validity and accuracy are tested by comparing rain rates (R) and mass-weighted diameters (Dm) estimated from the modified technique to the same quantities computed directly from the DSD spectra. It is indicated that the modified algorithm is superior in accuracy and robustness to retrievals using the standard method. This technique, in some modified form, will also be applicable to the upcoming Aerosol, Cloud, Convection, and Precipitation (ACCP) Designated Observable from the *2017 Earth Science Decadal Survey*.

Contributors: L. Liao (612, MSU), R. Meneghini (612)

Reference: Liao, L, and R. Meneghini, 2019: A modified dual-wavelength technique for Ku- and Ka-band radar rain retrieval. *J. Appl. Meteor. Climatol.*, **58**, 3-18, https://doi.org/10.1175/JAMC-D-18-0037.1.

2.2.7. Objective Algorithm Automates the Detection of Dry, Well-Mixed Layers (WMLs) in North Africa

Particularly during the boreal summer, deep, dry, and potentially dusty well-mixed layers (WMLs) are a nearly ubiquitous climatological feature of the Sahara Desert associated with strong surface heating and dry convection. We define dry WMLs as layers with water vapor mixing ratios at or below 7 g kg^{-1}, which constitutes a Saharan-like dry airmass, and where the potential temperature and water vapor mixing ratio lapse rates are both nearly constant. Our open-source algorithm objectively identifies and characterizes dry, WMLs using thermodynamic profiles (temperature and moisture) derived from weather balloons (left), satellite (center), and weather model (right) data. While the satellite and model product profiles are not capable of capturing small-scale vertical changes (< 300 m thick), the detection methodology was sensitive enough to identify WMLs from those products in the same region as the weather balloon observations. Despite these limitations, our algorithm expands upon our capability to observe the existence and evolution of WMLs, which are a key influence on both Atlantic tropical cyclone initiation and convective system generation in North Africa. The upcoming Earth Surface Mineral Dust Source Investigation (EMIT) EV-I 4 and the 2020 Aeolus instrument validation field campaign, which aim to investigation dust transport (include that within WMLs) and its role on global radiative balance.

Contributors: S. D. Nicholls (612, JCET) and K. I. Mohr (610)

Reference: Nicholls, S.D. and K.I. Mohr, 2019: An Automated Detection Methodology for Dry Well-Mixed Layers. *J. Atmos. Oceanic Technol.*, **36**, 761-779, https://doi.org/10.1175/JTECH-D-18-0149.1.

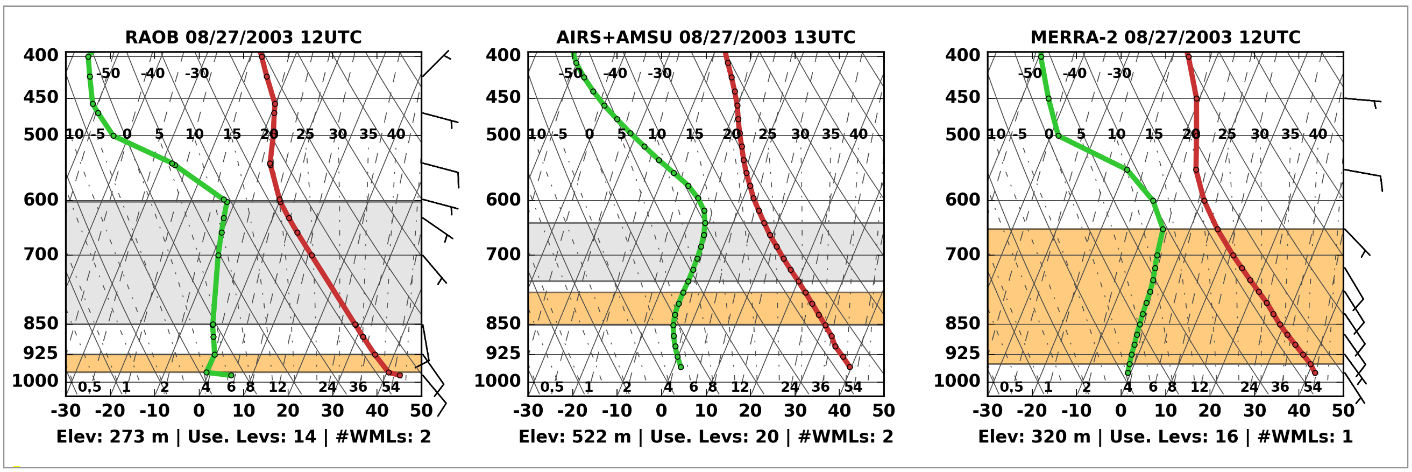


Figure 2.2.7: *Zonal cross section (latitude vs height) of mean cloud heating (latent heating + cloud eddy effects) retrieved from the latest version of the Goddard Convective-Stratiform Heating (CSH) algorithm for the 3 month period, April-June 2014. Overlaid are zonal mean surface rainfall (solid black line) and zonal mean equivalent surface rainfall.*

2.2.8. Upgraded IMERG Precipitation Data Extended to the TRMM (Year 2000) Era and More Polar Locations

IMERG is the most-requested GPM dataset; it integrates the entire GPM constellation and generates a relatively fine-scale, long-term record with three different latencies that addresses a wide range of expert and non-expert uses and societal benefit areas. It provides precipitation rates for nearly the entire world every 30 minutes, and a long-term time series comparison illustrates how the new Version 06B compares to established datasets. Examples include flood and landslide analysis, drought analysis, agricultural forecasting, climatological statistics (including extreme precipitation case analyses), micro-insurance, water-related disease tracking, wildfire analysis in boreal forests, global water cycle studies, and numerical model validation. IMERG depends critically on high-quality retrievals from individual sensors, so continued progress on improving these retrievals for “difficult” situations is important, particularly the retrieval of solid precipitation, particularly when the surface is snowy/icy. In turn, improved quality in these retrievals will improve the quality of IMERG products and materially affect the research and societal benefit areas listed. The upcoming Aerosols, Clouds, Convection and Precipitation concept, which is being developed out of the Decadal Survey, should provide key process insights for these retrievals and subsequent improvement of IMERG quality for users.

Contributors: G. J. Huffman (612), D. T. Bolvin (612, SSAI), E. J. Nelkin (612, SSAI), J. Tan (613, USRA)

References: DOI: Early 10.5067/GPM/IMERG/3B-HH-E/06, Late 10.5067/GPM/IMERG/3B-HH-L/06, Final 10.5067/GPM/IMERG/3B-HH/06.

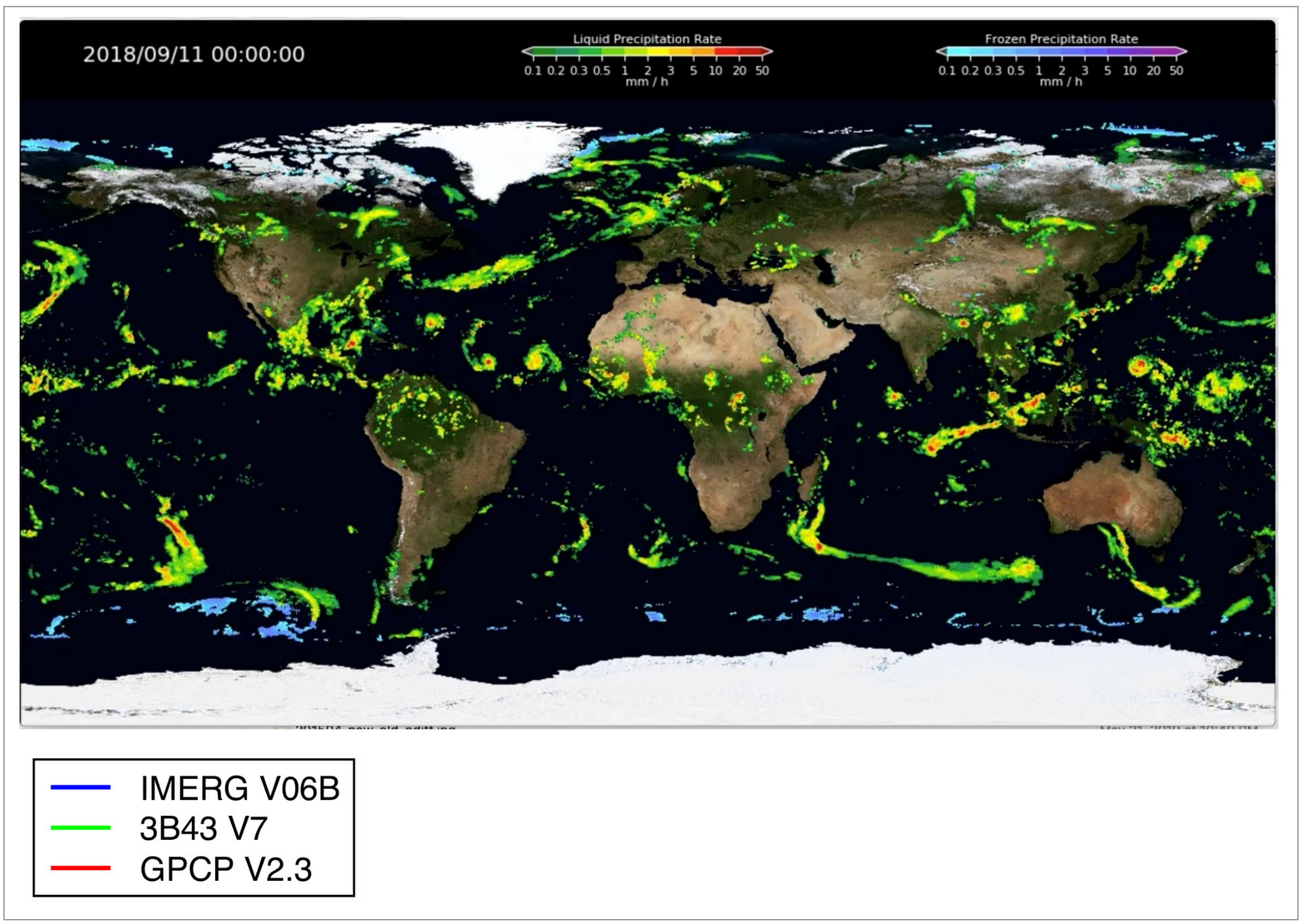


Figure 2.2.8: *IMERG provides half-hourly 0.1°x0.1° precipitation estimates that are nearly globally complete, only lacking coverage in polar regions, where the surface is snowy/icy. This particular figure was chosen because it displays three tropical cyclones in the tropical Atlantic Ocean and two off the east coast of Asia, in addition to the usual Intertropical Convergence Zone (rainfall near the Equator), subtropical highs (rain-free zones at low latitudes), and mid-latitude storm tracks.*

2.2.9. Detailed Ice Crystal Shapes Facilitate Improved Comparisons between Radar Observations and Models

This work allows for the more rigorous evaluation of ice microphysical modeling. Our understanding of these processes is limited, given the complexity of natural ice particles in the atmosphere, and the fact that their growth depends on interactions between ice particles. Other factors affecting growth are temperature, humidity, and liquid water content of the atmosphere. The ability to take simulated ice particle properties (e.g., mass, size, shape) and accurately calculate their radar signatures allows for radar observations to help constrain the uncertainties found in microphysical models. Because microphysical models, by necessity, use simplified representations of ice particles to simulate their growth, there is ambiguity in the detailed shapes that these simplified particles represent. Therefore, there is also uncertainty in the radar signatures of these simplified representations of ice particles. We developed a forward model to calculate the radar signals of ice crystals given limited information from ice growth models. By generating a variety of ice crystals, we simulated radar signals for a range of particle shapes. Using these results, the probabilistic forward model accurately calculates radar signals from limited model information and provides an estimate of the uncertainty. These improvements will have a substantial impact for the Aerosol, Cloud, Convection, and Precipitation (ACCP) concept currently being studied, as the objectives of this Decadal Survey Designated Observable include understanding the underlying processes behind clouds and precipitation.

Contributors: R. S. Schrom (612, USRA), M. R. Kumjian (PSU)

Reference: Schrom, R.S. and M.R. Kumjian, 2019: A Probabilistic Radar Forward Model for Branched Planar Ice Crystals. *J. Appl. Meteor. Climatol.*, **58**, 1245-1265, https://doi.org/10.1175/JAMC-D-18-0204.1.

2.2.10. Model Planetary Boundary Layer Heights and Ground-Based, Airborne, and Satellite Lidar Data Provide New Insight on Air Quality

High-resolution Weather Research and Forecasting (WRF) modeled planetary boundary layer heights (PBLHs) are evaluated against ground-based micro pulse lidar (MPL), the NASA Langley airborne High Spectral Resolution Lidar-1 (HSRL-1), and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on the CALIPSO satellite during the DISCOVER-AQ Baltimore-Washington, D.C. field campaign. WRF-lidar differences were dependent on model configuration, PBLH calculation method, and synoptic conditions. Contrasting synoptic conditions show poor agreement between WRF and lidar-derived PBLHs on a day with poor air quality (July 11) and good agreement on a day with moderate air quality (July 14). An additional finding from July 11 is the method used to determine the PBLH from WRF and ozonesonde profiles (gradient, bulk Richardson, or parcel) produced results that varied by as much as 1 km. The fact that there were such large differences between the PBLHs attributable to the calculation method suggests that the meteorological PBL structure is less distinct. A potentially quantifiable degree of uncertainty in the mixing-height estimates could be used in conjunction with retrospective air quality simulations to better understand the causes of pollution events such as high-ozone episodes. Since high-ozone days in the northeastern United States often occur with synoptic surface winds from the southwest direction, this uncertainty characterization of the mixing height estimates could be of significant importance. Furthermore, this research can provide guidance towards future studies of PBL processes such as bay breezes and the PBLH gradient that exists between urban and rural areas. In addition to using CALIPSO data, this work will facilitate formulation of two *Decadal Survey* missions: the Aerosol, Cloud, Convection, and Precipitation Designated Observable and the Planetary Boundary Layer Incubator.

Contributors: J. Lewis (612, UMBC/JCET), E. Welton (612), E. McGrath-Spangler (610.1, USRA); J. Hegarty (AER)

Reference: Hegarty, J.D., J. Lewis, E.L. McGrath-Spangler, J. Henderson, A.J. Scarino, P. DeCola, R. Ferrare, M. Hicks, R.D. Adams-Selin, and E.J. Welton, 2018: Analysis of the Planetary Boundary Layer Height during DISCOVER-AQ Baltimore–Washington, D.C., with Lidar and High-Resolution WRF Modeling. *J. Appl. Meteor. Climatol.*, **57**, 2679-2696, https://doi.org/10.1175/JAMC-D-18-0014.1.

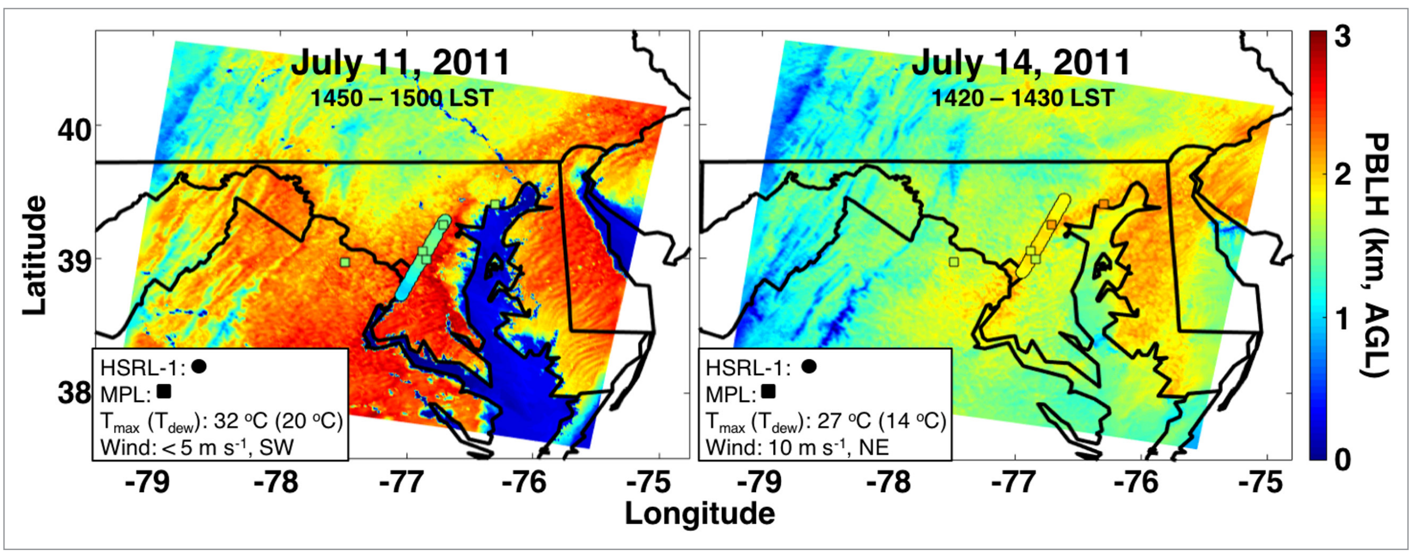


Figure 2.2.10: *High-resolution WRF simulations with horizontal grid spacing of 1 km and eight different combinations of PBL schemes, urban parameterization, and sea surface temperature inputs were evaluated against ground-based, airborne, and satellite lidars. Two days with contrasting weather conditions are shown for July 11 (left figure) and July 14 (right figure).*

2.2.11. Comparing GPM and CloudSat Products Emphasizes the Challenge of Observing Snowfall from Space

Retrievals of falling snow from space-based observations represent key inputs for understanding and linking the Earth's atmospheric, hydrological, and energy cycles. This work quantifies and investigates causes of differences among the first stable falling snow retrieval products from the Global Precipitation Measurement (GPM) Core Satellite and CloudSat's cloud profiling radar (CPR) falling snow product. An important part of this analysis details the challenges associated with comparing the various GPM and CloudSat snow estimates arising from different snow-rain classification methods, orbits, resolutions, sampling, instrument specifications, and algorithm assumptions. After equalizing snow-rain classification methodologies and limiting latitudinal extent, CPR observes nearly 10 (3) times the occurrence (accumulation) of falling snow as GPM's DPR. The occurrence disparity is substantially reduced if CloudSat pixels are averaged to simulate DPR radar pixels and CPR observations are truncated below the 8 dBZ reflectivity threshold. However, even though the truncated CPR- and DPR-based data have similar falling snow occurrences, average snowfall rate from the truncated CPR record remains significantly higher (43%) than the DPR, indicating that retrieval assumptions (microphysics and snow scattering properties) are quite different. Diagnostic reflectivity (Z) - snow rate (S) relationships were therefore developed at Ku and W band using the same snow scattering properties and particle size distributions in a final effort to minimize algorithm differences. CPR-DPR snowfall amount differences were reduced to ~16% after adopting this diagnostic Z-S approach.

Contributors: L. Milani (612, UMD), G. Skofronick-Jackson (NASA/HQ), M. S. Kulie (NOAA), S. J. Munchak (612), N. B. Wood (UW), V. Levizzani (ISAC-CNR)

Reference: Skofronick-Jackson, G., M.S. Kulie, L. Milani, S.J. Munchak, N.B. Wood, V. Levizzani, 2019: Satellite Estimation of Falling Snow: A Global Precipitation Measurement (GPM) Core Observatory Perspective. *J. Appl. Meteor. and Climatol.,* **58**, 1429-1448.

2.2.12. Chemical Transport Model Recreates Vertical and Spatial Propagation of Stratospheric Smoke Plume Using Space Based Lidar (CATS & CALIOP) Constrained Aerosol Emission Injection Altitudes

Smoke particles can be injected by large forest fire events (pyrocumulonimbus) into the upper troposphere and lower stratosphere, but their effects on atmospheric composition and the radiative budget of the planet have not been well quantified. Here, we show the GEOS-Chem chemical transport model using space based lidar constrained aerosol injection altitudes can accurately recreate the spatial and vertical propagation of aerosols as observed by the Earth Polycromatic Imaging Camera (EPIC), and the Cloud-Aerosol Transport System (CATS) and Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) space-based lidars. Additionally, this work is among the first to attempt to quantify the effects of pyrocumulonimbus events on the radiative balance of the planet. These modeling results indicate ~1K in lower stratospheric warming, a 5+ month aerosol lifetime, and a net positive radiative forcing. The net positive radiative forcing from the pyrocumulonimbus smoke aerosols at the top of the plumes is opposite the effect seen in analogous volcanic aerosol plumes due to the presence of black carbon, an efficient absorber of solar radiation, in the smoke plume. This work supports NASA's strategic objective 2.2 (2014 strategic plan) to advance knowledge of Earth to meet the challenges of environmental change. In addition, identifying vertical profile measurements of UTLS aerosols, trace gases, volcanic emissions, and biomass burning emissions is classified as a very important area in the *2017 Decadal Survey*.

Contributors: K. Christian (612, USRA/NPP), J. Wang (U Iowa), J. Yorks (612), M. McGill (612), et al.

Reference: Christian, K., Wang, J., Ge, C., Peterson, D., Hyer, E., Yorks, J., & McGill, M., 2019: Radiative Forcing and Stratospheric Warming of Pyrocumulonimbus Smoke Aerosols: First Modeling Results With Multisensor (EPIC, CALIPSO, and CATS) Views From Space. *Geophys. Res. Lett.*, **46**, 10,061-10,071. https://doi.org/10.1029/2019GL082360.

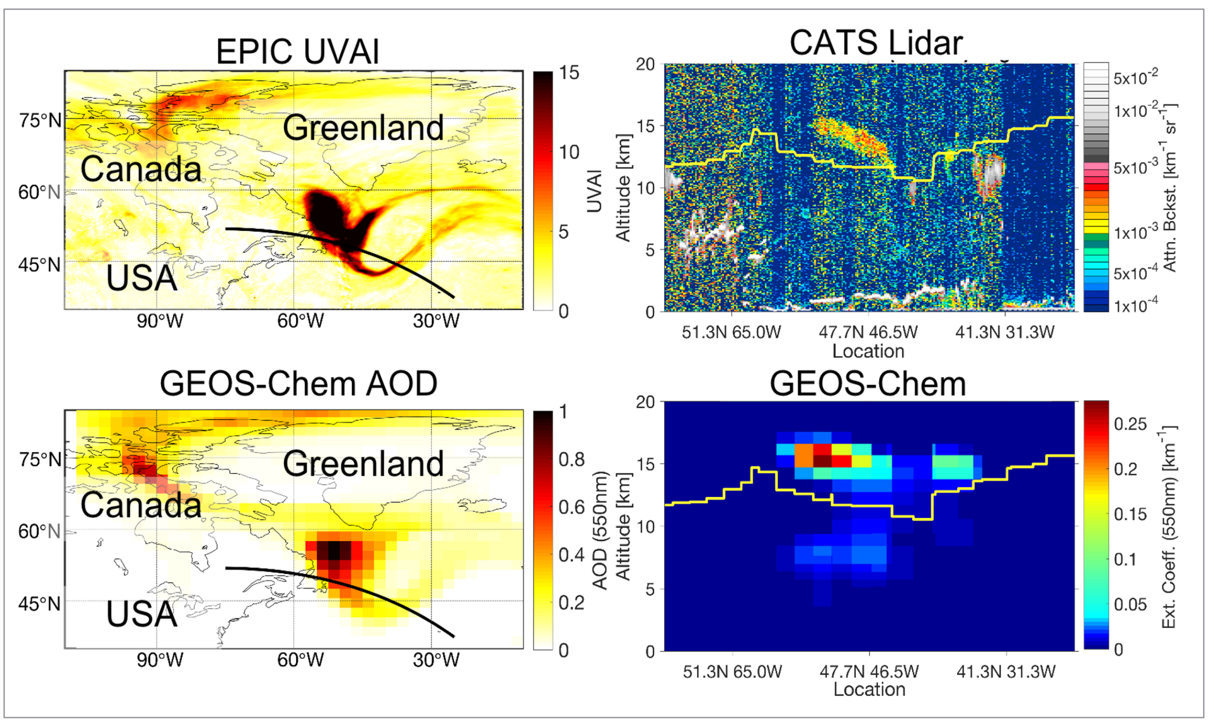


Figure 2.2.12: *Agreement between satellite observations (EPIC UVAI (top left) and CATS total attenuated backscatter (top right)) and GEOS-Chem modeled AOD (bottom left) and extinction coefficients (bottom right) on August 19, 2017—about a week after the PyroCb event.*

2.3. 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 website 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 (GCMs). The projects link on the Climate and Radiation Laboratory website 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 2019 are summarized below.

2.3.1. Satellite-based insights into effects of combustion aerosols on Arctic clouds

The Arctic is rapidly changing, with implications for a host of socioeconomic and environmental issues. However, models have difficulty reproducing the Arctic energy budget. Large errors stem from uncertainties in aerosol impacts on cloud phase and cloud fraction. For example, in this work we found a ~10 Wm^{-2} difference in longwave heating at the surface during polar night when column combustion aerosols are in the upper versus lower quartile range of modeled levels. In this work, we can show that meteorological co-variability likely can account for much or most of the longwave heating signal, but not all. This study provides insight into how combustion aerosols affect freezing processes over large regions of the rapidly changing Arctic. We provide insight into how aerosols affect clouds, which can help us understand how this important region will change in the future. Aerosol-mediated freezing effects on clouds are hard to distinguish from co-varying meteorological factors, contributing to large uncertainties in the Arctic energy budget. Using NASA satellite data, we characterized cloud properties in clean versus combustion-polluted conditions under similar meteorological conditions. We found that relative to clean clouds, Arctic low clouds are on average icier, more likely to be precipitating, and less extensive. These trends are opposite to those of high clouds. This method has the potential to be applied to other regions of the planet to help resolve the current large uncertainties in aerosol microphysical impacts on clouds, which represent a major uncertainty in global climate overall. Addressing uncertainties in vertical air motion, not done here, would improve future studies that follow this approach.

Contributors: L. Zamora (613, ESSIC), R. Kahn (613)

Reference: Zamora, L. M., Kahn, R. A., Huebert, K. B., Stohl, A., and Eckhardt, S., 2018: A satellite-based estimate of combustion aerosol cloud microphysical effects over the Arctic Ocean. *Atmos. Chem. Phys.*, **18**, 14,949-14,964, https://doi.org/10.5194/acp-18-14949-2018.

2.3.2. Volcano-induced global anisotropy anomaly in scattered radiances

The radiance anisotropy from multi-angle observations is highly sensitive to the stratospheric volcanic aerosols (SVA). Significant anisotropy perturbations were seen in MISR DF-DA radiance differences shortly after strong volcanic eruptions during 2006-2018, which are consistent with CALIPSO SVA observations. Multi-angle observations provide unique information on weak scattering signals induced by SVA

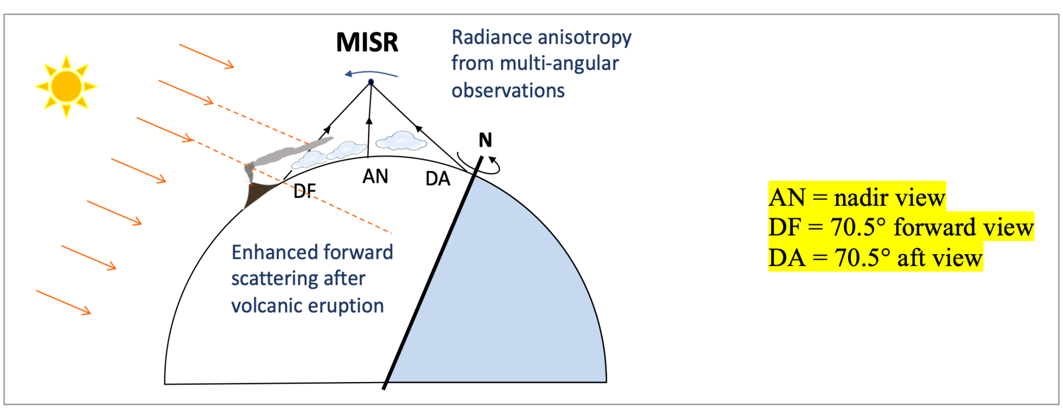


Figure 2.3.2: *Multi-angle observations provide unique information on weak scattering signals.*

in the upper troposphere and lower stratosphere. This paper is the first report of SVA-induced radiance anisotropy at slant viewing angles from space-based, multi-angle measurements. The MISR observations suggest that enhanced global forward scattering by SVAs could make a significant contribution to the shortwave radiation budget.

Contributors: D. L. Wu (613), T. Wang, T. Várnai, J. Limbacher, R. Kahn (613), G. Taha, J. Lee, J. Gong (SSAI), and T. Yuan (USRA)

Code 613, NASA/GSFC, UMD/ESSIC, UMBC/JCET, SSAI, and USRA

Reference: Wu, D. L., et al., 2018: MISR Radiance Anomalies Induced by Stratospheric Volcanic Aerosols. *Remote Sens.*, **10**, 1875, doi:10.3390/rs10121875.

2.3.3. How much extra smoke can be retrieved from MODIS during the 2015 Indonesia fire event?

Extreme aerosol events, resulting from severe biomass burning, have large regional and global impacts. Satellite aerosol products, both from passive and active sensors have trouble identifying and retrieving these events, particularly over very thick smoke plumes. The extreme Indonesian fire and smoke event of 2015 caused severe public health, economic, and environmental damage. The standard MODIS Dark Target (DT) aerosol algorithm significantly underestimated smoke levels during this episode, as the most intense parts of the plume were filtered out. This motivated the development of a research algorithm that was able to recover these erroneously-filtered areas, while still correctly removing cloud-contaminated pixels. In the research product, the number of pixels with a very high aerosol optical depth (AOD) above 1, indicating extreme smoke, doubles during this event. These results are expected to influence the future development of the global DT aerosol algorithm.

Contributors: Y. Shi (613, USRA), R. Levy (613), S. Mattoo (613, SSAI), T. Eck (618, USRA), B. Fisher (614, SSAI), I. Slutsker (618, SSAI), L. Remer (UMBC-JCET), J. Zhang (UND)

Reference: Shi, Y. R., Levy, R. C., Eck, T. F., Fisher, B., Mattoo, S., Remer, L. A., Slutsker, I., and Zhang, J., 2019: Characterizing the 2015 Indonesia fire event using modified MODIS aerosol retrievals. *Atmos. Chem. Phys.*, **19**, 259-274, https://doi.org/10.5194/acp-19-259-2019.

2.3.4. The subgrid variability of precipitation in different cloud systems

A cloud field spanning across 100 km usually contains a mixture of cloud types and the precipitation reaching the surface will vary widely. It can be intense but sporadic, or it can be light but widespread. It can be convective or stratiform, or mixture of both.

Moreover, it can vary in phase: rainfall, snowfall, or mixed phase. Cloud regimes (CRs) provide an objective way of classifying cloud fields globally based on the distribution of their properties into mesoscale atmospheric systems such as organized convection, extratropical storms, and stratocumulus fields. Previous studies have analyzed CR grid-mean precipitation—that is, the average precipitation over the entire system—demonstrating the distinct amount of precipitation produced by these systems. By compositing IMERG precipitation by cloud regime CR as identified by MODIS, we can identify how much precipitation is associated with different cloud systems near-globally. The higher spatial resolution of IMERG allows us to compute the areal fraction of each CR's precipitation. The combined perspective demonstrates that some CRs have intense but sporadic precipitation (CR1), and that even the wettest CR2 precipitates in only half its area on average—a testament to rainfall's high spatial variability. These insights reveal the nature of different atmospheric systems globally, contributing towards our understanding of the atmosphere in the real world and providing guidance into how they are represented in numerical models.

Contributors: J. Tan (613, USRA), L. Oreopoulos (613)

References: Tan, J., and L. Oreopoulos, 2019: Subgrid Precipitation Properties of Mesoscale Atmospheric Systems Represented by MODIS Cloud Regimes. *J. Climate*, **32**, 1797-1812, doi:10.1175/JCLI-D-18-0570.1.

Oreopoulos, L., N. Cho, D. Lee, and S. Kato, 2016: Radiative effects of global MODIS cloud regimes. *J. Geophys. Res.: Atmos.*, **121**, 2299-2317, doi:10.1002/2015JD024502.

Huffman, G. J., and Coauthors, 2018: Algorithm Theoretical Basis Document (ATBD) Version 5.2. NASA Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG). NASA, https://pmm.nasa.gov/data-access/downloads/gpm.

2.3.5. Extending the MODIS Cloud Product Data Record to SNPP-VIIRS

Observational studies aimed at detecting and assessing meaningful climate trends require long-term, stable, global data records spanning multiple decades. While Earth-observing satellites can provide the necessary global perspective, multi-decadal data records require coupling the observational records of multiple, often different, satellite remote sensing instruments. For clouds, NASA's MODIS onboard the EOS Terra and Aqua platforms has offered unique capabilities for retrieving key geophysical parameters such as cloud-top pressure, cloud optical thickness, and effective particle size. However, though their missions are expected to extend into the early 2020s (20+ year data records), these data records alone are insufficient for establishing cloud climate trends. The VIIRS imager onboard the joint NASA/NOAA SNPP satellite, as well as the NOAA operational series JPSS, offers the opportunity to extend the EOS MODIS data records well into the 2030s. Creating long-term time series of satellite-derived cloud properties for climate research requires coupling the data records of multiple, and often differing, sensors. The recently released cloud mask (CLDMSK) and cloud top and optical properties (CLDPROP) products are a result of an effort to bridge NASA's EOS-MODIS and operational SNPP-VIIRS eras using a common algorithm. A number of issues that impact cloud optical/microphysical property continuity are still being investigated, such as inter-sensor differences in spatial resolution, pixel growth across swath, sampling of successive scan overlap, relative radiometry, etc.

Contributors: K. Meyer (613), S. Platnick (610AT), S. Ackerman, Bob Holz (U. Wisc.); Andrew Heidinger (NOAA); et al.

References: Frey, R., S. Ackerman, R. Holz, S. Dutcher, 2019: The Continuity MODIS-VIIRS Cloud Mask (MVCM) User Guide, https://modis-atmosphere.gsfc.nasa.gov/sites/default/files/ModAtmo/MODIS_VIIRS_Cloud-Mask_UG_Feb_2019.pdf

Platnick, S., A. Heidinger, K. Meyer, R. Holz, et al., 2019: EOS MODIS and SNPP VIIRS Cloud Properties: User Guide for the Climate Data Record Continuity Level-2 Cloud Top and Optical Properties Product (CLDPROP), https://modis-atmosphere.gsfc.nasa.gov/sites/default/files/ModAtmo/EOSSNPPCloudOpticalPropertyContinuityProductUserGuidev1.pdf.

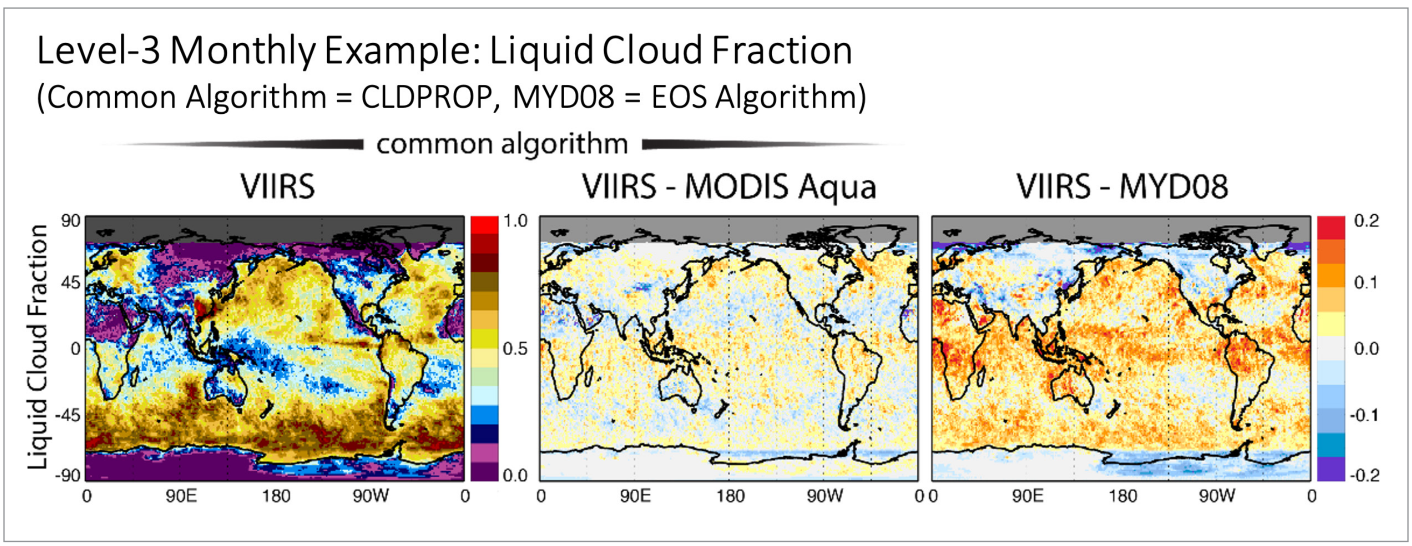


Figure 2.3.5: *Fraction of observations during February 2014 having liquid phase clouds derived from the common algorithm CLDPROP applied to SNPP-VIIRS (left), along with differences with respect to Aqua-MODIS liquid cloud fractions derived from CLDPROP (center) and the heritage EOS algorithms (MYD06, MYD08, right).*

2.3.6. Cloud Observations from DSCOVR EPICC

The Earth Polychromatic Imaging Camera (EPIC) on board the Deep Space Climate Observatory (DSCOVR) satellite has been providing a continuous view of the sunlit side of the Earth from the Earth-Sun system L1 Lagrangian point, since June 2015. Our algorithms generate standard EPIC Level 2 cloud products, such as cloud mask, cloud effective pressure/height, and cloud optical thickness. Comparison with co-located cloud retrievals from geosynchronous Earth orbit (GEO) and low Earth orbit (LEO) satellites shows that the EPIC cloud product algorithms are performing well and are consistent with theoretical expectations. These products are publicly available at the Atmospheric Science Data Center (ASDC) at the NASA Langley Research Center for climate studies and for generating other geophysical products that require cloud properties as input. Our work has shown that observations from the 10 EPIC spectral channels are unique for cloud viewing and cloud product development, and also demonstrate the utility and advantages of deep space vantage points for Earth monitoring.

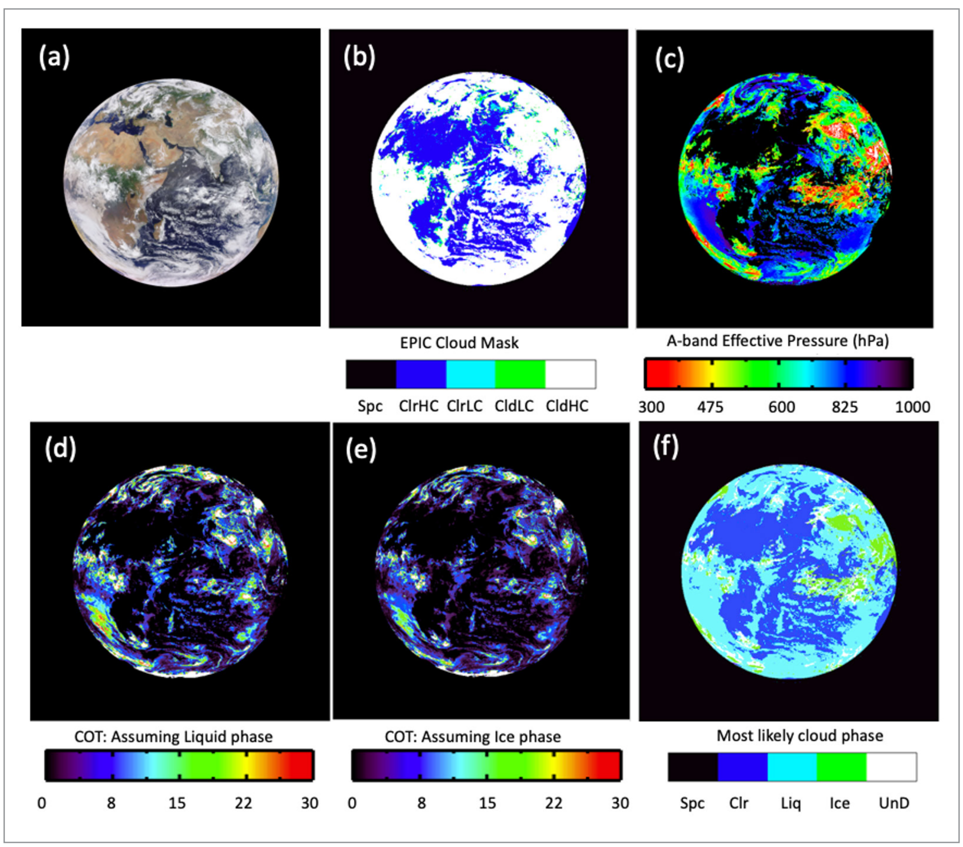


Figure 2.3.6: *EPIC L2 cloud product examples for August 18, 2016, 08 UTC: (a) EPIC RGB image; (b) EPIC cloud mask. Spc: space pixels, ClrHC: high confidence clear, ClrLC: low confidence clear, CldLC: low confidence cloudy, and CldHC: high confidence cloudy; (c) oxygen A-band cloud effective pressure; (d) cloud optical thickness assuming liquid phase; (e) cloud optical thickness assuming ice phase; (f) most likely cloud phase.*

Contributors: Y. Yang (613), K. Meyer (613), G. Wind (613, SSAI), Y. Zhou (13, MSU), A. Marshak (613), S. Platnick (610AT)

Reference: Liao, L, and R. Meneghini, 2019: A modified dual-wavelength technique for Ku- and Ka-band radar rain retrieval. *J. Appl. Meteor. Climatol.*, **58**, 3-18, https://doi.org/10.1175/JAMC-D-18-0037.1.

2.3.7. Finding the World's Ship-tracks with a Deep Learning Model

Ship-tracks are one of the best examples of anthropogenically-induced aerosol-cloud interaction, one of the most uncertain issues in climate science. The ability to detect them automatically at global scales will help us reduce uncertainty about this phenomenon through better understanding of its extent and variability under different conditions. Our test run has already found more than 10 times the number samples than all previous studies combined. We developed a deep learning model to identify, in satellite images, marine clouds modified by ship emissions, also known as ship-tracks. This paves the way for routine automatic detection of ship-tracks worldwide, and the creation of a unique dataset for detailed aerosol-cloud interactions studies. They can also be used to identify shipping activities around the world. Our technique can be applied to any future imagers similar to MODIS and VIIRS, and can potentially provide a wealth of data to advance aerosol-cloud interaction studies. In addition, our methodology can be used to study climate change impacts of specific ship-traffic and trade patterns.

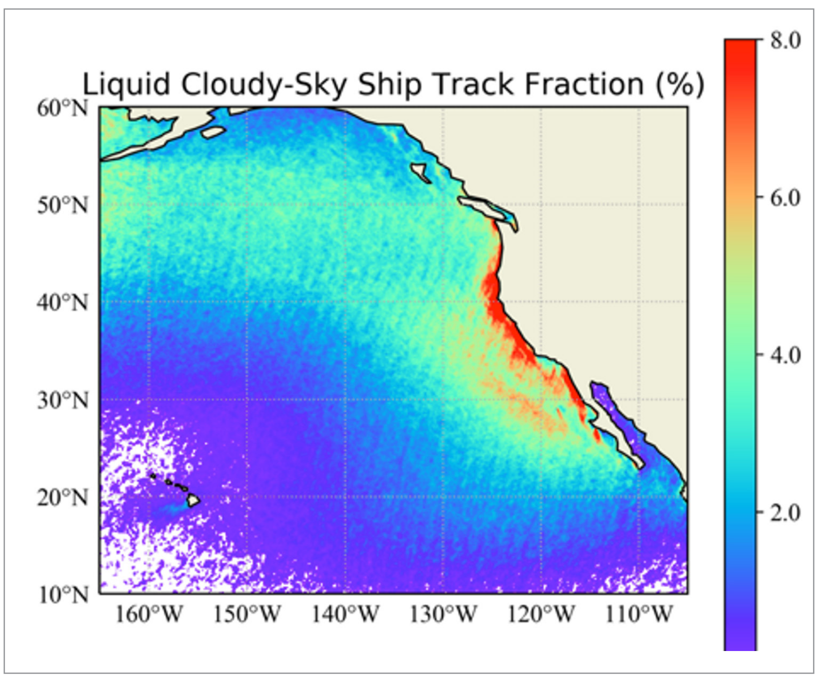


Figure 2.3.7: *Applying our model to data off the coast of California produces a ship-track density map that agrees the ship traffic patterns in this region, offering an additional validation of the technique.*

Contributors: Tianle Yuan, Chenxi Wang, Hua Song, S. Platnick (610AT), K. Meyer (613), L. Oreopoulos (613)

Code 613, NASA/GSFC JCET-UMBC, ESSIC-UMD, SSAI

Reference: Nicholls, S.D. and K.I. Mohr, 2019: An Automated Detection Methodology for Dry Well-Mixed Layers. *J. Atmos. Oceanic Technol.*, **36**, 761-779, https://doi.org/10.1175/JTECH-D-18-0149.1.

2.3.8. Finding the World's Ship-tracks with a Deep Learning Model

This work demonstrates that airborne measurements can bring significant improvements in the accuracy of satellite-based radiative flux estimates. In particular, it is shown that aircraft measuring the full angular distribution of reflected sunlight can help improve smoke albedo estimates for current and planned broadband satellite instruments such as CERES or CLARREO (Climate Absolute Radiance and Refractivity Observatory), even if conditions are fairly different for the satellite and airborne observations. The aircraft data can help, because satellites estimate the total reflection using observations taken from a single view direction. They also rely on statistical models to account for the angular variations that have been obtained here for a smoke plume using detailed Cloud Absorption Radiometer (CAR). During the ARCTAS campaign conducted in Western Canada, the CAR instrument, installed in the nose cone of the NASA P-3B aircraft, observed the full angular distribution of reflected sunlight as the aircraft circled above a smoke plume. The data collected from the instrument help to improve the accuracy of satellite data on the radiative impact of smoke from wildfires. This research contributes to NASA efforts regarding the "impact of aerosols on global warming," one of the research priorities identified as "very important" in the recent *Decadal Survey*.

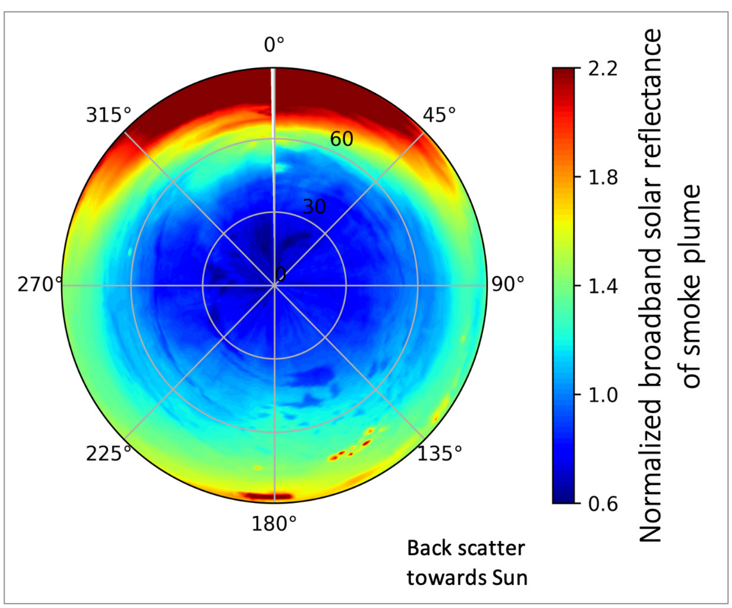


Figure 2.3.8: *Applying our model to data off the coast of California produces a ship-track density map that agrees the ship traffic patterns in this region, offering an additional validation of the technique.*

Contributors: Tamás Várnai, Charles Gatebe, Code 613, NASA/GSFC, UMBC/JCET, USRA

Reference: Várnai, T. (613/UMBC), C. Gatebe (613/USRA), R. Gautam, R. Poudyal, and W. Su, 2019: Developing an Aircraft-Based Angular Distribution Model of Solar Reflection from Wildfire Smoke to Aid Satellite-Based Radiative Flux Estimation. *Remote Sens.*, **11**, 1509. doi: 10.3390/rs11131509.

2.3.9. Observing Cloud Edges with Shortwave Spectrometers

Entrainment of dry air into clouds and mixing of dry air with cloudy air affect the cloud amount and the cloud microphysics. However, it is unclear whether the mixing process is predominantly homogeneous, inhomogeneous, or a combination of the two. The cloud edge area is an important region for understanding the mechanisms of the cloud mixing process. Yang et al. (2019) study demonstrated that the variation of cloud droplet size in cloud edges of continental clouds (more homogeneous mixing) is characteristically different from that for maritime clouds (more inhomogeneous mixing), suggesting different mixing mechanisms. By approximating the shortwave spectra in the cloud-clear transition zone as a linear combination of purely clear and purely cloudy spectra, we can characterize cloud optical thickness and cloud droplet effective radius in the transition zone. When applying this method to the measurements of a ground-based shortwave spectroradiometer in continental and maritime conditions, we found that cloud optical depth consistently decreases in both cases, but droplet size decreases much more substantially for the continental regime, suggesting different mixing processes for the two types of clouds. Our findings on the transition zone between clear and cloudy air can potentially lead to improvements in space-based estimates of aerosol radiative forcing and aerosol indirect effects. Taken as a function of cloud and aerosol microphysical properties, this leads to a better understanding of the spatial structure of cloud boundaries and their droplet size distributions.

Contributors: A. Marshak (613), Weidong Yang (613/USRA), and Guoyong Wen (613/MSU)

Code 613, NASA/GSFC, USRA, Morgan State University

References: Yang, W., Marshak, A., & Wen, G., 2019: Cloud edge properties measured by the ARM shortwave spectrometer over ocean and land. *J. Geophys. Res.: Atmos.*, **124**, https://doi.org/10.1029/2019JD030622.

Pinsky, M., & Khain, A. P., 2018: Theoretical analysis of the entrainment–mixing process at cloud boundaries. Part I: Droplet size distributions and humidity within the interface zone. *J. Atmos. Sci.*, **75**, 2049-2064, https://doi.org/10.1175/JAS-D-17-0308.1.

2.3.10. Satellite Observations Suggest Too Efficient Dust Removal in Models

The satellite-based estimates of dust deposition produced from this study fill the geographical gaps and extend time span of scarce in situ measurements of dust deposition, particularly in open oceans. The dataset can be used to study impacts of mineral dust on ocean biogeochemical cycles and climate change, as well as to guide the improvement of model parameterizations of dust processes. Significant differences among existing satellite measurements of dust manifest the necessity of developing advanced satellite sensors with enhanced capabilities of characterizing three-dimensional distribution of aerosol and deciphering aerosol properties to distinguish dust from other types of aerosol for the ACCP mission recommended by the *2017 Decadal Survey*. Decade-long (2007-2016) records of CALIOP, MODIS, MISR, and IASI observations were used to quantify dust deposition flux and loss frequency (LF) over the tropical Atlantic Ocean. Deposition flux and LF show distinct variations in season and space. The satellite observations suggest that models remove dust too fast (i.e., LF being 2-5 times higher) along the trans-Atlantic transit, which has led to an ongoing analysis of models to better define model deficiencies.

Contributors: H. Yu (613), Q. Tan (BAERI), M. Chin (614), L. Remer (UMBC/JCET), R. Kahn (613), et al.

Reference: Yu, H., Q. Tan, M. Chin, L. A. Remer, R. A. Kahn, H. Bian, D. Kim, Z. Zhang, T. Yuan, A. H. Omar, D. M. Winker, R. C. Levy, O. Kalashnikova, L. Crepeau, V. Capelle, A. Chedin, 2019: Estimates of African dust deposition along the trans-Atlantic transit using the decade-long record of aerosol measurements from CALIOP, MODIS, MISR, and IASI. *J. Geophys. Res.: Atmos.*, **124**, 7975-7996. https://doi.org/10.1029/2019JD030574.

2.3.11. 3D-Winds from Low-Earth and Geostationary Stereo Imaging

Advanced Image Navigation and Registration (INR) of low-Earth (LEO) and geostationary orbit (GEO) sensors enables accurate retrievals of atmospheric motion vector (AMV) and cloud height from LEO-GEO stereo technique, to study planetary boundary-layer (PBL) dynamics and processes. This work demonstrates potential of the stereoscopic imaging technique for high-accuracy measurements of AMVs and cloud/plume heights. The LEO-GEO stereo technique is applied successfully to the contemporaneous MODIS and GOES-R series ABI imagery for a case of wildfire plumes in the planetary boundary layer (PBL). The AMV height accuracy from LEO-GEO stereo technique offers great potential for future PBL science missions as well as for the understanding of atmospheric processes that requires 3D coverage of cloud dynamics. The advantages of using MODIS and MODIS-like imagers with GOES are that MODIS offers a wider swath (2330 km) and eight thermal IR bands that pair well with those of ABI. The 3D-winds retrieval model is based on our previous MISR-

GOES work and is universally applicable to LEO-GEO, GEO-GEO, and LEO-LEO pairings. The LEO-GEO stereo technique require no synchronization between the LEO and GEO observations from heterogeneous platforms, because the retrieval model accounts for the non-simultaneity by solving the disparities induced by motion and parallax together. The new methods are enabled by the accurate geolocation provided by modern imaging systems like MODIS and ABI.

Contributors: D. L. Wu (613), J. L. Carr (Carr Astronautics), R. E. Wolfe (619), H. Madani (613), G. Lin (619, SSAI), and B. Tan (619, SSAI)

References: Carr, J. L., D. L. Wu, R. E. Wolfe, H. Madani, G. Lin, and B. Tan, 2019: Joint 3D-Wind Retrievals with Stereoscopic Views from MODIS and GOES. *Remote Sens.*, **11**, 2100; doi:10.3390/rs11182100.

Carr, J. L., D. L. Wu, M. A. Kelly, and J. Gong, 2018: MISR-GOES 3D Winds: Implications for Future LEO-GEO and LEO-LEO Winds. *Remote Sens.*, **10**(12), 1885; doi.org/10.3390/rs10121885.

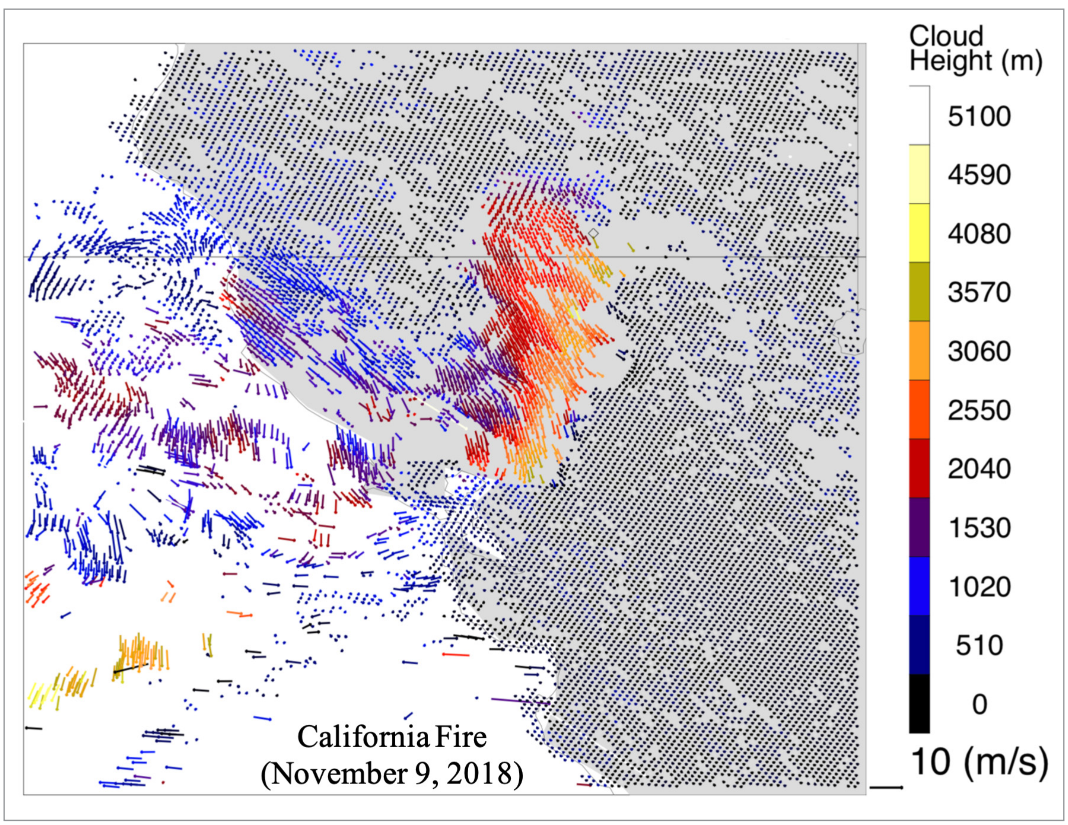


Figure 2.3.11: *The map shows the retrieved MODIS-GOES AMV and height over the northern California, which captures a moment of rapid development of Camp Fire at 18:55 UTC (11:55 Local Time).*

2.3.12. Surface Polarized Reflectance is not Spectrally Invariant

Knowledge of surface polarized reflectance, Rp, is important for accurate characterization of aerosol properties based on multi-angle spectro-polarimetric measurements. Several state-of-the-art retrieval algorithms [1, 2] assume spectrally flat Rp which would suggest that surface properties can be retrieved at low atmospheric influence NIR wavelengths, and then be applied to process the visible and UV bands. Using the ISS-based lidar CATS (2015-17) [3, 4], which measures polarization at 532 and 1064 nm, we show that this premise is not true and that the surface polarized reflectance actually depends substantially on wavelength. Our study [5] demonstrates the uniqueness of lidars like CATS for analysis of surface polarized reflectance because of the high signal, particularly during nighttime measurements, resulting from the low orbit, the negligibly small contribution of atmospheric backscattering, and the presence of two polarized bands.

Contributors: Sergey Korkin (613, USRA/GESTAR), A. Lyapustin (613)

Reference: Korkin S., Lyapustin A., 2019: Surface polarized reflectance analysis for aerosol remote sensing, SPIE Proceedings, v.11152. *Remote Sens. Clouds Atmos. XXIV*, 111520I [10.1117/12.2531426].

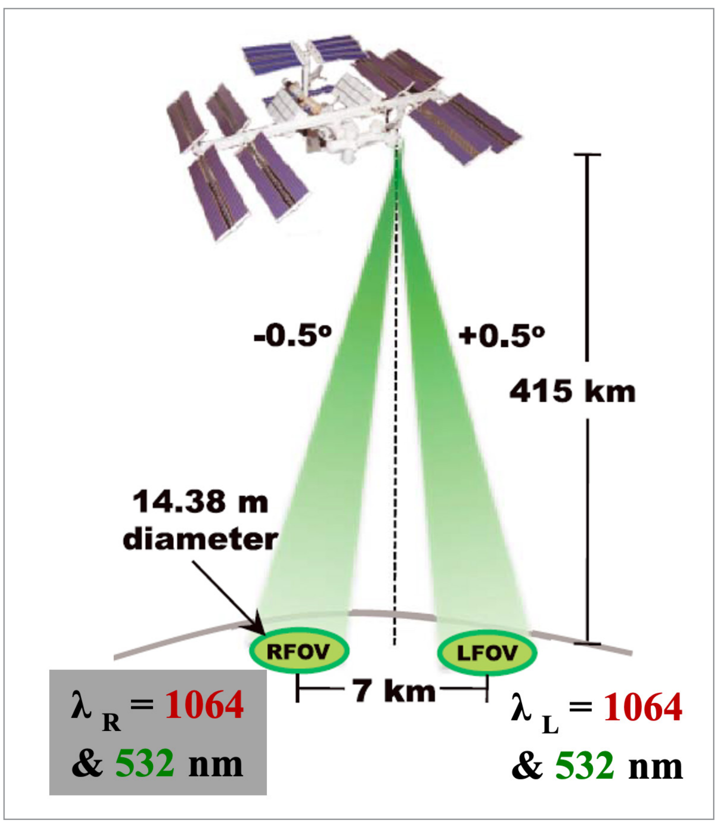


Figure 2.3.12: *The CATS lidar onboard the International Space Station (ISS) offers: a) measurement of polarization at 532 & 1064 nm, and b) two fields of view, 7km apart which allows to filter noise*

2.4. 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. Dry deposition of NO_2 and SO_2 contributes excess nitrogen and sulfur to vegetation, soil, and water. Deposited nitrogen can cause eutrophication, leading to a loss of biodiversity. Deposited nitrogen and sulfur both have the potential to acidify soil and water, and may influence climate by perturbing the carbon uptake of an ecosystem. Measurements of NO_2 and SO_2 columns from the Ozone Monitoring Instrument (OMI) in combination with the GEOS-Chem chemical transport model have provided the first global budgets and estimates of spatial patterns of NO_2 and SO_2 dry deposition. These results have potential applications in a range of fields, from atmospheric chemistry to ecology. The upcoming NASA Earth venture mission TEMPO (Tropospheric Emissions: Monitoring of Pollution) will allow dry deposition to be quantified at very high spatial and temporal resolution.

2.4.1. A new global anthropogenic SO_2 emission inventory for the last decade: A mosaic of satellite-derived and bottom-up emissions

Sulfur dioxide (SO_2) has a significant effect on global and regional climate by changing radiative forcing and contributes to acid deposition that damages aquatic and terrestrial ecosystems.

We have combined satellite-based emissions for large sources with a bottom-up inventory HTAP derived from reported fossil fuel combustion for smaller sources, to construct a new inventory, OMI-HTAP. OMI-HTAP is novel in that it is the first inventory with inclusion of nearly 40 OMI-detected sources that are not captured in previous leading bottom-up inventories. It enables more accurate emission estimates for regions with such missing sources, e.g., the Middle East and Mexico. OMI-HTAP provides dynamic emissions for over 400 OMI-based large sources since 2005, allowing for updates to the emissions over time. OMI-HTAP with accurate location information of each large point source contributes to correction of the 40 uncaptured emissions in bottom-up inventories. More accurate estimates for diurnally and seasonally varying emissions can be expected using upcoming geostationary satellite instruments, e.g., NASA Tropospheric Emissions: Monitoring of Pollution (TEMPO), which will enable estimations for different times of the day.

Contributors: Fei Liu (USRA/GSFC), SungyeonChoi (SSAI/GSFC), Can Li (ESSIC/GSFC), et al

Reference: Liu, F., Choi, S., Li, C., Fioletov, V. E., McLinden, C. A., Joiner, J., Krotkov, N. A., Bian, H., Janssens-Maenhout, G., Darmenov, A. S., and da Silva, A. M., 2018: A new global anthropogenic SO_2 emission inventory for the last decade: a mosaic of satellite-derived and bottom-up emissions. *Atmos. Chem. Phys.*, **18**, 16,571-16,586, https://doi.org/10.5194/acp-18-16571-2018.

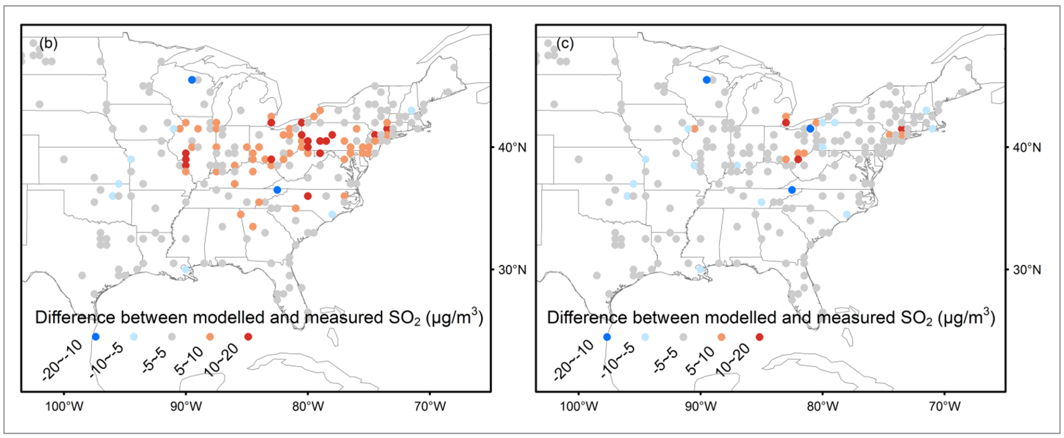


Figure 2.4.1: *Improved model performance with the new emission product OMI-HTAP.*

2.4.2. 40-year Multi-Satellite Volcanic Sulfur Dioxide (SO_2) Global Database released as part of MEaSUREs SO_2 project

Stratospheric loading of volcanic SO_2 by major eruptions leads to the formation of sulfuric acid (or sulfate) aerosols. The aerosols scatter incoming solar shortwave radiation and absorb outgoing thermal radiation over timescales of months to years, cooling the troposphere and warming the stratosphere. Volcanic eruptions can also release reactive halogen species into the atmosphere, such as chloride and bromide. Halogens can impact the total column ozone amount and profile shape, if injected into the lower stratosphere, but sulfate aerosols are also required to catalyze the heterogeneous chemical reactions that can efficiently deplete ozone. Hence, to understand the impacts of volcanic eruptions on climate, and in order to predict possible outcomes in the event of a major eruption, long-term satellite measurements of volcanic SO_2 emissions are essential. The volcanic SO_2 climatology from 1978-present reveals highly variable inter-annual volcanic SO_2 forcing dominated by two major eruptions (El Chichon in 1982 and Pinatubo in 1991), with the post-2000 period dominated by smaller eruptions.

Although none of these smaller eruptions have, individually, produced measurable climate effects, collectively they have garnered significant interest as they may play an important role in sustaining the persistent, background stratospheric aerosol layer, which is an important factor in global climate forcing.

Contributors: S. A. Carn (MTU), N. A. Krotkov (614), B.L. Fisher (614, SSAI), C. Li (614, ESSIC), P. Leonard (ADNET)

Reference: Carn, S., 2019: Multi-Satellite Volcanic Sulfur Dioxide L4 Long-Term Global Database V3, Greenbelt, MD, USA, Goddard Earth Science Data and Information Services Center (GES DISC), Accessed: 18 February 2019, 10.5067/MEASURES/SO2/DATA404.

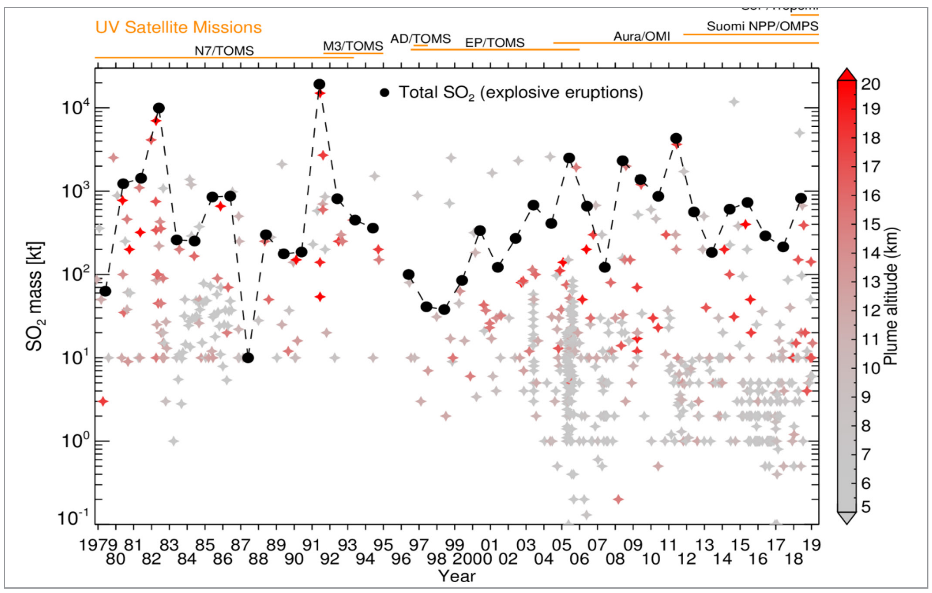


Figure 2.4.2: *Multi-decadal record of global SO_2 emissions by volcanic eruptions observed by NASA's fleet of satellites observing TOA UV radiances. Eruptions (star symbols) are color-coded by estimated plume altitude. The annual total explosive volcanic SO_2 production (omitting SO_2 discharge from effusive eruptions) is shown in black. Reference: Simon Carn (2019), Multi-Satellite Volcanic Sulfur Dioxide L4 Long-Term Global Database V3, Greenbelt, MD, USA, Goddard Earth Science Data and Information Services Center (GES DISC), Accessed: 18 February 2019, https://doi.org/10.5067/MEASURES/SO2/DATA404*

2.4.3. Mapping the Oxidizing Capacity of the Global Remote Troposphere

The hydroxyl radical (OH) is central to myriad atmospheric processes. OH is highly variable in space and time, but current observation-based methods cannot resolve local and regional OH gradients. Such information is crucial both for understanding the processes that modulate OH and for isolating issues in global models, which currently cannot accurately simulate OH.

We combined airborne observations from NASA's Atmospheric Tomography (ATom) mission with OMI retrievals of formaldehyde (HCHO) to infer the distribution of total-column OH throughout the remote troposphere. This novel dataset reveals regional-scale natural and anthropogenic perturbations and can guide efforts to improve simulations of global atmospheric composition. Future research will focus on refining this technique for wider application (e.g., over land, on longer timescales), as well as leveraging recent (TROPOMI) and upcoming (TEMPO) orbital observations of atmospheric composition for increased resolution and precision.

Contributors: G. Wolfe (614, JCET), J. Nicely (614, ESSIC), et al.

Reference: Wolfe, G. M. (614/JCET), Nicely, J. M. (614/ESSIC), St Clair, J. M. (614/JCET), Hanisco, T. F. (614), Liao, J. (614/USRA), Oman, L. D. (614), Brune, W. B., Miller, D., Thames, A., González Abad, G., Ryerson, T. B., Thompson, C. R., Peischl, J., McKain, K., Sweeney, C., Wennberg, P. O., Kim, M., Crounse, J. D., Hall, S. R., Ullmann, K., Diskin, G., Bui, P., Chang, C. and Dean-Day, J., Mapping hydroxyl variability throughout the global remote troposphere via synthesis of airborne and satellite formaldehyde observations. *Proceedings of the National Academy of Sciences of the United States of America*, **116**(23), 11,171-11,180, doi:10.1073/pnas.1821661116.

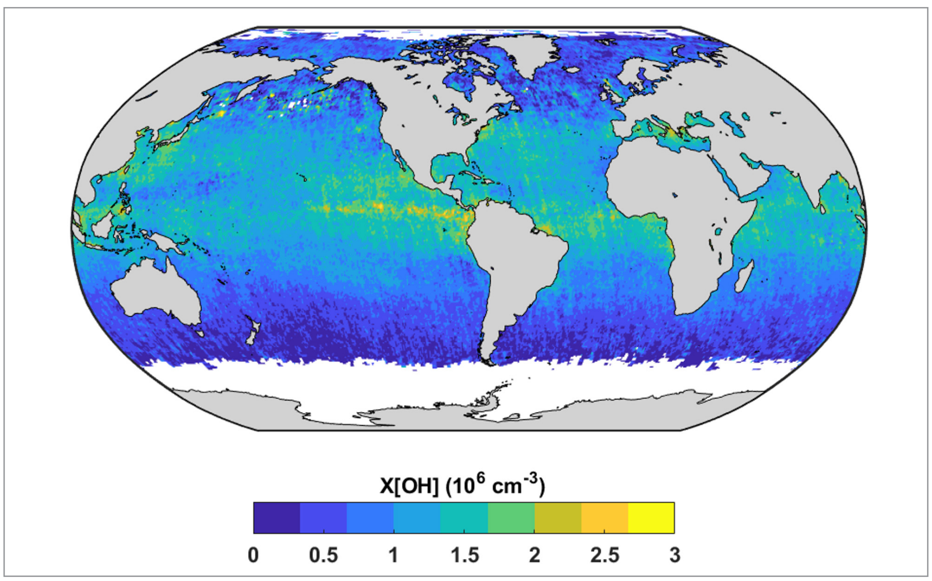


Figure 2.4.3: *Monthly mean tropospheric [OH]*

2.4.4. Changes in the Diurnal Cycle of Surface Ozone

Metrics that relate ozone exposure to human health, such as the maximum 8-hour ozone concentration, typically focus on just a portion of the day. Consequently, changes in ozone's diurnal cycle in addition to changes in the daily average concentration can impact the trends in these metrics. Since surface observations are not available in parts of the world, the MERRA2-GMI simulation provides a global estimate of how the diurnal cycle has changed in different regions. The diurnal cycle of ozone affects metrics that quantify how ozone impacts human health and vegetation. The MERRA2-GMI model simulation shows decreases in the magnitude of the ozone diurnal cycle in the eastern U.S. and Europe, where OMI shows that NO_2 decreased, and increases in Asia, where NO_2 increased. The reduced magnitude over the eastern U.S. agrees with surface ozone observations. In the future, geostationary satellite observations of ozone precursors will provide valuable data for constraining the diurnal cycle of surface ozone.

Contributors: Sarah Strode (614, USRA), J. Ziemke (614, MSU), L. Oman (614), et al.

Reference: Strode, S. A., J. R. Ziemke, L. D. Oman, L. N. Lamsal, M. A. Olsen, and J. Liu, 2019: Global changes in the diurnal cycle of surface ozone. *Atmos. Environ.*, **199**, 323-333, doi:10.1016/j.atmosenv.2018.11.028.

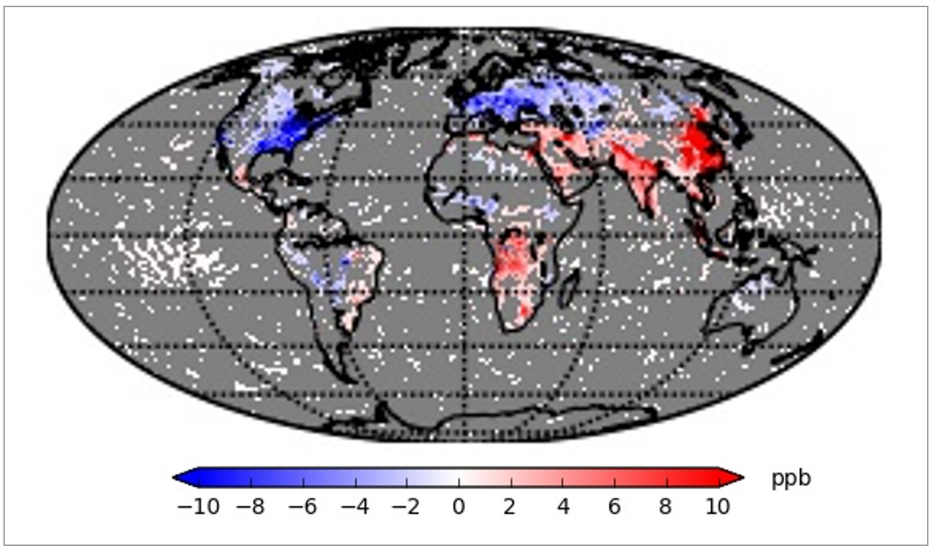


Figure 2.4.4: *The change in the peak-to-peak magnitude of the diurnal cycle of July surface ozone between the 1980s and 2006-2015 is calculated from the MERRA2-GMI model simulation.*

2.4.5. Aura/OMI Solar Spectral Irradiances: Comparisons with Independent Datasets and Model Predictions

Climate studies rely on detailed knowledge of the total energy balance, in particular, on the spectral and temporal changes of solar flux. These changes should be followed with ~weekly (preferably, ~daily) observations spanned over a typical solar cycle (~11 years), preferably multiple cycles. The Aura Ozone Monitoring Instrument is uniquely positioned to deliver the required long-term, stable, accurate ~daily solar data that span the entire solar cycle 24. The improved model of optical degradation of the instrument provides the solar spectral irradiances (SSI) that are broadly used for validation of the solar models, NRLSSI2 in particular. Comparison with the concurrent independent observations and model predictions show good-to-excellent (predominantly, to ~0.1% in UV, and down to ~0.01% in the visible) agreement between the various models and observations, if one to consider the relatively short-term (~months) events related to line-of-sight passage of active solar regions. The long-term (decadal, solar cycle) SSIs pose more challenges, with model-observation and observation-observation disagreements frequently exceeding ~0.5% in the UV range (especially in the mid-UV domain populated by strong spectral transitions). In the visible, though, the long-term model-observation inter-comparisons show good agreement, down to ~0.05%.

Contributors: S. V. Marchenko (614, SSAI), T. N. Woods (University of Colorado at Boulder), M. T. DeLand (614, SSAI), S. Mauceri (University of Colorado at Boulder), P. Pilewski (University of Colorado at Boulder), M. Haberreiter (Physikalisch-Meteorologisches Observatorium and World Radiation Center, Davos)

Reference: Marchenko, S.V., Woods, T.N., DeLand, M.T., Mauceri, S., Pilewski, P., Haberreiter, M., 2019: Aura/OMI Solar Spectral Irradiances: Comparisons with Independent Datasets and Model Predictions. *Earth and Space Sci.*, in review.

2.4.6. Temporal characterization of dust activity in the Central Patagonia desert (years 1964-2017)

One of the most outstanding climate question concerns the processes that modulate CO_2 removal from the atmosphere. Ice-cores found in Antarctica reveal correlations between temperature, CO_2, and dust deposition variability extending for thousands of years. Stimulation of phytoplankton photosynthesis through the deposition of nutrients carried by dust in the Southern Ocean (with Patagonia as the main supplier) has been proposed to explain this variability. Modern dust activity in South America can reveal whether this phenomena is currently operating and provide insights into paleo-climate questions. However, dedicated model assessment studies lack the observational datasets of dust activity in South America at time resolutions (decades) appropriate for verify the simulations. Historical time series of weather observations, along with NASA's long term series of satellite observations, contribute to better understand dust activity in this sector of the world and support climate model efforts. Local surface observations showed a multi-decadal increasing trend in the number of dusty days (NDD) per month at the largest and most active source in South America. Independent satellite observations of the Aerosol Index (sensors N7-TOMS, EP-TOMS and Aura-OMI) confirmed the trend.

Contributors: S. Gassó (613, ESSIC), O. Torres (614)

References: Gassó, S., and O. Torres, 2019: Temporal characterization of dust activity in the Central Patagonia desert (years 1964-2017). *J. Geophys. Res.: Atmos.*, **124**, https://doi.org/10.1029/2018JD030209

Torres, O., et al., 2018: TOMS/N7 Near UV Aerosol Index and LER 1-Orbit L2 Swath 50×50 km, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), https://doi.org/10.5067/MEASURES/AER/DATA201

Torres, O., et al., 2018: TOMS/EP Near UV Aerosol Index and LER 1-Orbit L2 40×40km, Goddard Space Flight Center, Goddard Earth Sciences Data and Information Services Center (GES DISC), https://doi.org/10.5067/MEASURES/AER/DATA202

Torres, O., 2006: OMI/Aura Near UV Aerosol Optical Depth and Single Scattering Albedo 1-orbit L2 Swath 13×24 km V003, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/Aura/OMI/DATA2004

2.4.7. Space-Based Observations for Understanding Changes in the Arctic-Boreal Zone (ABZ): Recommendations for Improving Upon the Current Observational Network

For the last several years, the CABS (Changes in the Arctic-Boreal System) task group has been working on a Review of Geophysics article (https://doi.org/10.1029/2019RG000652), led by Bryan Duncan (614) and Lesley Ott (610.1). Numerous GSFC (610.1, 613, 614, 615, 618) & LaRC personnel contributed to this effort, as well as, non-NASA scientists from Arctic nations, including the U.S., Finland, and Canada.

The purpose of the article is to review the strengths and limitations of the current suite of observations from satellites to provide the necessary information to understand the complex interaction between components of the ABZ. In addition, we make recommendations for improving satellite observations of individual components of the ABZ, and for an interdisciplinary and stepwise approach to develop a comprehensive ABZ Observing Network (ABZ-ON).

In 2014, Doug Morton (618), with enthusiastic support from Piers Sellers, initiated the CABS task group at GSFC to encourage inter-disciplinary research at GSFC on Arctic-Boreal Zone (ABZ) issues.

Contributors: B. Duncan (614), L. Ott (610.1)

Reference: Bryan N. Duncan, Lesley Ott, (in alphabetical order) James B. Abshire, Ludovic Brucker, James Carton, Josefino C. Comiso, Emmanuel P. Dinnat, Bruce C. Forbes, Alemu Gonsamo, Watson W. Gregg, Dorothy K. Hall, Iolanda Ialongo, Randi Jandt, Ralph A. Kahn, Alexey Karpechko, Seiji Kato, Stephan R. Kawa, Timo Kumpula, Erkki Kyrola, Tatiana V. Loboda, Kyle C. McDonald, Paul M. Montesano, Ray Nassar, Christopher S. R. Neigh, Claire L. Parkinson, Benjamin Poulter, Jouni Pulliainen, Kimmo Rautiainen, Brendan M. Rogers, Cecile S. Rousseaux, Amber J. Soja, Nicholas Steiner, Johanna Tamminen, Patrick C. Taylor, Maria A. Tzortziou, Henrik Virta, James S. Wang, Jennifer D. Watts, David M. Winker, and Dong L. Wu, Space-Based Observations for Understanding Changes in the Arctic-Boreal Zone. Accepted to *Rev. Geophys.*, https://doi.org/10.1029/2019RG000652.

2.4.8. Evaluation of NASA's high-resolution global composition simulations: Understanding a pollution event in the Chesapeake Bay during the summer 2017 OWLETS campaign

The complex climate, emissions, and meteorological processes in coastal environments, such as the Chesapeake Bay, can only be fully understood in combination of observational data and model simulations. This work has shown that global chemical model simulations can help air quality investigations of complex processes occurring at small spatial and temporal scales within changing terrain. This study presented one of the first known evaluations of the NASA GEOS-CF through a comparison to observations obtained in an intensive field campaign (OWLETS). The GEOS-CF, freely-available, near-real-time global simulation with a resolution of 25×25 km^2, is able to simulate surface level ozone diurnal cycles and vertical ozone profiles at sub-regional scales. For these reasons, the GEOS-CF simulations should be considered as a potential reference tool for air quality managers and forecasters. The high-resolution vertical structure characterized by TOLNet LiDARs, in conjunction with CCMMs, will be critical to fully evaluate future geostationary satellite instruments like the Tropospheric Emissions: Monitoring of Pollution (TEMPO) which will provide hourly measurements of pollutants for North America. Application of the synergistic approach used here should be further utilized for evaluations of intensive field campaigns that have applications for future air quality satellites such as TEMPO. Evaluations of model simulations coupled with various campaign measurements (e.g., surface, airborne, ground-based LiDARs, etc.) at smaller scales will aid air quality scientists' understanding of complex processes occurring at small spatial and temporal scales within complex terrain changes. This will also yield improvement to mechanisms used for model simulations and atmospheric composition forecasts.

Contributions: N. Dacic (614, SSAI), J. T. Sullivan (614), K. Emma Knowland (610.1, USRA-GESTAR), G. M. Wolfe (614, JCET), L. D. Oman (614), T. A. Berkoff (LaRC), G. P. Gronoff (SSAI/LaRC)

Reference: Dacic, N., Sullivan, J.T., Knowland, K.E., Wolfe, G.M., Oman, L.D., Berkoff, T.A., Gronoff, G.P., 2019: Evaluation of NASA's high-resolution global composition simulations: Understanding a pollution event in the Chesapeake Bay during the summer 2017 OWLETS campaign. *Atmos. Environ.*, doi: https://doi.org/10.1016/j.atmosenv.2019.117133.

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. Introduction

Spaceflight missions are central to NASA's ability to carry out its science programs. A comprehensive set of observations from existing and planned missions are required. Code 610AT scientists serve as Project and Deputy Project Scientists and Investigators for the following missions.

3.1.1.1. 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 Goddard project scientist. TROPICS is expected to launch no earlier than 2021. In the time prior to launch, activities are focused on development and evaluation of the rainfall retrieval algorithm using simulated orbital data based on a high-resolution hurricane nature run. Post launch, TROPICS funds will cover the project scientist, data assimilation work in the Global Modeling and Assimilation Office (GMAO), and research on moisture impacts on the precipitation structure and the intensity of storms. TROPICS will provide rapid-refresh (~50-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 six CubeSats in two or three ~550-km altitude, 30°-inclination orbital planes for at least one year. TROPICS successfully completed satellite construction by the end of September 2019 and is now awaiting an appropriate launch opportunity. Launch date and number of orbital planes still to be confirmed by NASA Headquarters.

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

3.1.2 Active Missions

3.1.2.1 Terra

Launched on December 18, 1999, as NASA's Earth Observing System (EOS) flagship observatory, Terra carries a suite of five complementary instruments: (1) Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER), contributed by the Japanese Ministry of Economy, Trade, and Industry with an American science team leader at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, provides a unique benefit to Terra's mission as a stereoscopic and high-resolution instrument used to measure and verify processes at fine spatial scales; (2) Clouds and the Earth's Radiant Energy System (CERES, Langley) investigates the critical role that clouds, aerosols, water vapor, and surface properties play in modulating the radiative energy flow within the Earth-atmosphere system; (3) Multi-angle Imaging SpectroRadiometer (MISR, JPL) characterizes physical structure from microscopic scales (aerosol particle sizes and shapes) to the landscape (ice and vegetation roughness and texture) to the mesoscale (cloud and plume heights and 3D morphologies); (4) Moderate Resolution Imaging Spectroradiometer (MODIS, Goddard) acquires daily, global, and comprehensive measurements of a broad spectrum of atmospheric, ocean, and land properties that improves and supplements heritage measurements needed for processes and climate change studies; and (5) Measurement Of Pollution In The Troposphere (MOPITT), sponsored by the Canadian Space Agency with an NCAR science team, retrieves carbon monoxide total-column amounts as well as mixing ratios for 10 pressure levels; its gas correlation approach still produces the best data for studies of horizontal and vertical transport of this important trace gas.

The mission's long lifetime, vantage point from space and robust suite of sensors combine to provide a unique, cost-efficient, and long-term climate and environmental record not available from any other satellite platform. Terra products are also made easy to use and more widely available in response to feedback from the scientific community. As an example, a new global topography map had more than one million downloads within the first four weeks of its August 2019 delivery, highlighting both the accessibility and demand for the product. Multiple federal agencies used Terra's land and atmosphere products for volcanic ash monitoring, weather forecasting, forest fire monitoring, carbon management, and global crop assessment. Fire monitoring is an excellent example of the community making use of all of Terra's five instruments to investigate fire location and intensity, burn areas and revegetation, and injection and transport of aerosols and carbon monoxide in the atmosphere. The mission's long-term record shows a greening of global lands, especially in China and India. Decreases in the concentration of atmospheric pollutants such as hazes and dust are seen in the US and Europe while parts of Asia and the Middle East have increasing concentrations, reflecting the impacts of transportation, industrial and agricultural activity, climate change, and pollution controls. Terra products also provided the data record needed to evaluate the impact of variations in Arctic sea ice and ocean heat transport leading to improved climate model accuracy.

The Terra Team received the prestigious 2019 William T. Pecora Group Award for the mission's outstanding contributions toward understanding the Earth through remote sensing. To celebrate the success of Terra Mission, 20 Years of Science, Remote Sensing of Environment will devote a special issue in 2020 to highlight science relying on data from multiple Terra sensors or through combinations of data between Terra and other missions.

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

3.1.2.2. Terra

Launched on December 18, 1999, as NASA's Earth Observing System (EOS) flagship observatory, Terra carries a suite of five complementary instruments: (1) Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER), contributed by the Japanese Ministry of Economy, Trade, and Industry with an American science team leader at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, provides a unique benefit to Terra's mission as a stereoscopic and high-resolution instrument used to measure and verify processes at fine spatial scales; (2) Clouds and the Earth's Radiant Energy System (CERES, Langley) investigates the critical role that clouds, aerosols, water vapor, and surface properties play in modulating the radiative energy flow within the Earth-atmosphere system; (3) Multi-angle Imaging SpectroRadiometer (MISR, JPL) characterizes physical structure from microscopic scales (aerosol particle sizes and shapes) to the landscape (ice and vegetation roughness and texture) to the mesoscale (cloud and plume heights and 3D morphologies); (4) Moderate Resolution Imaging Spectroradiometer (MODIS, Goddard) acquires daily, global, and comprehensive measurements of a broad spectrum of atmospheric, ocean, and land properties that improves and supplements heritage measurements needed for processes and climate change studies; and (5) Measurement Of Pollution In The Troposphere (MOPITT), sponsored by the Canadian Space Agency with an NCAR science team, retrieves carbon monoxide total-column amounts as well as mixing ratios for 10 pressure levels; its gas correlation approach still produces the best data for studies of horizontal and vertical transport of this important trace gas.

For more than 19 years, the Terra mission has been providing the worldwide scientific community with an unprecedented 83 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 the U.S. Forest Service (ASTER, MODIS, MISR); and carbon management and global crop assessment by USDA and USDA-FAS (MODIS, CERES). On October 6, 2018, Terra completed its 100,000th orbit around Earth. Data from Terra, in combination with Aura, were analyzed to show that clean air programs have continued to improve fine particle pollution while declines in carbon monoxide emissions are slowing down and efforts to reduce nitrogen oxide emissions have not been as successful as expected. Terra's long lifetime, view from above, and its unique combination of sensors provided the spatial assessment for these results that would not be available if those programs used only ground-based measurements. Likewise, Terra's unique views allowed tracking of fire intensity, smoke plume heights, and spatial extent of wildfire activity and pollution during the 2018 Western U.S. fire season, evaluation of the impact of Hawaii's Kilauea eruption, and better understanding of the tracks and impacts Hurricanes Florence and Michael.

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

3.1.2.2. 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 in extended operations with four of its instruments (AIRS, AMSU, CERES, and MODIS) continuing to collect valuable data at an approximate rate of 88 Gbytes/day. The 2017 Earth Science Senior Review endorsed the Aqua mission for continued operations through 2020, and preliminarily, through 2023. In 2020, the Aqua mission will go once again through the Senior Review and will seek extension of operations for three more years.

Aqua's observations pertain to the atmosphere, oceans, land, and cryosphere and 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. Aqua data have been used, among others, to: (1) obtain the vertical structure of temperature and humidity within the eyes of hurricanes; (2) monitor changes in global burned area which was shown to have declined by ~25% over the past 18 years; (3) reveal the relationship between ocean biological productivity and the El Niño and Southern Oscillation (ENSO); (4) pinpoint the vulnerability of current and future communities to the detrimental effects of heat waves and extreme heat in urban areas; (5) show that the global distribution of aerosol particles produced by human activities, natural dust storms, and fires is relatively stable; (6) support operationally the United States Drought Monitor (USDM) with surface temperature and humidity observations.

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

3.1.2.3. Aura

On July 15, 2004, the Aura spacecraft was launched with four instruments to study the composition of Earth's atmosphere. Two of the instruments, the Ozone Monitoring Instrument (OMI) and the Microwave Limb Sounder (MLS), continue to make measurements of aerosols, clouds, ozone, and constituents related to ozone in the stratosphere and troposphere. With these measurements, the science team has addressed questions concerning the Antarctic ozone hole, stratosphere's protective ozone layer, tropospheric composition, and air pollution.

OMI data continue to be used to monitor global air pollution trends, determine the efficacy of mitigation control strategies, and estimate emissions in 2019. For instance, several recent studies used OMI nitrogen dioxide data to infer co-emitted carbon dioxide emissions from major US cities and world power plants. This information is important for constraining global emissions as well as for developing efficient climate change mitigation strategies. Efforts are ongoing to compare OMI data to data from other recently launched instruments—e.g., Ozone Monitoring Profiler Suite (OMPS) on the NOAA 20 satellite and the ESA Tropospheric Monitoring Instrument (TROPOMI)—in order to assure consistent long-term records. OMI is also being used for studies on solar spectral irradiance. OMI core team members created OMI solar spectral irradiance (SSI) data at UV and visible wavelengths for the full time range of solar cycle 24 (2006-2018). Short-term SSI variations show very good agreement with concurrent observations and model predictions (0.1% in the UV, 0.02% in the visible). Long-term SSI changes have unprecedented accuracy over solar cycle time scales (0.05-0.1%). OMI results are being used to validate state-of-the-art SSI models.

MLS continues to provide unique and valuable daily near-global profile observations of a range of species in the middle atmosphere in 2019. These include stratospheric ozone, chlorine and bromine species (source, reservoir, and active forms) that lead to ozone depletion, long-lived trace gases used to diagnose air motions, and other trace gases that play a role in polar ozone chemistry. Together these measurements enable the disentanglement of chemical influences on ozone from the meteorologically-induced variability that, in many regions and seasons, mask the signature of ozone layer recovery. MLS observations played a major part in the latest WMO ozone assessment, released in early 2019, which reported evidence of recovery in upper stratospheric ozone, and in the Antarctic ozone hole. However, the assessment concluded that a longer observation record is needed to confirm recovery in other regions. MLS observations of stratospheric water vapor (an important and poorly understood greenhouse gas) continue to be central to measurement- and model-based studies of the processes controlling the transport of air into the stratosphere and regulating stratospheric humidity.

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

3.1.2.3. DISCOVR

The Deep Space Climate Observatory (DSCOVR) is located near the Earth's L1 point where it monitors the solar wind and observes the Earth with two sensors: NISTAR (https://epic.gsfc.nasa.gov/about/nistar) and EPIC (https://epic.gsfc.nasa.gov). Earth sensors measure radiative fluxes of the entire sunlit Earth and key spectral characteristics at 10-15 km resolution. The DSCOVR NISTAR and EPIC Science Team Meeting was held at the Goddard Visitor Center, September 17-19. For three days, scientists discussed the current status of NISTAR observations and the EPIC Level 2 products (ozone, sulfur dioxide, aerosols, clouds, and vegetation). The first DSCOVR science results obtained from NISTAR and EPIC observations were also reported. The presentations are available at https://avdc.gsfc.nasa.gov/pub/DSCOVR/Science_Team_Meeting_Sept_2019/.

The DSCOVR gyros have deteriorated significantly over the years to the point that NOAA has placed the spacecraft into safehold on June 28, 2019. This temporarily terminated EPIC and NISTAR data generation. A new flight software is being developed that will allow continued operations relying only on the star tracker and Sun sensors. The spacecraft is expected to return to full operations on March 2, 2020.

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

3.1.2.5. 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 (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. In February 2019, Robert Levy (613) became the Deputy to Flight Project Scientist, Joel McCorkel (618), and the current series is known as GOES-R.

Two of the four satellites in the GOES-R series have been launched: GOES-R was launched in November 2016 to become GOES-16, with GOES-S launched in March 2018 to become GOES-17. Both satellites went through post-launch testing in orbit at 89.5°W before moving to operational positions. GOES-16 was moved to 75.2°W and became NOAA's GOES-East satellite in December 2017. GOES-17 was moved to 137.2°W and was declared operational as GOES-West in February 2019. The two Earth-facing sensors are the Advanced Baseline Imagers (ABI) and the Geostationary Lightning Mappers (GLM). The Advanced Baseline Imagers (ABI) provide persistent imagery in 16 visible to thermal infrared spectral channels at spatial resolutions of 0.5 to 2 km. The two ABIs provide consistent imagery from New Zealand to Western Africa at 10 minutes, over the Continental U.S. every 5 minutes, and mesoscale scans every 30 seconds. The GLM detects all forms of lightning during both day and night, characterizing the frequency, location, and extent of lightning discharges to identify intensifying thunderstorms and tropical cyclone development.

Although the ABI on GOES-16 performed nominally at launch, the ABI on GOES-17 has had issues with its cooling system. Essentially, at particular times of the year and at particular time of day, the cooling system cannot sufficiently counteract the heating due to the Sun's impact. This results in elevated temperatures which lead to noise and saturation in the thermal infrared detectors (channels 8-16), impacting the ability to accurately retrieve some essential meteorological parameters. However, teams of experts from NOAA, NASA, the ABI vendor, and industry worked to diagnose and mitigate the problem, regaining >96% of the imaging capability by adjusting operational sensor parameters and modifying the ground system processing algorithms. Continued mitigation and improvement efforts are underway. In addition to the major issue of the cooling system on GOES-17, there has mitigation for smaller issues related to calibration (on both satellites) and image striping (on GOES-17). GLMs on both satellites are generally working nominally. Operational products from both GOES-16 and 17 are going through review, from beta to provisional to full validation.

In December 2019, GOES-16 became fully operational to the NWS Space Weather Prediction Center (SWPC) in Boulder, CO (https://www.swpc.noaa.gov/news/changes-goes-data-space-weather-prediction-center).

The future GOES satellites, T and U, are currently scheduled for launch in 2021 and 2024. In 2018, The ABI on GOES-T underwent redesign of its cooling system based on studies conducted after the GOES-17 anomaly, and is being rebuilt. The GLM encountered hardware issues and mitigation efforts have been pursued.

For further information, please contact Robert Levy (robert.c.levy@nasa.gov).

3.1.2.6. SORCE

The Solar Radiation and Climate Experiment (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 CU-LASP. The software was installed via uplink radio commands in time for a special campaign in 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 Satellite-3. Additional SORCE flight software, deployed in February 2014, enabled a "Day-Only Operations" (DO-Op) mode to stabilize the battery substantially. 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 since 2014. SORCE had successfully overlapped with the Total and Spectral Solar Irradiance Sensor-1 (TSIS-1) for more one year since TSIS-1 became operational in March 2018. Both TSIS-1 and SORCE instruments tracked daily TSI variations consistently to within 0.004 percent.

The SORCE mission has played a key role in extending the uninterrupted TSI record to 40 years. The project established the longest SSI record for the near ultraviolet, visible, and near infrared wavelength ranges that together comprise almost 96 percent of the incoming Sun's total energy. Important in these solar records is the amount by which the TSI and SSI increase and decrease over an 11-year period, known as the solar activity cycle. Global energy-balance estimates and climate studies use the SORCE solar irradiance measurements. Collecting accurate Total Solar Irradiance (TSI) and Solar Spectral Irradiance (SSI) data spanning multiple years helps scientists understand how much solar radiation is deposited in the atmosphere and at the surface and thus how much energy is available to influence weather, climate, the cryosphere, atmosphere dynamics, and ocean currents. The solar irradiance has been at solar cycle minimum level during 2019. As solar activity begins to pick up in the new cycle (solar cycle 25), SORCE observed the first dark sunspot event in April 2019. The SORCE mission ended in late February 2020.

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

3.1.2.7. 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.

In 2019, Suomi NPP continued to meet its two primary goals: (1) providing satellite observations to NOAA for NOAA products and services, primarily weather forecasts, and (2) providing satellite observations to continue the Earth science data products created using data from the NASA Earth Observing System (EOS) satellites. A number of primary S-NPP products have now demonstrated their capabilities to provide critical continuity and near-real-time data, extending the EOS observation long time series, in monitoring changes in land, ocean and atmosphere as well as Earth's radiation budget. In 2019, researchers using VIIRS ocean color data unveil the most comprehensive view of the distribution of a zooplankton species to date, and alter our understanding of the behavior of this key zooplankton species, which will provide important resources to the fishery industry. OMPS total ozone data indicate that the 2019 ozone hole is the smallest on record since its discovery in 1982, thanks to the unusual warmer temperatures during the 2019 Antarctic spring. OMPS Limb Profiler data have further revealed details of the development of the Antarctic ozone hole in 3D. By adding the VIIRS observations, the NASA land products has now built a 50+ years long time series, about land surface vegetation resources and monitoring with implications on carbon storage, biodiversity, coastal zone impacts, and progress in cropland monitoring, which can provide early and local insights on crop yield and is critical for farmers, government agencies, and the financial markets. In addition, VIIRS data were used extensively to provide timely information during the disaster events such as the Alaska and California wildfires 2019. Suomi-NPP nighttime Black Marble products also help conduct damage assessments of power outage impacts in the Carolinas from Hurricane Dorian.

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

3.1.2.8. JPSS-1 (NOAA 20)

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 2019, 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.

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, instruments including 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). On May 30, 2019, NOAA declares the NOAA-20 instruments and spacecraft fully operational. All the instruments are in routine operational use by NOAA and NASA. 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 NOAA-20, VIIRS, CrIS, ATMS, and OMPS. In 2019, The JPSS-2 VIRIS and OMPS instruments completed their pre-ship reviews and are in storage awaiting integration on the JPSS-2 spacecraft. The ATMS and CrIS instruments are in final environmental test and anticipate their pre-ship reviews in early 2020.

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

3.1.3.9. GPM

The Global Precipitation Measurement (GPM) mission 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 (the product is called IMERG) 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. In 2019, the IMERG algorithm was applied to TRMM and GPM data to produce a 20-year time series (2000-2019) of global rainfall. The GPM mission is advancing our understanding of the water and energy cycles, and is extending the use of precipitation data to directly benefit society. The GPM-CO completed its three-year prime mission lifetime in 2017 and is currently in extended operations. GPM has conducted a series of field campaigns with international and domestic partners, with the data providing crucial information to improve the GPM mission's measurements of light rain and snow, to assess the hydrological impacts of precipitation, to directly validate the satellite data products, as well as to help researchers understand how precipitation changes across land and ocean. Significant milestones and activities were met in 2019 including:

- GPM's Version 06 IMERG products were reprocessed for the TRMM and GPM eras. Reprocessing was done for early (near real time), late, and final products.

- Test algorithms to extend dual-frequency radar and combined radar-radiometer retrievals across the full Ku-band swath (due to a change in radar scanning in May

2018) have been developed and are being evaluated, with experimental products to be released in Fiscal 2020.

- GPM all-sky radiances from the GPM Microwave Imager (GMI) began to be assimilated into the NASA Goddard Earth Observing System (GEOS) global model and assimilation system in July 2018, yielding significant forecasting improvements out to 3 days lead time. In 2019, GPM constellation radiometers were added to the assimilation system.

- In November 2019, the science team met in Indianapolis, Indiana, to review science progress, algorithm development, and planned future activities.

- GPM's vigorous outreach and education efforts continue and included numerous video and online features, progress on a website update, and a community workshop on applications for GPM and the Decadal Survey Aerosols, Clouds, Convection, and Precipitation (ACCP) study.

For further information, please contact Scott Braun (scott.a.braun@nasa.gov) or visit the GPM home page at https://gpm.nasa.gov.

3.1.2.10. 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 (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-GHz 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-GHz cloud radiometer had experienced a large (10°C-35°C) orbital temperature variation and achieved 3K radiometric calibration stability. The CubeSat demonstrated capability to operate the 5.6-W payload continuously on both day and night, as well as spinning operation at a rate as high as 3.3 degrees/second. IceCube acquired 16 months of cloud data at orbital altitudes of 200-400 km before its reentry to the atmosphere on October 3, 2018. On September 29, 2018, four days before its reentry, IceCube was able to capture cloud features from Typhoon Trami at an orbital altitude of ~200 km. The IceCube calibrated radiances produced the first 883-GHz cloud ice map, which shows consistent amplitudes with the cloud ice observed during the same period by MLS at 240 and 640 GHz.

IceCube had produced 15-month of scientifically useful data. Despite a slight degradation in the instrument gain, the cloud radiance data are being recalibrated and made available to the science community. A book chapter and development description about IceCube can be found in https://atmospheres.gsfc.nasa.gov/climate/index.php?section=259.

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

3.1.2.11. mini-LHR

On December 5, 2019 the SpaceX Commercial Resupply Mission (CRS) 19 launched from Cape Canaveral carrying the NASA/GSFC & LLNL (Lawrence Livermore National Laboratory) CubeSat MiniCarb to the ISS. From the ISS, MiniCarb will be deployed into a Low Earth Orbit in mid-January, 2020. Mini-Carb is a passive, occultation-viewing laser heterodyne radiometer designed to observe CH_4, CO_2 and H_2O.

GSFC team: Emily Wilson (610), AJ DiGregorio (614/SSAI), Guru Ramu (699/Beacon), Jennifer Young (540/Genesis), Paul Cleveland (448/Energy Solutions), Melissa Floyd (699)

LLNL team: Bill Bruner, Vincent Riot, Lance Simms, Darryll Carter.

For further information, please contact Emily Wilson (emily.l.wilson@nasa.gov).

3.1.2.12. TSIS-1

The main objective of the Total and Spectral solar Irradiance Sensor-1 (TSIS) mission is to acquire solar irradiance measurements to monitor effects of solar radiation on climate. Successfully launched to the International Space Station (ISS) in December 2017, TSIS-1 will provide the continuity of the multi-decadal uninterrupted record of incoming total solar radiation, or total solar irradiance (TSI), which is the dominant energy source driving the Earth's climate and the most precise indicator of solar energy input to Earth's system. In January 2018, TSIS-1 made the first-light measurement of solar irradiance, and continues to make new solar observations in 2019 when it was not interfered by the ISS activities. The solar activity was very quiet in 2018-2019 and TSIS-1 observed less than 0.002 percent variability in TSI, except for 0.003 percent decreases during three small sunspot events in April-June 2019. New SSI data from TSIS-1 are the most accurate solar spectrum in the 200-2400 nm wavelength bands that helps scientists to evaluate the solar spectrum used in climate models. This solar spectral band accounts for 97 percent of solar energy input to the Earth system.

Measuring the incoming solar energy at different spectral wavelengths provides critical elements for understanding how that energy is absorbed by the Earth's atmosphere and surface. The solar spectra measured during 2018-2019 established a new reference that allows to cross-calibrate other satellite sensors for global climate and environmental studies. The TSIS-1 SSI data have been made available to Global Space-based Inter-Calibration System (GSICS) as an international collaborative effort under the World Meteorological Organization (WMO) and the Coordination Group for Meteorological Satellites (CGMS).

TSIS-1 and SORCE have achieved an overlap for more than one year, to assure the consistency of solar irradiance measurements from two observatories. The overlapped measurements have shown that these instruments can track daily TSI variations consistently within 0.004 percent. The TSIS-1 data are publicly available since September 2018 at Goddard Earth Sciences Data and Information Services Center (GES DISC), or https://disc.gsfc.nasa.gov/datasets?keywords=TSIS&page=1. The nominal mission lifetime is 5 years with potential 2-year extension.

TSIS-1 includes two instruments: Total Irradiance Monitor (TIM) and Spectral Irradiance Monitor (SIM), integrated into a single payload. The TSIS-1 TIM and SIM instruments are upgraded versions of the two instruments that are flying on the SORCE mission launched in January 2003. The Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder (CU) provided the TIM and SIM instruments, as well as the precision solar pointing of the instruments, and provides mission operations. LASP also developed and built the instruments for SORCE.

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

3.2. Project Scientists

A number of special career positions exist in NASA to help carry out its research programs and missions which are unique in the science community. These include Project Scientists, Study Scientists, and Instrument Scientists. 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 3.2.1 lists project and deputy scientists for current and planned missions. Table 3.2.2 lists the Instrument scientists and major participants in field campaigns.

Project Scientist	Project
Bryan Duncan	Aura
Steven Platnick	EOS
Scott Braun	GPM
James Gleason	JPSS
James Gleason	SNPP
Dong Wu	SORCE
Dong Wu	TSIS-1
Scott Braun	TROPICS
Dong Wu	Earth-ICECube

Deputy Project Scientist	Project
Joanna Joiner	Aura
Lazaros Oreopoulos	Aqua
Alexander Marshak	DSCOVR
Robert Levy	GOES
George Huffman	GPM
Si-Chee Tsay	Terra
Christina Hsu	SNPP

Table 3.2.1: *610AT Project and Deputy Project Scientists*

Validation Scientist	Project
Ralph Kahn	EOS/MISR
Matthew McGill	ISS/JEM-EF/CATS

Instrument Scientist/Manager	System	Recent Campaign
Ellsworth Welton	MPLNET	FIREX- McCall, Idaho
Si-Chee Tsay	XBADGER	7 SEAS and RAJO MEGH
Si-Chee Tsay/David Wolff	ACHIEVE	Wallops Facility Operations
David Wolff	NPOL, D3R, ICE-POP	Wallops Facility Operations
Gerald Heymsfield	HIWRAP	IMPACTS Planning
Thomas McGee	TROPOZ	NDACC and TROLIX 19
Robert Swap	Pandora	SCOAPE, ESA TROLIX 19 and ESA S5P
Anne Thompson	SO_3 Sondes/SHADOZ	Launches were ongoing at 13 stations
Paul Newman/Thomas Hanisco	ISAF	Atom
Steven Platnick	eMAS	FIREX AQ
Stephan Kawa		CARAFE

Table 3.2.2: *610AT Validation (top) and Instrument (bottom) Scientists*

Validation Scientist	Project
Ralph Kahn	EOS/MISR
Matthew McGill	ISS/JEM-EF/CATS

Instrument Scientist/Manager	System	Recent Campaign
Ellsworth Welton	MPLNET	SEALS-sA, ORACLES
Si-Chee Tsay	XBADGER	Wallops Facility Operations
Si-Chee Tsay/David Wolff	ACHIEVE	Wallops Facility Operations
David Wolff	NPOL, D3R, ICE-POP	Wallops Facility Operations
Gerald Heymsfield	HIWRAP	SHOUT
Thomas McGee	TROPOZ, NDACC	KORUS-AQ
Robert Swap	Pandora	KORUS-AQ, OWLETS
Anne Thompson	SO_3 Sondes/SHADOZ	Ascension Island Sondes
Paul Newman/Thomas Hanisco	ISAF	Atom
Steven Platnick	eMAS	ORACLES
Stephan Kawa		CARAFE

Table 3.2b: *610AT Validation (top) and Instrument (bottom) Scientists*

4. Field Campaigns

Field campaigns are investigator-led observational studies planned in specific areas for a defined time period during which measurements are made from airborne platforms and/or ground sites to study physical and chemical processes in the atmosphere. The resources of NASA, other agencies, and other countries are used to carry out scientific experiments and campaigns. The observation platforms serve as a step in the development of space borne instruments or validation and calibration measurements for existing space systems or collecting information leading to a basic understanding of relations between atmospheric process. In 2019, scientists supported the following activities as scientific investigators, or as mission participants, in the planning and coordination phases.

4.1. MPLNET

The Micro Pulse Lidar Network (MPLNET) project added two new permanent sites in 2019, some older ones were discontinued, and two short term field campaigns were completed. At this time, there are 20 active sites in the network. A new site was setup at Cape San Juan, Puerto Rico to contribute to MPLNET's long term observations of Saharan dust transport over the North Atlantic, to support air quality research under the Caribbean Aerosol Health Network (CAHN), and serves as a main dust profiling site for the WMO Sand and Dust Storm Warning and Advisory System (SDS-WAS) new Pan American forecast node. Another new site was setup in Sao Paolo with partners at the Instituto de Física Universidade de São Paulo, and the lidar will eventually be relocated to the Amazon basin for permanent observations. Our site in Doi Inathon, Thailand was discontinued and the lidar was moved to support a field campaign in Fang, Thailand then relocated to Princess Sirindhorn Astropark near Chiang Mai. Our permanent site at Kuching, Malaysia is temporarily down while a new agreement is being prepared to allow continued observations. The lidar at Bidur, Nepal has been shut down and will soon return following the conclusion of the NASA High Mountain Asia field campaign. Finally, MPLNET supported the FIREX field campaign in the Northwestern United States during summer 2019, with a lidar installed at McCall, Idaho.

The MPLNET staff also completed development of the new Version 3 (V3) processing system in December 2019, this is the cumulation of a 5-year effort to overhaul and upgrade the network to provide a more stable and mature system capable of multi-decadal operations. The V3 effort included polarizing all lidars in the network to provide more information on particle shape, as well as more accurate ability to detect thin layers. In addition, an automated instrument diagnostic and alert system was created to track instrument health, data availability, and calibrations and provide automated email alerts when necessary. A multi-threaded processing system was created with detailed logging and online access that is capable of growing as the network does. Finally, new methods of calibrating the lidars were established. These combined efforts allow for easier management of the network and more up-to-date calibration histories. The V3 development also included the creation of new data products and enhancements to existing ones, notably the addition of cloud phase and thin cloud optical depths to the cloud product. Also improved calibrations for the aerosol product along with addition of lunar AOD derived night time lidar profiles and aerosol depolarization ratios. Finally we now release a new PBL product with continuous mixed layer height and estimates of the mixed layer AOD vs the total column AOD.

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

4.2. SHADOZ

SHADOZ launches are ongoing at 13 stations (see Map). The SHADOZ website features more than 8000 sets of v 6.0 SHADOZ ozone and radiosonde profiles: https://tropo.gsfc.nasa.gov/shadoz. These include the re-processed records described in four 2017 and 2018 publications. Users may download files with specified total ozone uncertainty, the first ozonesonde archive to incorporate that information.

Major activities for SHADOZ in 2019 were: (1) on-going participation in the WMO-sponsored ozonesonde quality assurance activity ASOPOS (Assessment of Standard Operating Procedures for Ozonesondes) and related conferences; (2) a March 2019 station visit to San Pedro, Costa Rica; (3) discovery and characterization of a post-2014 drop-off in total and stratospheric ozone that affects 8 SHADOZ station records and 17 of 37 of the most active ozonesonde stations globally. The drop-off refers to a sudden loss of 2-8% in the total column ozone (TCO) amount when the sonde is referenced to the OMI or OMPS satellite or to co-located Dobson or Brewer spectrometers (Figure). The drop-off appears to be related to the ozonesonde instrument but no single property of the sensor is a clear-cut cause of the low ozone (R. M. Stauffer et al., *Geophys. Res. Lett.*, submitted, 2019). The SHADOZ website and the World Ozone Date Centre now list stations affected by the drop-off. SHADOZ v 6.0 data are decidedly more accurate than prior versions but for each of the stations, once the drop-off occurs, the records should not be used for lower-mid stratospheric trends.

A photo of the Brussels ASOPOS Workshop in September follows. The core 614 SHADOZ team (Anne Thompson, Ryan Stauffer, Debra Kollonige [new Archiver since June 2019]) also attended a celebration of 50 years of Uccle, Belgium, ozonesondes, in connection with the ASOPOS meeting where Thompson gave an invited talk on "SHADOZ and the Special Role of Tropical Ozonesondes." SHADOZ activities were reported at other meetings: American Meteorological Society Annual Meeting in Phoenix (January 2019), the NOAA Global Monitoring Annual Conference in Boulder (May 2019), 2019 AGU Meeting (San Francisco). The September-October 2019 Earth Observer, featured an article on "SHADOZ at 20 Years: Accomplishments of a Strategic Ozonesonde Network."

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

Map of operating SHADOZ stations in 2019.

Photo: *ASOPOS ozone experts meeting at the National Archives, St-Gilles, Brussels, 17 September 2019. Photo credit: R. M. Stauffer (UMD/ESSIC at GSFC).*

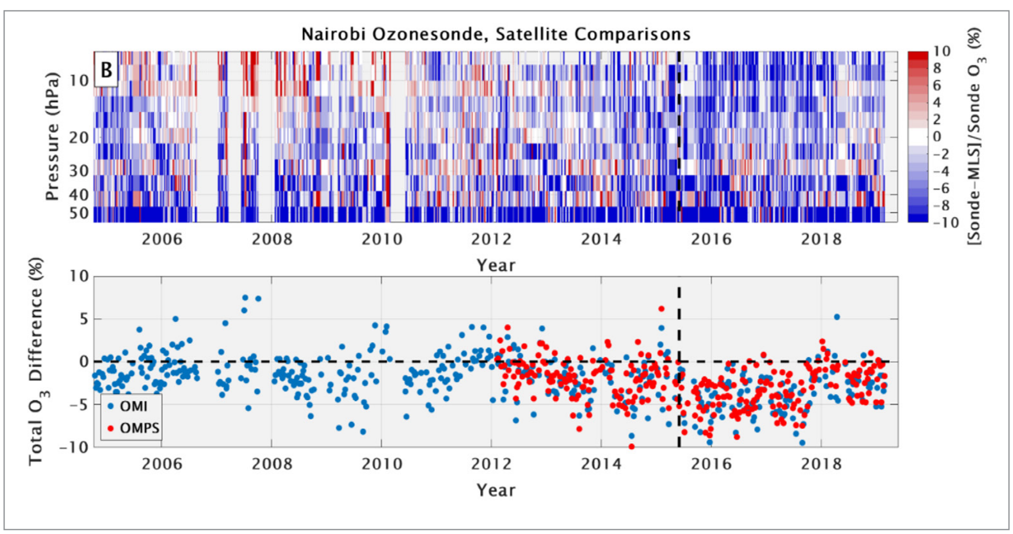


Figure 4.2: *Time series of comparisons at the Nairobi SHADOZ station between ECC ozonesondes and Aura MLS stratospheric ozone profiles (top panel), and TCO from the OMI (blue dots) and OMPS (red dots) satellites (bottom panel). Red or blue colors on the top panel indicate where the ECC ozone reading is greater or less than MLS. The horizontal dashed line is the 0% line for TCO comparisons. The vertical dashed line marks the onset of an instrumental low bias, denoted by a sudden drop in ECC TCO relative to the satellites. Credit: R. M. Stauffer (UMD/ESSIC at GSFC)*

4.3. eMAS/Oracles/FIREX-AQ

Onboard the ER-2 for the FIREX-AQ experiment, eMAS flew 10 science missions from 2-21 August, with both quick-look imagery products and preliminary Level 1B data generated daily for use by the science team. One of the 38 eMAS bands (3.7um) failed just prior deployment, but data in the mid-wave IR is available from MASTER (sister instrument to eMAS) flown onboard the DC8 during FIREX-AQ).

In support of the FIREX-AQ mission objective to study the characteristics and development of wild and prescribed fires, eMAS made a total of 71 flight legs over eight different fires. Passes over any given fire ranged in number from 1-20, with five of the eight fires overflown on three separate days. A summary of all the fire overpasses can be found here: https://mas.arc.nasa.gov/data/deploy_html/firex-aq_home.html.

The figure below presents eMAS true color and false color RGB imagery for three passes over the Sheridan Fire to show the evolution of the fire and smoke plume. The true color RGB is on the left and false color RGB on the right. The band selection of the false color RGB image (2.1, 1.6, and 0.55µm) enhances the fire pixels and burn scar, but the smoke displays as semi-transparent with a bluish hue because it is nearly transparent in the shortwave IR. The yellow-orange fire pixels are clearly more prevalent in the earlier (leftmost) imagery.

Another FIREX-AQ mission objective was to evaluate the efficacy of emission estimates from satellite-based measurements. During the deployment eMAS under-flew 8 different satellites a total of 30 times. Full evaluation of satellite/eMAS colocation and data comparison for matching bands is underway.

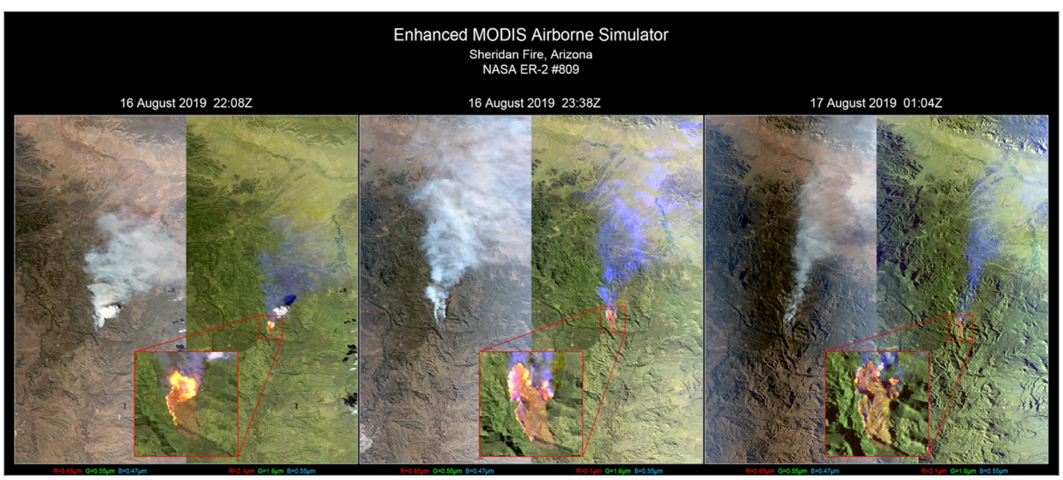


Figure 4.3.1: *eMAS true color and false color RGB imagery for three passes over the Sheridan Fire to show the evolution of the fire and smoke plume. For further information please contact Arnold Thomas at (tom.arnold@nasa.gov).*

4.4. TROLIX'19

A Sentinel-5p/TROPOMI validation campaign (PI: Arnoud Apituley/KNMI) was held in the Netherlands based at the Cabauw Experimental Site for Atmospheric Research during September 2019. The TROpomi vaLIdation eXperiment (TROLIX) consisted of active and passive remote sensing platforms in conjunction with several balloon-borne, airborne and surface chemical measurements. The goal of this geophysical validation campaign was to make intensive observations to establish the quality of TROPOMI L2 main data products (UVAI, Aerosol Layer Height, NO_2, O_3, HCHO, Clouds) under realistic non-idealized conditions with varying cloud cover and a wide range of atmospheric conditions.

Since TROPOMI is a hyperspectral imager with a very high spatial resolution of 3.5 × 7 km^2, understanding local effects such as inhomogeneous sources of pollution, sub-pixel clouds and variations in ground albedo is important to interpret TROPOMI results. Therefore, the campaign includes sub-pixel resolution local networks of sensors, involving Pandora and MAXDOAS instruments, around Cabauw (51.97° N, 4.93° E) and within the city of Rotterdam. Cabauw is considered rural while Rotterdam is densely populated and industrialized. These focal areas will be connected through airborne as well as ground based mobile observations. Cabauw, using its comprehensive in-situ and remote sensing observation program in and around the 213 m meteorological tower, will be the main site of the campaign with focus on vertical profiling using lidar instruments for aerosols, clouds, water vapor, tropospheric and stratospheric ozone, as well as balloon-borne sensors for NO_2 and ozone.

NASA GSFC (Code 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 TOLNet lidar was deployed to Cabauw, NL to provide profiles of ozone from the boundary layer into the free troposphere during TROPOMI overpasses. Pandora and AERONET instruments were also deployed to sample column amounts of trace gases and aerosols. This combination of observations has provided a unique characterization of O_3 and other pollutants to help provide feedback to the S5P satellite evaluation team as well as future satellite remote sensing systems such as NASA's TEMPO mission.

Participating in the TROLIX campaign from the 614 lidar group are: John Sullivan, Laurence Twigg, Thomas Mcgee, Grant Sumnicht.

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

4.5. NDACC

NDACC Validation: The Stratospheric Ozone Lidar finished a deployment at the Deutscher Wetterdienst (DWD) observatory, at Hohenpeissenberg in southern

Germany in March of 2019. It was there 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 Protocol for NDACC instrumentation at different sites around the globe. After leaving the site in Southern Germany, the Stratospheric Ozone Lidar was transported to The Netherlands to participate in a TropOMI Satellite Validation campaign, TROLIX'19. Also participating was another NDACC Lidar from 614, the Tropospheric Ozone Lidar. This campaign took place in September and October at the Cabauw Observatory near Utrecht, Netherlands Participating in these deployments were Thomas McGee (614), PI of the group, John Sullivan (614), PI of the Tropospheric Ozone Lidar, along with staff from SSAI, Laurence Twigg, and Grant Sumnicht. Both instruments have returned to GSFC and are now undergoing maintenance in preparation for upcoming operations here at Goddard and future campaigns. The AT trailer is undergoing a significant upgrade to the radar used to control the transmission of laser light into navigable airspace, which is expected to be completed in early 2020.

For further information, contact Thomas McGee (thomas.j.mcgee@nasa.gov), or John Sullivan (john.t.sullivan@nasa.gov).

4.6. SEAS

Southeast Asia (SEA), an extensive agrarian region, has witnessed vibrant economic growth and rapid urbanization in recent decades. During boreal spring in SEA, biomass-burning aerosols from natural forest fires and slash-and-burn agricultural practices strongly modulates the regional atmospheric composition over northern SEA. Questing for a deeper understanding of the way aerosols affect Southeast Asian weather, climate, and the environment, a grassroot Seven South East Asian Studies (7-SEAS) project integrates an international effort involving Indonesia, Malaysia, Philippines, Singapore, Taiwan, Thailand, Vietnam, and the U.S. (NASA Goddard and Navy/ONR) in forming a highly interdisciplinary science team. Research topics include seven focus areas from which the program derives its name: (1) clouds and precipitation, (2) radiative transfer, (3) anthropogenic and biomass-burning emissions and evolution, (4) natural background atmospheric chemistry, (5) tropical-subtropical meteorology, (6) regional now casting, forecasting, and interannual/climate outlooks, and (7) satellite and model calibration/validation.

7-SEAS project started in May 2007 and immediately launched a warm-up exercise (Virtual Biomass Burning Experiment, at https://www.nrlmry.navy.mil/aerosol/7seas), using all data collected in August 2007 over entire SEA. Subsequently, two pilot Intensive Observation Periods (IOPs), one focused mainly on studies over the maritime continent and the other in the northern regions of the 7-SEAS domain, were successfully conducted. Two 7-SEAS special issues were published collectively for these activities (https://doi.org/10.1016/j.atmosres.2012.06.005 and https://doi.org/10.1016/j.atmosenv.2013.04.066) in 2013. To further facilitate an improved understanding of the regional air quality as influenced by aerosol-cloud effects in climatologically important cloud regimes, 7-SEAS/BASELInE (Biomass-burning Aerosols & Stratocumulus Environment: Lifecycles & Interactions Experiment) was conducted in spring 2013-2015 over northern SEA (https://doi.org/10.4209/aaqr.2016.08.0350, which represents the third volume of the 7-SEAS special issue in 2016). Consequently, the recent *Decadal Survey* (2017) targeted Earth's planetary boundary layer (PBL) as a high priority and crosscutting science measurement for incubation studies of future satellite observations. Thus, the follow-on 7-SEAS/BASELInE (spring 2018-2020) are designed to take these challenges. Remote sensing and in situ observations from suborbital—e.g., Unmanned Aircraft System (UAS)—and ground-based platforms, though spatially limited, can supply information on evolving properties of aerosols and light rainfall at low levels and near the Earth's surface, thereby filling satellite observational gaps and providing additional constraints on model microphysics. Many PBL profiles of thermodynamic parameters (e.g., T, P, RH, wind) and aerosol microphysics/optical properties (e.g., mass, number concentration, scattering and absorption) have been acquired in spring 2019 in the vicinity of Chiang Mai, Thailand, near the source regions of biomass-burning activities. Additional units of UAS from international participants (e.g., Taiwan, Thailand and Vietnam) are planned to participate the spring IOPs in 2020 over northern 7-SEAS. These measurements are crucial not only for studying aerosol impact on air quality and human health, but also for evaluating and improving microphysical process representation in models to better understand aerosol-cloud interactions and the relationships between in-cloud and surface precipitation characteristics.

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

4.7. RAJO-MEGHA

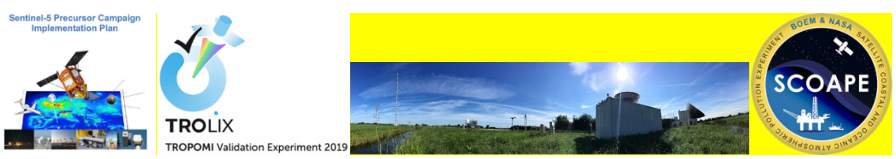
The objectives of the Radiation, Aerosol Joint Observation-Modeling Exploration over Glaciers in Himalayan Asia (RAJO-MEGHA, Sanskrit for Dust-Cloud) project are to exploit the latest developments of satellite, ground-based networks and modeling capabilities in addressing the overarching scientific question: What are the spatiotemporal properties of light-absorbing aerosols in the atmosphere-surface column and their relative roles in causing accelerated seasonal snowmelt in the High Mountain Asia (HMA)? Comprehensive regional-to-global simulation/assimilation models, advancing in lockstep with the advent of satellite observations and complementary surface network measurements, are playing an ever-increasing role in better understanding the changes of Earth environment. However, the complex characteristics of HMA, such as its rugged terrain, atmospheric inhomogeneity, snow susceptibility, and ground-truth accessibility, introduce difficulties for the aforementioned research tools to retrieve/assess radiative effects on snow/ice melting with a high degree of fidelity. RAJO-MEGHA project started in the fall of 2017 and is scheduled to last until the onset of Asian summer monsoon in late May 2020. The Goddard team participated jointly in the International Centre for Integrated Mountain Development (ICIMOD)'s fall/

spring expedition to the Yala glacier regions, yearly. Since October 2017, a suite of solar-powered AERONET Sun/sky spectro-radiometer and SMARTLabs solar/terrestrial radiometers have been in operational at two high elevation sites of Kyanjin (3.9 km a.s.l.) and ICIMOD Black Carbon station (4.9 km a.s.l.), the latter similar to the recently discontinued EvK2-Pyramid observatory (5.05 km a.s.l. near Mt. Everest basecamp at 27.95°N, 86.81°E). Starting in the fall of 2018, a Lagrange-like setting of radiance/irradiance/backscatter-intensity measurements (AERONET/SMARTLabs/MPLNET) are conducted along airmass inflows from the Indo-Gangetic Plains to High Himalaya-Nepal to evaluate the evolution of aerosol/trace-gas properties. Furthermore, multiple AERONET Sun-sky spectroradiometers will be deployed in setting like the Distributed Regional Aerosol Gridded Observation Networks (DRAGON) centered around the foothill supersite (Bidur, Nepal) in the spring season of 2020 to characterize aerosol optical depth and single-scattering albedo, among other parameters, in a 2D domain for satellite retrievals and model simulations comparison/validation. Thus, large-scale satellite and uniquely distributed ground-based network measurements, synergized with modeling results, establish a critically needed database to advance our understanding of changes in snowmelt processes over HMA due to the presence of light-absorbing aerosols.

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

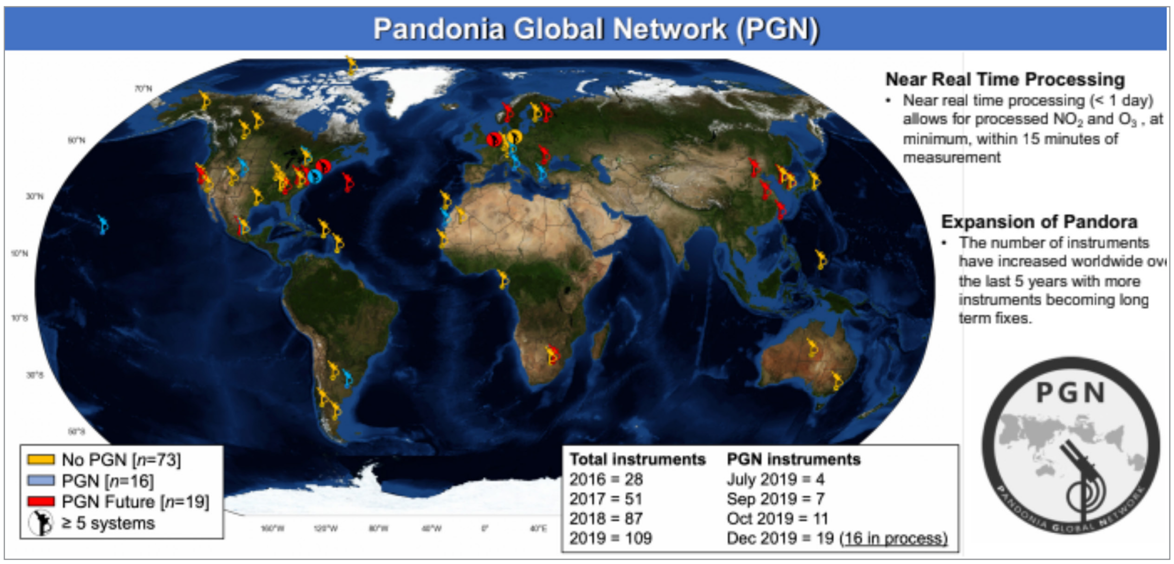
4.8. Pandora

During the summer of 2019, the NASA Pandora Project supported three field campaigns—BOEM's SCOAPE (PI Bryan Duncan, Co-PI, Anne Thompson) ESA TROLIX (Co-I J. Sullivan) and ESA S5P Satellite Validation (PI A. Richter) NASA field campaigns with 3, 1 and 3 instruments, respectively.



NASA Pandora / PGN Meetings, Workshops, Trainings, Presentations

- NASA OWLETS/TOLNET STM, College Park MD, May 2019
- CEOS/ACVC, Japan, June 2019
- NDACC STM, Japan, October 2019
- GSFC Pandora Student Training, VCU, Oct 2019
- 2019 Fall AGU Annual Meeting, San Francisco, CA, Dec 2019
- Environment, Climate Change Canada, Toronto, Canada, Nov 2019
- NASA Ames Research Center, Mountainview CA, Nov 2019
- NASA Jet Propulsion Laboratory, Pasadena CA, Nov 2019
- University of Alabama – Huntsville, AL, Dec 2019
- 2020 AMS Annual Meeting, Boston MA, Jan 2020



NASA Pandora Project Investment in People, Equipment and Facilities

- ESA training workshop for three GSFC people at Luftblick in Innsbruck (May 2019) resulting in increase in total number of calibrations and calibration files produced by Luftblick and NASA GSFC.
- Establishment of new subcontract that reconfigured existing personnel and allowed for the onboarding of two new technicians and 0.5FTE of contracted expert in retrievals at a substantial savings to the project.
- Onboarded a FN postdoc dedicated 0.6FTE to production of Calibration files 0.4FTE to Pandora Project R&A.
- Investment in GSFC calibration facilities (e.g., addt'l labs/ lasers (325, 355, 377, 404, 447, 490, 514, 532, 561, 640, 686, 726 nm) to characterize stray light, FOV for O_3 and CH_2O.
- Instruments now calibrated w/fiber guide in place ensuring further stabilization of radiometric calibration.

NASA Pandora Project Progress Related to Programmatic Calibration and Calibration Files production

Year	2018			2019		
Institution	NASA	Luftblick	SciGlob	NASA	Luftblick	SciGlob
Physical Lab Calibrations	29	49	35	56	51	45
Calibrations Analyzed Cal Files Produced	0	41	N/A	36	52	N/A

4.9. SCOAPE

The Satellite Coastal & Oceanic Atmospheric Pollution Experiment (SCOAPE) project has the goal to scope out the feasibility of using NASA resources to monitor air pollution over areas of oil and natural gas extraction activities in the Gulf of Mexico. The project is funded through a 2017 reimbursable agreement between NASA and the Department of Interior Bureau of Ocean Energy Management (BOEM), which is responsible for monitoring offshore air quality and assessing the impact of air pollution from offshore sources on onshore air quality. The NASA Applied Sciences Program also provided funds to support civil servant participation in this project.

In 2019, SCOAPE personnel participated in a number of ongoing "scoping" activities, including 1) investigating the utility of using satellite data of nitrogen dioxide to infer emissions from rigs and platforms, and 2) exploring using satellite data of air pollutants and the GEOS-CF model, developed in the NASA Global Modeling and Assimilation Office (GMAO), to understand the complex mix of pollutants from both offshore and onshore sources over the Gulf of Mexico. A major activity was the SCOAPE field campaign in May 2019, which had the goal to understand the relationship between satellite data, such as from the Aura Ozone Monitoring Instrument (OMI), the S5P TROPOMI, SNPP VIIRS, and concentrations of pollutants in the boundary layer. The campaign was conducted from 10-19 May 2019 with Bryan Duncan overseeing land-based measurements of NO_2 at Cocodrie, Louisiana, that included a surface analyzer, two Pandora spectrometers and NO_2-sondes supplied by the Dutch Met Office (KNMI). Anne Thompson was Chief Scientist on the Research Vessel Point Sur that traversed the area of primary oil and natural gas extraction off the eastern Louisiana Gulf Coast (Figure 4.9.1). The ship sampled standard trace gases (NO_2, ozone, methane, CO_2) along with VOC canisters for dozens of hydrocarbons and a sea-going Pandora. To date, there are two important findings from the campaign. First, although large deep-water platforms are visible from space (Figure 4.9.2), the ship's data collected during on-shore conditions showed minimal impact on ozone pollution; that changed when offshore winds brought industrial pollution onto the

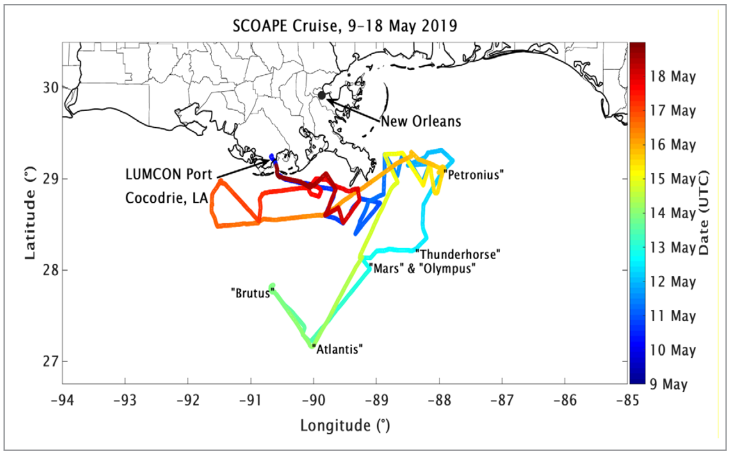


Figure 4.9.1: *SCOAPE cruise track for 9-18 May 2019 with named deep-water platforms of interest for sampling. Color bar denotes date of Research Vessel Point Sur's location in the Gulf of Mexico.*

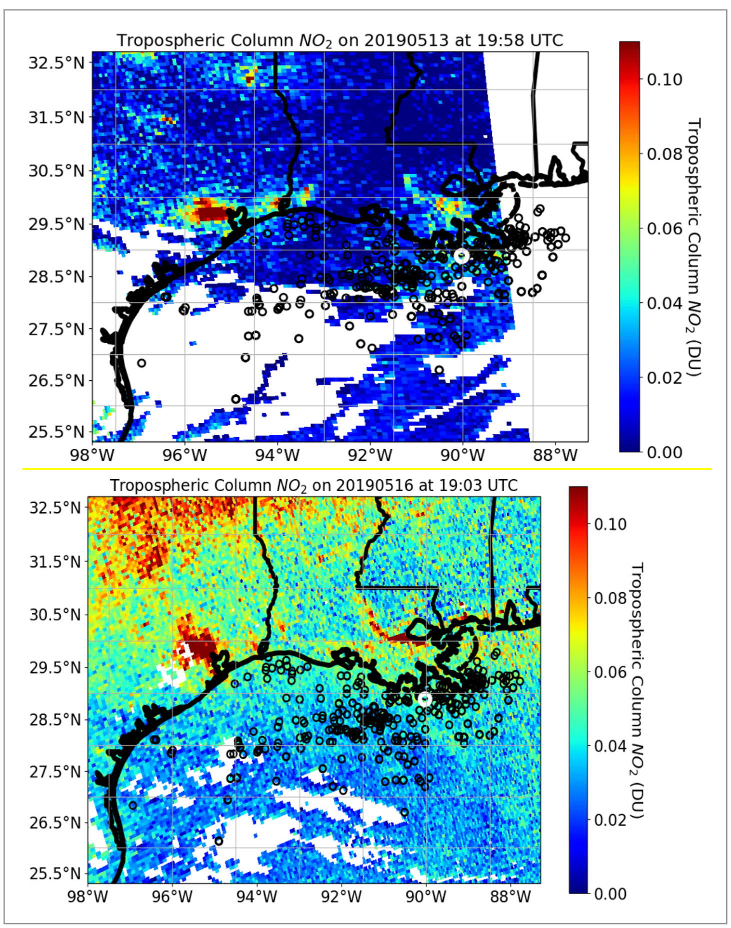


Figure 4.9.2: *TROPOMI daily tropospheric column NO_2 maps during SCOAPE cruise. There was clean, marine air over the Gulf of Mexico on 13 May 2019 (left panel) with on-shore winds before the transition to offshore winds and a more polluted continental air mass over the sampling area on 16 May 2019 (right panel).*

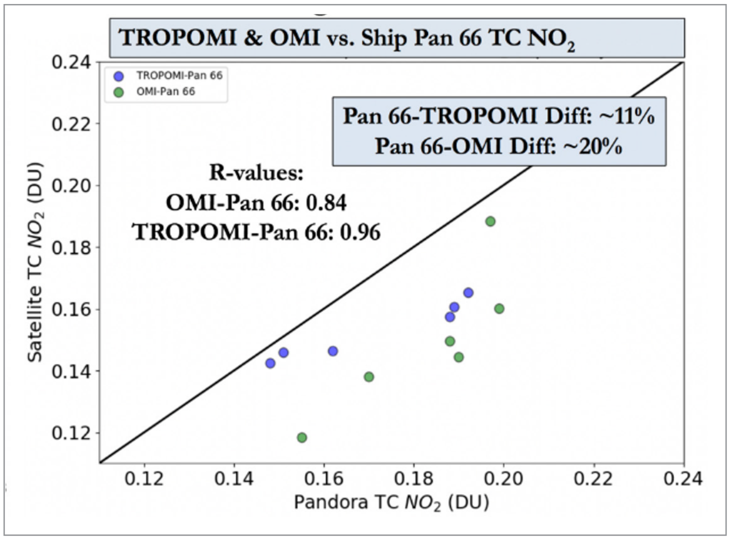


Figure 4.9.3: *Comparison of satellite (TROPOMI-blue points and OMI-green points) Total Column (TC) NO_2 with ship Pandora 66 TC NO_2 during SCOAPE cruise. Both satellites correlate well with Pandora, showing differences ~ 11% and 20% respectively.*

Gulf during the last four days of the cruise. Second, comparisons of total column NO_2 from satellite and the ship Pandora averaged 11% agreement with TROPOMI (Figure 4.9.3) and 20% with OMI (OMNO2 L2 v003). Analysis of the data is ongoing. The cruise data are archived at: https://www-air.larc.nasa.gov/missions/scoape/index.html.

For further information, please contact Bryan Duncan (bryan.n.duncan@nasa.gov).

4.10. IMPACTS

Northeastern U.S. snowstorms impact large populations in major urban corridors, and cause major disruptions to transportation, commerce, and public safety. Snowfall within these storms is frequently organized in multi-scale banded structures that are poorly understood and poorly predicted by current numerical forecast models. Despite this, no major study of U.S. East Coast snowstorms has taken place in over 30 years. To address these needs, the Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) Earth-Venture Suborbital-3 (EVS-3) field campaign will take place during the winters of 2020-2022 to sample a range of East Coast snowstorms using airborne remote sensing and in situ instrumentation. The ER-2 aircraft will fly at high altitude and carry a suite of remote sensing instruments including cloud and precipitation radars, lidar, and passive microwave instruments to simulate satellite-borne instrumentation. The P-3 aircraft will fly within clouds and sample environmental and microphysical quantities using a turbulent air motion measurement system, microphysics probes, and a dropsonde system to sample vertical profiles of temperature, humidity and winds. Goddard will provide the HIWRAP, CRS, EXRAD, CPL, and CoSMIR instruments on the ER-2. These airborne measurements will be supplemented with ground-based measurements from raw ins ondes launched from mobile sounding systems and at National Weather Service stations, ground-based radars stationed over Long Island, and the New York State mesonet ground network. With this suite of instrumentation, IMPACTS will provide observations critical to the understanding of the dynamical and thermo dynamical mechanisms of snowband formation, organization and evolution. IMPACTS will also examine how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands and apply this understanding to improve remote sensing and modeling of snowfall.

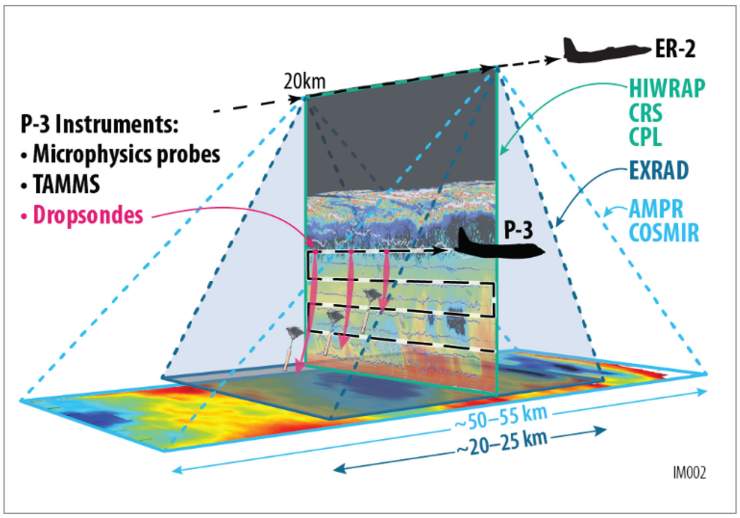


Figure 4.10: *The P-3 aircraft will fly within clouds and sample environmental and microphysical quantities using a turbulent air motion measurement system, microphysics probes, and a dropsonde system to sample vertical profiles of temperature, humidity and winds. Goddard will provide the HIWRAP, CRS, EXRAD, CPL, and CoSMIR instruments on the ER-2.*

5. Code 610 Web Development Team—2019 Significant 610AT Accomplishments

- Completed a complete redesign and redevelopment of all AT (and HBG) laboratory research websites. Sites were built in Drupal 8. Pages include laboratory research information, science highlights, news and event information, field campaign highlights, publications, instrument information and other features. Please see the example links below:

  https://earth.gsfc.nasa.gov/acd

  https://earth.gsfc.nasa.gov/climate

- Atmosphere Discipline Team Imager Products Website: Developed and deployed the Level 3 MODIS Standard Image Browsing Application. This will assist the MODIS Science Team and other users in processing and science quality assurance activities. Please see the example link below:

  https://atmosphere-imager.gsfc.nasa.gov/images/l3/daily

- Improved Build Processes/Automation: Integrated our private repositories with Drupal 8's Composer workflow to improve speed of custom code deployment and updated Ansible playbooks for running bulk Drupal updates. These and other improvements reduce human error and time associated with code deployments.

- Completed Launchpad integration for 65 of 81 websites within Code 610 HBG and AT. This includes both development and operational websites. Launchpad integration facilitates improved access control for certain users and staff performing content updates to these websites.

- Hired Nathan Perrin as a new web developer, who arrived in September. Lost Roosevelt Purification from the task in November.

- For further information, please contact Keith Duffy (keith.duffy@ssaihq.com).

6. Awards and Special Recognition

This year many deserving employees were recognized for outstanding accomplishments, leadership, or service. Notable achievements were recognized by Goddard Space Flight Center, 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.

6.1. Agency Honor Awards

Honor Award	Recipient	Citation
Outstanding Leadership Medal	Matthew McGill (610)	For outstanding leadership of the Cloud-Aerosol Transport System (CATS) project for the ISS.
Exceptional Scientific Achievement Medal	Fei Liu (614)	For exceptional service in For innovation in creating a new merged satellite - bottom up emission inventory for sulfur dioxide to be used in air quality and aerosol forecasting to support NASA missions.
Group Achievement Awards	TRMM/GPM Ground Validation Team (David Marks, 610.W)	For outstanding support of the GPM Ground Validation program through data collection, quality control, instrument calibration, unique software development, and IT security.
	Earth Science Partnerships Team (Kevin Ward, (613, SSAI)	Team Excellence Award as part of the 2019 Headquarters Honor Award and Group Awards.
	Tropospheric Ozone Lidar Network (TOLNet)	For the development and implementation of a network of tropospheric-ozone lidars to measure time series of vertical profiles of atmospheric ozone for air quality studies.
	Members of GSFC who were a part of this team include Kirk Knobelspiesse (616), Robert Swap (614), Peter Colarco (614), Arlindo da Silva (610), Karla Maria Longo de Freitas (610) and Ellen Gray (130).	NASA ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) Earth Venture airborne Earth science mission team.

6.2. Robert H. Goddard Awards

Atmospheric Research team members received the following individual awards.

Robert H. Goddard Award	Recipient	Citation
Engineering Excellence Group Award	Gerald Heymsfield (612), Gerald McIntire (612/SGT), Charles Helms (612/USRA), and Peter Pantina (612/SSAI)	Outstanding dedication and support of the IMPACTS mission 2020 deployment.
Exceptional Achievement for Outreach	Geoffrey Bland (610.W)	For outstanding and long serving outreach to science education at all levels.
Exceptional Achievement for Science	Lazaros Oreopoulos (613)	For outstanding contributions in the use of satellite observations to elucidate global cloud property statistics through the development of novel methodologies.
Exceptional Achievement for Science	John Yorks (612)	For outstanding leadership in developing the CATS instrument and applying it to create and analyze key cloud and aerosol datasets.
Exceptional Achievement for Science	Hongbin Yu (613)	For outstanding contributions that have greatly advanced our understanding of the intercontinental transport of pollution.
IMERG Development Team	George Huffman (612)	For outstanding performance in developing the Version 6 IMERG precipitation dataset covering both the TRMM and GPM eras.

6.3. Sciences and Exploration Directorate

Jae N. Lee (613/UMBC) and Dong L. Wu (613) were awarded the 2019 Piers J. Sellers Award for Interdisciplinary Science at the 12th Annual Sciences & Exploration Directorate New Year's Poster Party, February 26.

6.4. External awards and recognition

Congratulations to Dr. Anne Douglass for being named recipient of the 2020 AMS Joanne Simpson Mentorship Award. Her citation reads: "For patient guidance and boundless encouragement of young scientists, and for leading by example as a researcher, writer, and project scientist." Her award will be presented at the 100th AMS Annual Meeting in Boston, Massachusetts, in January 2020. Congratulations to Anne on this honor and for continuing Dr. Joanne Simpson's legacy of mentorship at GSFC. As stated by Jim Irons: It is entirely fitting that Anne is receiving an award named after Joanne Simpson as Anne has carried forward Joanne's legacy of mentorship at GSFC.

6.4.1. NASA-USGS Pecora Team Awards

The Ozone Monitoring Instrument (OMI) International team has won the prestigious NASA-USGS Pecora award (https://www.usgs.gov/land-resources/national-landimaging-program/william-t-pecora-list-recipients) "For fifteen+ years of sustained team innovation and international collaboration to produce daily global satellite data that revolutionize urban air quality and health research." The OMI International Team is comprised of Dutch, Finnish, and American scientists (many of whom are at GSFC), who have worked tirelessly to produce science-quality data sets of Earth's atmosphere. OMI flies on the NASA Aura satellite launched in 2004.

The Terra Team received the prestigious 2019 William T. Pecora Group Award for the mission's outstanding contributions toward understanding the Earth through remote sensing. Joanna Joiner (614) accepted the 2018 William T. Pecora Group Award on behalf of the Ozone Monitoring Instrument (OMI) International Team at the PECORA 21/ISRE 38 Conference on October 8.

6.4.2. External Advisory Board for the NOAA Center for Atmospheric Sciences and Meteorology (NCAS-M)

Robert J. Swap (614) has been elected Chair of the External Advisory Board led by Howard University.

6.4.3. External Advisory Board for the NOAA Center for Atmospheric Sciences and Meteorology (NCAS-M)

Can Li (614/UMD) is an elected member of the iCACGP and attended the 27th IUGG General Assembly held in Montreal, Canada, July 8-18. He attended the business meeting and gave an oral presentation entitled "Significant Recent Changes in Regional SO_2 Pollution: Satellite Observations and Potential Impacts".

Joanna Joiner (Code 614) was named to the 2019 Clarivate Analytics annual list of Highly Cited Researchers. The list identifies scientists and social scientists who produced multiple papers ranking in the top 1% by citations for their field and year of publication, demonstrating significant research influence among their peers.

6.5. 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 Joanne Simpson on November 4, 1994. All current and past atmospheric science recipients of this award are listed below.

Ralph Kahn

The Earth Sciences Division was thrilled to announce the selection of Ralph Kahn as the 2019 William Nordberg Memorial Award for Earth Science winner. Ralph Kahn has dedicated most of his scientific career to studying aerosols and their major influences on air quality, aviation safety, cloud properties, and global climate. He has conducted pioneering work to greatly advance our understanding of aerosol interactions with their environment and to influence relevant research directions of GSFC, NASA, and the Earth science community as a whole. His work as MISR aerosol scientist has resulted in more than 15 years of global high quality aerosol observations from MISR. Ralph has validated detection algorithms of key sources of biomass burning aerosols, characterized their strength and injection heights into the atmosphere, and showed how to identify and track ash plumes from volcanic eruptions. These techniques are routinely used by aerosol scientists worldwide.

Kahn has built an enduring legacy at GSFC for his outstanding ability to build collaborations between NASA mission teams. He has been instrumental in bringing together the aerosol teams of MISR, MODIS, CALIPSO, and OMI and urged the modeling and satellite communities to come together. Kahn's scientific influence is also evident in his prodigious publication record. Publication prowess is only one facet of his scientific reputation and standing. Kahn entertains a ceaseless stream of invitations for talks at scientific meetings and educational/research institutions. Ralph also cares deeply about community outreach and mentoring early-career scientists. His educational credentials include contributions to the Encyclopedia of Remote Sensing, lending frequently his expertise for Earth Observatory stories, and being a founder and editor of PUMAS, an online journal providing pre-college teachers peer-reviewed enrichment material (Outstanding Education Product Award in 1999). Many of his former mentees have moved on to successful positions in academia and government.

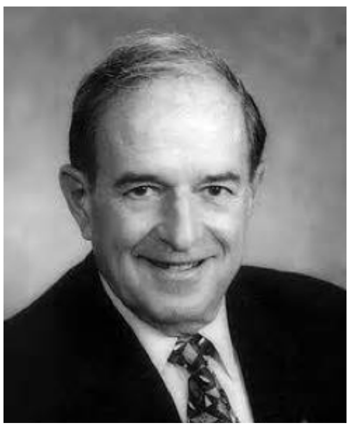
William Nordberg Award Recipients	Year
Joanne Simpson	1994
Mark Schoeberl	1998
William K. M. Lau	1999
Michael D. King	2001
P. K. Bhartia	2003

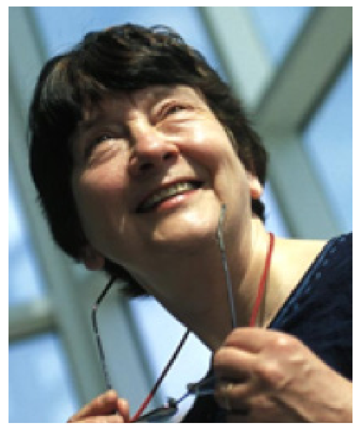
William Nordberg Award Recipients	Year
Robert Adler	2007
Wei-Kuo Tao	2008
Paul Newman	2011
Anne Douglass	2013
Anne Thompson	2018
Ralph Kahn	2019

6.6. American Meteorological Society

6.6.1. Honorary Members

"Honorary members [of the American Meteorological Society] shall be 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.





Honorary AMS members: *David Atlas, left (The David and Lucille Atlas Remote Sensing Prize); Joanne Simpson, center (The Joanne Simpson Mentorship Award); and Eugenia Kalnay, right.*

6.6.2. 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. Scott Braun (612) and George Huffman (612) were named new 2019 Fellows and honored at the AMS Annual Meeting in January 6-10, 2019.

2019 AMS Fellows: Scott Braun, left and George Huffman, right.

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

6.7. American Geophysical Union

6.7.1. 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 of Fellows." 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, and/or (4) sustained impact." The following current and former Goddard atmospheric scientists have received this distinguished honor. Founded in 1919, AGU is a not-for-profit scientific society dedicated to advancing Earth and space science for the benefit of humanity.

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

6.7.3. 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 from NASA Goddard Space Flight Center, 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

7. Communication

7.1. 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 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.

7.2. University and K-12 Interactions

Students Margaret Bone and Jami Hamman from Harpeth Hall High School in Nashville, Tennessee, who were planning a research experience at GSFC in early January, during the shutdown were able to complete their experience by working with Gala Wind (613/SSAI) at office space provided at UMBC. The interns were instructed in practical Fortran programming and basic Earth system science. They then learned to acquire and process data from SNPP-VIIRS and DSCOVR-EPIC.

On January 15, Brian Campbell (610W/GST) planned and implemented the 5th Trees Around the GLOBE Student Research Campaign webinar. The webinar featured a student and teacher from Croatia presenting on their green up/green down, tree height, and atmospheric composition research in Mlaka Park, Croatia. This webinar was attended by 51 participants from ten countries.

On January 22, Dorian Janney (612/ADNET) created and presented a webinar for Marymount's Teacher Education Program that focused on the GPM mission and how to access and use GPM resources with students: https://youtu.be/tx1oXCtrW9A.

On February 8, Dorian Janney (612/ADNET), Dalia Kirschbaum (617), and Andrea Portier (617/SSAI) worked with 15 participants who were attending the at the 2019 Maryland Association for Environmental and Outdoor Education (MAEOE) Conference. Although the conference was being held in Towson, MD, these participants came to GSFC for this three-hour workshop. Dalia presented on the use of NASA Earth observing missions to study the Chesapeake Bay Watershed region. Andrea shared several applications for NASA EOS data in the Chesapeake Bay area. Dorian gave a hands-on workshop to show participants how to use the GLOBE and GLOBE Observer resources to collect meaningful environmental data in this water shed, with an emphasis on the GLOBE "Mission Mosquito" campaign.

On February 9, Dorian Janney (612/ADNET) presented to 46 participants who were attending the 2019 Maryland Association for Environmental and Outdoor Education (MAEOE) Conference in Towson, MD. She gave an hour-long presentation entitled "Using NASA Earth observing satellite data to Predict and Respond to Disease".

Brian Campbell (610W/GST) planned and implemented the sixth NASA Trees Around the GLOBE webinar to thirty-four participants from six countries (United States, Croatia, Switzerland, Argentina, Trinidad, and Oman), on February 19. During the webinar, Brian and his colleague, Peder Nelson from Oregon State University, introduced guiding investigative questions that provide students with questions to explore while collecting and analyzing their GLOBE protocol data.

On February 19, Brian Campbell (610W/GST) presented a data and research webinar to several students from the Shumate Middle School in Gibraltar, Michigan. These students have been conducting NASA GLOBE research in SMAP volumetric soil moisture and are designing research products using their collected data. Brian serves as an advisor to these students.

Brian Campbell (610W/GST) presented two hands-on activities at the 2019 Better Living Expo at the Wicomico Youth and Civic Center in Salisbury, Maryland, February 23. These hands-on activities focused on the ICESat-2 mission, lasers, and the "ICESat-2 Bouncy Ball Photon-Counting Challenge." The activities were attended by 25 adults and 63 children.

On February 21, Dorian Janney (612/ADNET) presented a data and research webinar to several students from the Shumate Middle School in Gibraltar, Michigan. These students have been conducting NASA GLOBE research in using the GLOBE Observer Mosquito Habitat Mapper. Dorian serves as an advisor to these students.

Santiago Gassó (613/UMD) accepted an invitation to participate in the South to North Atlantic Transect (SoNoAT) cruise onboard the German research vessel Polarstern. He will be one of 13 instructors selected to participate in a five week cruise during the summer of 2019. The cruise will depart from Port Stanley (Falkland Islands, 51S) and end in Bremerhaven (Germany, 53N). This will be a training course where 27 graduate students (among 800 applicants) selected from all over the world are taught the principles of oceanography, climate and instrumentation including remote sensing. Santiago Gassó will teach the remote sensing module and will carry out aerosol measurements onboard using Micro tops sensors. The project is funded by the Partnership for Observation of the Global Oceans (POGO), AtlantOS, Regionale Klimaänderungen (REKLIM), the Nippon Foundation, and the Alfred Wegener Institute for Polar and Marine Research (AWI).

On February 21, Dorian Janney (612/ADNET) presented a data and research webinar to several students from the Shumate Middle School in Gibraltar, Michigan. These students have been conducting NASA GLOBE research in using the GLOBE Observer Mosquito Habitat Mapper. Dorian serves as an advisor to these students.

On February 26, Dorian Janney (612/ADNET) wrote a blog for the GLOBE website entitled "GLOBE Mission Mosquito Spotlight on Thailand" which shares the work that a GLOBE teacher and her students in Trang, Thailand are doing with the Mosquito Habitat Mapper. http://bit.ly/2tFRmfu.

On March 2, Brian Campbell (610W/GST) gave the keynote address at the 2019 Delaware Science Olympiad at Delaware State University in Dover, Delaware. Brian's address, entitled "Earth Science at NASA: What We See" was attended by 1,000+ students, educators, parents, and the public.

On March 4, Brian Campbell (610W/GST) presented a virtual tutorial on the GLOBE SMAP Block Pattern Soil Moisture Protocol and visualizing SMAP data on the NASA Worldview Tool with students from the Detroit Public Schools. The students are working on GLOBE Virtual Science Fair Projects comparing their soil moisture measurements with those of the SMAP satellite.

On March 6, Dorian Janney (612/ADNET) led a two-hour workshop for the Montgomery County Environmental Education CPD (Continuing Professional Development) class participants in Rockville, Maryland. She shared information on the GPM mission, NASA's Earth observing satellite missions and related educational resources, and the GLOBE Program. The 29 adult participants, who are in-service educators, used the GLOBE Observer app to collect cloud and mosquito data, and learned how to become involved in the Mission Mosquito campaign.

On March 11, Brian Campbell (610W/GST) gave a virtual presentation to five students, visiting the NASA Langley Research Center, from the Fond du Lac Tribal and Community College in Minnesota. The presentation focused on the Trees Around the GLOBE Student Research Campaign and the NASA ICESat-2 satellite, and the GEDI Mission on ISS.

On March 15, Brian Campbell (610W/GST) gave three virtual presentations to schools in Ghana, Africa as part of the 2019 Ghana Science Festival held March 14-16, across Ghana. Brian's presentation, entitled, "NASA Earth Science, The GLOBE Program and Doing Real Science" was attended by 102 students and six educators. Ghana is a NASA GLOBE Program country with students taking and submitting data from many GLOBE measurement protocols.

On March 19, Brian Campbell (610W/GST) planned and implemented the seventh NASA Trees Around the GLOBE Student Research Campaign webinar to thirty-six participants from eight countries. During the webinar, GLOBE Campaign Member Oscar Garza and a student named White-tailed doe from the Kalispel Salish Tribe, showed how GLOBE protocols (specifically Green Up/Green Down) and citizen science have the potential to help efforts of many communities around the world in their task on language, culture and landscape revitalization and preservation in a dual-learning environment.

On March 25, Brian Campbell (610W/GST) gave a virtual presentation, from the NASA Goddard Distance Learning TV Studio, on the ICESat-2 Mission, The GLOBE Program's Trees Around the GLOBE Student Research Campaign, and the NASA GLOBE Observer new Trees Tool to fifty-nine students and three educators in Alaska. The students were from schools in Fairbanks and Metlakatla, Alaska and are active GLOBE Program students. This presentation was part of the "Arctic & Earth SIGNS Meet a NASA Scientist Program Partnership" with the NASA Langley Research Center.

The Applied Remote Sensing Training program (ARSET) completed an introductory online training: "Using Earth Observations to Monitor Water Budgets for River Basin Management". Attendees learned how to apply remote sensing observation and Earth system model data to estimate surface water budget components. Brock Blevins (614/SSAI), Elizabeth Hook(613/SSAI), and Selwyn Hudson-Odoi (614/UMBC) supported the training, led by Amita Mehta (612/UMBC) and Sean McCartney (610/SSAI). The webinar featured two guest speakers: Benjamin Zaitchik (Johns Hopkins University) and John Bolten (617), who provided answer and questions sessions with Ibrahim Mohammed (617/SAIC), and Perry Oddo (617/USRA). A recording of the webinar is available here: https://www.youtube.com/watch?v=V1jgEc6wqm4&feature=youtu.be Learn more about ARSET and upcoming trainings at: https://arset.gsfc.nasa.gov.

Dorian Janney (612/ADNET) presented on the GLOBE Observer Mosquito Habitat Mapper tool, the GLOBE Mission Mosquito campaign, and the ways that NASA EOS data is being used to predict, monitor, and respond to mosquito-transmitted disease during the Gaithersburg Middle School Family STEM Night, April 11. She gave three presentations throughout the two-hour event to 21 adults and 42 middle school students.

Dorian Janney (612/ADNET) organized and presented during the April Education GLOBE Mission Mosquito webinar, April 10. This webinar focused on teaching participants how to identify mosquito larvae. We had guest presenter Andre Radloff from the Smithsonian Education Center present on the "Mosquito!" curriculum, and Dr. Russanne Low took participants through alive demonstration of how to identify larvae. There were 42 participants from all across the US as well as from 12 countries around the world. http://bit.ly/2FiY4yn.

On April 15, Dorian Janney (612/ADNET) gave three presentations to students at the Olney Adventist Preparatory School during their Career Day event. She shared information about NASA's Earth Science missions as well as information on possible career options during her STEM Engagement presentations to 69 elementary school students and four teachers.

Sallie Smith (619/GST) and Geoff Bland (610.W) conducted a three-day AEROKATS (Advancing Earth Research Observations with Kites and Atmospheric/Terrestrial Sensors) workshop in Puerto Rico for fourteen educators from 4th grade through undergraduate levels. The workshop focused on team kite-flying operations and aerial imaging using NASA Aeropod technology. The educator team subsequently self-organized as the "Puerto Rico Fliers" to further their training and proficiency, and implement their educational project strategies. Franco Jimenez and Carlos Munoz from G-Works, inc., expertly facilitated this event, and Kay Rufty (610.W/GST) and Andy Henry (Wayne RESA) provided support during the extensive preparations. The training is anticipated to continue in 2020 and 2021. For an example of the results of this event see: https://services6.arcgis.com/W64mB6dmtwaeRAEQ/arcgis/rest/services/service_34fc49aa8796486dbbd8c6d63412037e/FeatureServer/0/57/attachments/67. Additionally, Kay Rufty (610.W/GST) supported Andy Henry (Wayne RESA) at the STEM Maker Summit held at the Henry Ford Museum's Lovett Hall April 15.

Puerto Rico Fliers

On April 26, Dorian Janney (612/ADNET) gave three presentations on the science, technology, and applications of the GPM mission to 568 middle school students and 16 staff members as the keynote speaker for the Chesapeake Math and IT Academy STEM Day.

Dorian Janney (612/ADNET) gave three presentations, and staffed a table, which featured hands-on activities and demonstrations to share how the GPM is able to measure precipitation from space, as well as used the GLOBE Observer Mosquito

Habitat Mapper to show an example of areal-world application for GPM data during Rockville Science Day on April 28.

Alexei Lyapustin (613) visited Yonsei University, Seoul, Korea, by invitation of Prof. Jhoon Kim, and gave an Atmospheric Meteorology Department seminar entitled "High-resolution Aerosol Retrievals with Algorithm MAIAC from Polar Orbiting and Geostationary Satellites" on April 30, and a keynote presentation with the same title at the opening ceremony of the Korean Meteorological Society, Atmospheric Physics Division on May 2.

On May 1, 80 students from the Incheon Science High School located in Incheon, South Korea visited Goddard. Daeho Jin (613/USRA), Jeewoo Park (672/USRA), and Yuni Lee (699/UMBC) gave presentations introducing the students to science and a scientist's life at NASA.

Dorian Janney (612/ADNET) presented a Clay Elementary School GPM STEM Engagement webinar on May 2 to 91 fourth grade students and their five teachers about the science, technology, engineering, and real-world applications of the GPM mission.

Brian Campbell (610W/GST), Valerie Casasanto (610/UMBC), Sabrina Delgado Arias (618/SSAI), John Cavanaugh (592), Adriana Manrique (615/USRA) and James Demacek (360) attended the 2019 Awesome Con event at the Washington D.C. Convention Center April 26-28. They represented NASA and the ICESat-2 Mission at the NASA Goddard Space Flight Center's exhibit as part of the "Future Con" section of the event, demonstrating the NASA ICESat-2 Augmented Reality (AR) Sandbox and demonstrating the science of taking elevation measurements as the ICESat-2 satellite does from space.

Brian Campbell (610W/GST) planned and implemented the eighth NASA Trees Around the GLOBE Student Research Campaign webinar to thirty-one participants from six countries, on May 7. During the webinar, a student from Mahopac High School in Mahopac, New York presented her research on tree heights, wetlands, and invasive species. Researchers from the Cornell Cooperative Extension at Cornell University, Invasives Strike Force, Lower Hudson Partnership for Regional Invasive Species Management, and the New York State Department of Environmental Conservation Trees for Tribs Program have been working with Mahopac High School students and teachers, and the GLOBE Program, to understand these impacts on trees and potentially eradicate these invasive species.

On May 8, Dorian Janney (612/ADNET) organized and presented during the GLOBE Mission Mosquito Education webinar, with a focus on prevention and protection during active mosquito season. The guest speaker was Brian Prendergast, the supervisor of mosquito control for the state of Maryland. https://youtu.be/UfLmTf9z13s.

Dorian Janney (612/ADNET) ran a table for the DOD and special invitees' program on May 10 at the 2019 Joint Base Andrews Air Force Show. At her table, she shared information about the science, technology, and real-world application for the Global Precipitation Measurement (GPM) mission as well as showed participants how to download and use the GLOBE Observer Mosquito Habitat Mapper. There were thousands of participants across all age levels who came to this event, and several hundred who visited the NASA tables.

On May 13, Brian Campbell (610W/GST) gave a virtual presentation to GLOBE students in Nienderuzwil, Switzerland focusing on the Trees Around the GLOBE Student Research Campaign. There were 22 students and one educator participating in the virtual presentation. Brian also gave five short presentations as part of the Career Day events at the Westside Intermediate School in Hebron, Maryland where he discussed his job in NASA Earth Science Outreach by highlighting several missions, including ICESat-2, SMAP, and GPM and also featured the GLOBE Program and the NASA GLOBE Observer Citizen Science effort he works on.

On May 14, Brian Campbell (610W/GST) planned and implemented the ninth NASA Trees Around the GLOBE Student Research Campaign webinar to 123 participants (36 educators and 87 students) from eight countries (United States (including Puerto Rico), Peru, Croatia, Switzerland, Brazil, Argentina, Poland, and Trinidad and Tobago). The students have been monitoring the beginning and ending of the growing season of trees helps scientists track plant growing seasons, through a Swiss GLOBE program called PhenoCam, a way to use automated cameras to take images of trees and create time-lapse videos and run color analysis of the trees over time.

Brian Campbell (610W/GST) gave five hour-long student workshops at the Annapolis Middle School in Annapolis, Maryland, entitled, "NASA Trees: Student Research and Space-Based Observations" on May 15.

Dorian Janney (612/ADNET) met virtually with students, a scientist, and a teacher from the Princess Chulabhorn Science High School in Trang, Thailand on May 31 to discuss their GLOBE IVSS science investigation entitled "Study of mosquito species and their number in a touristic place in Pak Meng beach, Trang".

Dorian Janney (612/ADNET) 6/3/19. Dorian met virtually with students and their teacher from Shumate Middle School in Gibraltar, Michigan to discuss their GLOBE IVSS science investigation entitled "What are the humidity, precipitation, and temperature conditions associated with active mosquito season?"

Dorian Janney (612/ADNET) 6/5/19. Dorian organized and presented during the GLOBE Mission Mosquito Education webinar that focused on the 2019 GLOBE IVSS projects, https://www.globe.gov/web/mission-mosquito/overview/webinars/archived-webinars.

Dorian Janney (612/ADNET) 6/6/19. Dorian gave a STEM Engagement presentation and shared the science, technology, and real-world applications of the GPM mission to 68 high school students and seven teachers the CMIT North Academy Public Charter High School in Laurel, Maryland.

On June 6, Dorian Janney (612/ADNET) gave two presentations and provided hands-on activities during the first NASA-USO "STEAM" event at Fort Meade, Maryland. She shared the science, technology, and real-world applications of GPM, as well as showed participants how to use the GLOBE Observer app to collect environmental data.

Dorian Janney (612/ADNET) 6/6/19. Dorian gave a STEM Engagement presentation and shared the science, technology, and real-world applications of the GPM mission to 327 3rd through 5th grade students and teachers the CMIT North Academy Public Charter Elementary School.

The NASA Applied Remote Sensing Training (ARSET) program conducted a three-session advanced webinar series entitled, "High Resolution NO_2 Monitoring from Space with TROPOMI." Preliminary estimates indicate there were 553 participants representing over 400 organizations and 76 countries. This course was organized and instructed by Pawan Gupta (MSFC/USRA) and Melanie Follette-Cook (614/MSU) and supported by Brock Blevins (614/UMBC), Elizabeth Hook (613/SSAI), and Selwyn Hudson-Odoi (614/UMBC). In this advanced webinar, attendees learned about current applications using OMI NO_2 data, and how to access and analyze OMI and TROPOMI data. The ARSET program is managed by Ana Prados (614/UMBC).

Andrea Portier (612/SSAI) gave a STEM engagement presentation and shared the science, technology, and real-world applications of the GPM mission to 40 fourth graders and two teachers at the William Hall Academy in Capital Heights, Maryland on June 4.

On June 12, Brian Campbell (610W/GST) planned and implemented the tenth Trees Around the GLOBE Student Research Campaign webinar. David Shelley, Center Director, of Congaree National Park in South Carolina, discussed research in the largest intact remnant of southern old growth bottomland (flood plain) forest remaining in North America and highlighted some key findings, unanswered questions, and park management challenges—as well as a few personal lessons from the forest.

Santiago Gassó (613/UMD) returned from a five-week trip onboard the German research vessel and icebreaker Polarstern. He was invited by the Alfred Wegener Institute (AWI) to participate as a remote sensing instructor overseeing a group of 23 college students selected among 800 applicants from all over the world. The South to North Atlantic Transect (SoNoAT) cruise departed from the Falklands Islands (52 S) in the South Atlantic to its home port of Bremerhaven, Germany (54 N), from June 2nd to June 29th. The SoNoAT is a training cruise that brings together international participants through a collaboration between the AWI, AtlantOS, Partnership for Observation of the Global Ocean (POGO) and funded through the Nippon Foundation.

On July 6, Dorian Janney (612/ADNET) worked with students and adults with the Capitol Experience Lab in Washington, D.C. She told them about the Global Precipitation Measurement mission, shared information about how and why NASA Earth observing satellite data are used to predict, monitor, and respond to mosquito-transmitted disease and showed them how to use the GLOBE Observer Mosquito Habitat Mapper.

Left: Santiago Gassó (UMD-ESSIC); Right: Polarstern Research Vessel

Summer Interns 2019

The following 613 interns presented their work at the Summer Intern Poster Session, held in Bldg. 28, July 31 and August 1:

- Mikael Nida (Mentor: Tianle Yuan): "Predicting Hurricane Genesis and Evolution with Deep Learning"
- Morgan Adair (Mentor: Jie Gong): Method of extracting interannual variability and trends of stratospheric gravity waves from nearly two decades of Atmospheric Infrared Sounder (AIRS) and Microwave Limb Sounder (MLS) observations"
- Anaiya Reliford (Mentor: Yingxi Shi): "Cluster analysis of global aerosol properties from Aerosol Robotic Network (AERONET) Version 3 inversion products using both almucantar and hybrid retrievals"
- Erick Shepherd (Mentor: Robert Levy): "Consolidating the Dark Target Aerosol Retrieval System".
- Mackenzie James (Mentor: Dong Wu): "Delayed Darkening of the Sun: Identifying and Analyzing Events with Time Lag Between Change in Total Solar Irradiance and Sunspot Area"
- Diego Principe (Mentor: Dong Wu): "MODIS GOES 3D Winds Algorithm"
- Justin Germann (Mentor: Yuekui Yang): "Optimization of a Machine Learning Model for Antarctic Blowing Snow Identification

Brian Campbell (610W/GST) gave a virtual talk entitled, "Students, Teachers, Citizen Scientists, and NASA Observing the height of our Planet, One Tree at a Time with ICESat-2 and GLOBE" to educators were participating in the Endeavor STEM Teaching Certificate Project on July 8.

Dorian Janney (612/ADNET) worked with participants at the Native Youth Community Adaptation and Leadership (NYCALC) at the National Conservation Training Center in Shepherdstown, West Virginia, July 11. This included a GPM/GLOBE focused table during the career fair, and then three workshops focused on the GLOBE Observer app and tools.

The GLOBE Observer Team, including Holli Kohl (610/SSAI), Kristen Weaver (610/SSAI), Dorian Janney (612/ADNET), Helen Amos (610/SSAI), Brian Campbell (610W/GST), and Trena Ferrell (610) participated in the Annual GLOBE Conference in Detroit, Michigan with presentations, talks, and hands-on activities July 14-18. Additionally, they talked at the Michigan Science Center.

Geoff Bland (610.W) and Kay Rufty (610.W/GST) participated in the 23rd GLOBE Annual Meeting in Detroit Michigan July 14-18, 2019. David Bydlowslki (Wayne RESA), Andy Henry (Wayne RESA), James Moon-Dupree (Wayne RESA), Jeff Warren (Public Lab) and Mimi Spahn Sattler (Public Lab), also participated as members of the AEROKATS and ROVER Education Network (AREN/NNX16AB95A) team. The AREN team conducted two workshops to provide GLOBE educators with hands-on training and practice that will enable kite-based remote sensing and in-situ observations with students and other faculty at their home institutions. The team also provided a public kite building workshop at the NASA/GLOBE event held at the Michigan Science Center on July 17.

Left: Flying; Right: Flight

George J. Huffman (612) presented to about 200 students and staff at Mayflower Secondary School, "Turning Satellite Data into Global Precipitation Maps" July 29, Singapore.

On August 1, Alan Chen, a summer intern in 612 and a student at Montgomery Blair High School, presented "Modeling of Extreme Values in the IMERG Precipitation Dataset" in the Summer Intern Poster Session summarizing the work he did with mentors George J. Huffman (612) and Yaping Zhou (613/MSU), applying a previous extreme value analysis system to the Integrated Multi-satellitE Retrievals for GPM (IMERG) precipitation dataset.

Dorian Janney (612/ADNET) gave a virtual presentation to share information about the GLOBE Observer Mosquito Habitat Mapper tool, the GLOBE Mission Mosquito campaign, and to describe how and why NASA Earth observations are used to predict, monitor, and respond to mosquito-transmitted disease for 24 high school students and eight college professors in Uganda.

Dorian Janney (612/ADNET) organized and presented to participants from seven countries during the GLOBE Mission Mosquito Education webinar on August 7. The archived recording can be viewed here: https://youtu.be/fcgB-8m4CsM.

George J. Huffman (612) hosted a "shadow" visit by summer intern Sheyenne Harris (250/U. Mich.).

NASA ARSET recently completed an introductory online training: Earth Observations for Disaster Risk Assessment & Resilience. Each of the four sessions walked participants through the theory and applications of NASA data for all phases of disaster risk assessment (DRA). The webinar covered natural disasters including tropical cyclones, flooding, and heat stress. Guest presenters included colleagues from NASA's Socioeconomic Data and Applications Center (SEDAC), the New York State Department of Health, World Resources Institute (WRI), and the Pacific Disaster Center (PDC). Amita Mehta (UMBC/612) and Sean McCartney (SSAI/610) led the training. Elizabeth Hook (SSAI/613), Brock Blevins (SSAI/614), Selwyn Hudson-Odoi (UMBC/614), and Ana Prados (UMBC/614) supported the training. There were 948 individuals from 101 countries and 39 US states, and a total of 825 organizations that attended the training. Learn more about the training and access the materials at: https://arset.gsfc.nasa.gov/disasters/webinars/19-DRA.

NASA ARSET completed an advanced online training: SAR for land cover applications. The two sessions walked participants through the theory of SAR and principles of radar remote sensing related to flooding and agricultural applications. Participants used Google Earth Engine and SAR data for flood analysis and learned how to analyze SAR data for agricultural applications, including retrieval of soil moisture and identifying crop types. Guest presenters included colleagues from Agriculture and Agri-Food Canada. Erika Podest (JPL) led the training. Sean McCartney (610/SSAI), Elizabeth Hook (613/SSAI), Brock Blevins (614/SSAI), Selwyn Hudson-Odoi (614/UMBC), David Barbato (UMBC/JCET), and Ana Prados (614/UMBC) supported the training. There were 1,231 individuals from 102 countries, and roughly 950 organizations that attended the bilingual training in Spanish and English. Learn more about the training and access the materials at: https://arset.gsfc.nasa.gov/disasters/webinars/2019-SAR.

Trena Ferrell (610) held the second Earth Science EPO showcase on September 11, to display educational products that scientists and engineers can use for outreach events. There were about 40-50 people in attendance and the following colleagues participated: Brian Campbell (610/GST), Valerie Casasanto (615/UMBC), Kristen Weaver (612/SSAI), Helen Amos (610/SSAI), Ginger Butcher (618/SSAI), and Mike Taylor (618/SSAI).

On September 27, Dorian Janney (612/ADNET) led a group of MCPS educators and their families on a GLOBE Water Quality Stream Study as a part of The GLOBE Program's Intensive Observation Period, which focused on water quality. The 12 adult participants and two children completed and submitted both the integrated hydrology and the freshwater macro invertebrates protocols.

MCPS teachers completing a stream study using GLOBE hydrology protocols. Photo credit: D. Janney (ADNET/GSFC).

On October 1, 110 students from the Busan Science High School located in Busan, South Korea visited Goddard. Daeho Jin (613/USRA) and Jeewoo Park (672/UMBC) gave presentations introducing the students to science and the life of a scientist at NASA.

Dorian Janney (612/ADNET) was an invited presenter for the Neelsville Career Day at Neelsville Middle School in Germantown, Maryland, on October 4. She gave four presentations about the Global. Precipitation Measurement mission and potential career opportunities at NASA/GSFC. She worked with 106 middle school students and nine teachers.

Joanna Joiner (614) visited the University of Iowa on October 10, and gave an invited seminar on estimating global terrestrial gross primary production using satellite data.

Daeho Jin (USRA/613) gave presentations to approximately 160 students from Jeonbuk Science High School (Jeonbuk, South Korea) and the Hansung Science High School (Seoul, South Korea) introducing the students to science and the life of a scientist at NASA, October 7 and 10.

On October 8, Brian Campbell (610W/GST) planned and implemented the thirteenth webinar for the Trees Around the GLOBE Student Research Campaign. This webinar marked the first webinar for Year 2 of the campaign. Brian gave the feature presentation, entitled "Year 2 of the Campaign Begins: Discussion on Data Counts, Year 1 Data Champions, ICESat-2 Data, and What Lies Ahead." The campaign was attended by 54 participants (19 adults and three classrooms with a total of 35 students) from Bulgaria, Croatia, Pakistan, India, Switzerland, Czech Republic, and the United States, including Puerto Rico.

On October 8, Steve Platnick (610.8)gave an overview presentation on the Earth Observing System (EOS) to the Goddard Retirees and Alumni Association.

Robert Swap (614), Lena Shalaby (614/UMBC), Alexander Kotsakis (614/USRA), Mariel Friberg (614/USRA), Fernando dos Santos (CAPES/ESSIC), Michael Gray (614/SSAI) from the NASA Pandora Project provided a hands-on training with nearly two dozen faculty and students from multiple universities, on October 16-17 at the VCU Rice River Center. Members of the team hosted a question and answer session regarding data processing and QA/QC of Pandora data, discussions on proper data handling and instrument maintenance, as well as future research collaboration efforts at the VCU Rice River Center alongside other Virginia institutions. The common research interests between institutions include aiming to better understand the complexities of air quality issues along air-water interfaces within the Chesapeake Bay air shed/watershed and eventually be able to better quantify air quality variability as it relates to health outcomes in the region.

On October 18, Yingxi Shi (613/UMBC) was invited to visit the Wyngate Elementary School in Montgomery County to introduce the students to science and NASA. She showed videos of NASA's achievements in exploring the universe and viewing Earth from the International Space Station. Explaining that NASA explores space and the Earth with different types of light, she demonstrated the differences between visible and near infrared light. Dr. Shi finished her talk with a hands-on demonstration of cold/warm fronts mixing. The children were very engaged during the demonstrations and shared in the fun of doing science.

On November 2, Dorian Janney (612/ADNET) had a table at the Montgomery County Public Schools STEM FEST in Silver Spring, MD. She shared the new GPM IMERG "precipitation towers" activity with the ~ 1,000 students, parents, and other community members who attended this event.

Steve Platnick (610) gave a seminar on November 7 to the Atmospheric and Oceanic Science department at the University of Maryland College Park, entitled "The NASA MODIS/VIIRS cloud property continuity product: Early results and ongoing challenges". The talk summarized work to date done by the imager cloud product team at GSFC and U. Wisconsin. Platnick gave a similar talk on October 14 to students and faculty in departments affiliated with the Earth, Planetary and Space Sciences Institute at Michigan Technological University in Houghton, MI.

On October 23, Brian Campbell (610W/GST) gave a hands-on demonstration on the NASA GLOBE Observer Trees Tool and the ICESat-2 Mission at the 2019 Earth to Sky Academy for National Park Service Interpreters at the NASA Goddard Space Flight Center. Brian had participants use hand-held clinometers and the online Trees Tool to measure the height of trees and compare measurement observations.

On November 2, Dorian Janney (612/ADNET) had a table at the Montgomery County Public Schools STEM FEST in Silver Spring, MD. She shared the new GPM IMERG "precipitation towers" activity with the ~ 1,000 students, parents, and other community members who attended this event.

On November 7, Dorian Janney (612/ADNET) presented during the GLOBE Mission Mosquito webinar. This webinar focused on the impact of climate change on mosquito populations, and the keynote presenter was Dr. Russanne Low. There were 36 participants from all over the U.S. and from several other countries.

On November 21, Dorian Janney (612/ADNET) was an invited presenter for the Parkland Magnet Middle School's STEM Family Night. She shared information about the Global Precipitation Measurement mission and engaged participants in interacting with the last 20 years of IMERG data through a hands-on activity. There were over 125 parents and children in attendance during the program.

On November 27, Dorian Janney (612/ADNET) did a virtual tag up with teachers and students in Colombia who are engaged in an Astronomy Olympics STEM engagement competition. She presented on the Global Precipitation Measurement mission to explain how and why we measure precipitation from space, and also described how these data can be used to help predict, monitor and respond to vector-borne disease.

On December 3 and 4, Brian Campbell (610W/GST), Dorian Janney (612/ADNET), Christopher Shuman (615/UMBC), with Peder Nelson (Oregon State University) and Peter Falcon (JPL) planned and implemented the fifteenth and sixteenth webinars, respectively, for the Trees Around the GLOBE Student Research Campaign, including providing vital resources for the participants. These webinars were informal open forums for students and teachers to brainstorm ideas for student research projects aligned to the campaign. Eighty people (fifty-four educators and twenty-six students) from eleven countries (Argentina, Brazil, Croatia, Georgia, India, Italy, Kenya, Pakistan, Poland, Thailand, and the United States) came up with thirteen potential questions for student research.

7.3. 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 2019 among the various laboratories.

Table 7.3.1: Atmospheric Sciences Distinguished Lecture Series
Seminar series coordinators: Luke Oman

Date	Speaker	Title
August 15	Greg McFarquhar University of Oklahoma	Use of In-situ Cloud Microphysical Observations for Quantifying Ice Cloud Microphysical Properties and Processes, and their Uncertainties
September 19	Robert Pincus University of Colorado	What the past and the present can (and can't) tell us about the future?
October 17	Joseph Rice National Institute of Standards and Technology (NIST)	The NIST Primary Optical Watt Radiometer and its Connection to Total Solar Irradiance
November 14	Johannes Quaas University of Leipzig	Progress in quantifying the effective radiative forcing due to aerosol-cloud interactions
November 21	Bill Blackwell MIT Lincoln Laboratory	Clouds in a Changing Arctic
October 12	Larry Di Girolamo, University of Illinois at Urbana-Champaign	Perspectives on Terra data fusion for improved Earth science products and knowledge
October 29	Kerry H. Cook, University of Texas at Austin	Overview of the NASA TROPICS CubeSat Constellation Mission

Table 7.3.2: Mesoscale Atmospheric Processes Laboratory

Date	Speaker	Title
May 28	Hui Chistophersen NOAA Hurricane Research Division	Assessment of Data Impacts on TC prediction in an OSE and OSSE
September 13	George Duffy Vanderbilt University	An empirical retrieval of mass weighted mean diameter from dual-frequency radar Ku/Ka-band observations, derived from measured snow clouds in three GPM GV experiments
September 27	Prof. Steven Rutledge Colorado State University	Polarimetric observations of tropical convection with the new CSU SEA-POL ship-based radar system

Table 7.3.3: Climate and Radiation

Seminar series coordinators: 2019 Seminar Series Coordinators: Yuekui Yang (613) and Jae N. Lee (UMBC)

Date	Speaker	Title
February 27	Dong L. Wu Code 613, Climate & Radiation Laboratory	A GEO-MEO Constellation for future Earth Radiation Balance (ERB) Observations
March 6	Peter Norris Code 610.1, USRA/GMAO	Issues of radiative transfer implementation and validation in GEOS-5: naive clear-sky definitions, RRTMGP, and the advent of Object-Oriented Fortran
March 20	Ann M. Fridlind Code 611, Goddard Institute for Space Studies	Supercooled water clouds at polar latitudes
April 2	Yongzhen Fan Nan Chen Knut Stamnes Stevens Institute of Technology	Ocean Color Products Retrieved from DSCOVR/EPIC Mission
April 5	YangYang Xu Department of Atmospheric Sciences Texas A&M University	Climate Extremes and Aerosols: Attribution of the Past and Compound Impact in the Future
April 17	Jennifer C. Wei 6ode Code 610.2, Goddard Earth Sciences (GES) Data and Information Services Center (DISC)	From Goddard DAAC to GES DISC - How can data science help you?
May 1	Xianglei Huang Department of Climate & Space Sciences & Engineering University of Michigan	Spectrum: An underutilized dimension in climate observations, diagnostics, and modeling

Date	Speaker	Title
May 15	Masanori Saito Department of Atmospheric Sciences Texas A&M University	Remote Sensing of Clouds Using Combined Active and Passive Sensor Measurements
May 22	Manisha Ganeshan Code 613, USRA	Investigating the representation of Antarctic surface stability and Antarctic Polar Low in the NASA GEOS model framework
June 19	Patrick C. Taylor Langley Research Center	The Local and Remote Mechanisms of Arctic Amplification: Friend or Foe?
June 26	Ukkyo Jeong Code 613, UMD-ESSIC	The Spectral Measurements for Atmospheric Radiative Transfer (SMART) units: Strategically deployable ground-based network for surface irradiances, trace gases, and aerosols
October 2	Ian S. Adams Code 612, Mesoscale Atmospheric Processes Laboratory	Three-dimensional microwave radiative transfer for modeling sensor observations of clouds and precipitation
October 16	Galina Wind Code 613, Science Systems & Applications, Inc.	The MARA System and Its Applications
November 6	William H. Swartz Johns Hopkins University Applied Physics Laboratory	Measuring Earth's Energy Budget from a CubeSat
December 4	Tianle Yuan Code 613, UMBC-JCET	Combining Experts and Deep Learning to Obtain Insights from NASA Data
December 18	W. Greg Blumberg Code 613, NPP	Investigations into Planetary Boundary Layer (PBL) Changes During the Afternoon-to-Evening Transition—Local and Non-Local Processes

7.3.1. 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 7.3.1.1: Manic Talks

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

Date	Speaker	Title
March 27	Mark Clampin Director, Sciences and Exploration Directorate	From Sea to Space: A Journey through Astrophysics, Instrumentation and Leadership
April 17	Nicholas E. White Sr. Vice President for Science Universities Space Research Association	What do you want to be when you grow up?
April 30	Edward Rogers Chief Knowledge Officer, GSFC	Anything Can Be a Game
May 14	H. Jay Zwally Senior Research Scientist University of Maryland/ESSIC	The Scientist (Space Physics to Polar Glaciology/ Climate)
May 22	Jennifer Wiseman Senior Project Scientist Hubble Space Telescope	The Big Picture of an Awesome Universe
June 26	Stephen Jurczyk NASA Associate Administrator	From HALOE to Headquarters: How did I ever end up here?
July 24	Lucy McFadden Emerita, Planetary Systems Laboratory, GSFC	In the Name of Science: Some wild and crazy stories and concurrent advances in planetary science
September 25	Stamatios (Tom) Krimigis Emeritus Head of the Space Exploration Sector Johns Hopkins Applied Physics Laboratory	Flying an Instrument to Every Planet, ad hoc: How to Get Lucky
November 20	Dixon M. Butler Founder/President YLACES	The Making of a Science Bureaucrat with Vision and Leadership
December 2	Dorothy J. Zukor Emerita, Associate Director for Earth Sciences, GSFC	No, Does Not Mean Never, It Only Means Not Now

Table 7.3.1.2: Atmospheric Chemistry and Dynamics

Date	Speaker	Title
February 7	Omar Torres Code 61	Long-term effect of the 2017 British Columbia Pyro-Cb on the stratospheric aerosol load: a multi-sensor view
March 14	Julie Nicely NASA GSFC, Code 614, UMD & Glenn Wolfe NASA GSFC, Code 614, UMBC	Variations in Global Tropospheric OH Over the Last Several Decades & Mapping OH Throughout the Global Remote Troposphere
March 21	Tom Hanisco/Jin Liao	Airborne remote sensing of OH & Satellite—in situ hybrid estimate for organic aerosol abundance
April 4	Natasha Dacic/Sarah Strode	Surface ozone: evaluation of the GEOS-CF and changes in the diurnal cycle
April 11	Bryan Duncan/Anne Thompson & Ryan Stauffer/ Debra Kollonige	Satellite Coastal & Oceanic Air Pollution Experiment (SCOAPE)
May 2	Geronimo Villanueva (Code 693)	Planetary Spectrum Generator (PSG)
May 9	Dr. Pu Lin (GFDL)	Simulating climate responses to ozone depletion: interpret the inter-model difference
May 16	Jason St. Clair/Reem Hannun	Formaldehyde Sources in the Remote Upper Typing CO_2 and CH_4 Flux to Land Type: Insights from Covariance Measurements
June 20	Natasha Dacic/Joe Robinson	Reflecting on our time as pre-early career scientists at GSFC and what lies ahead: MANIAC Edition
July 18	Valentina Aquila	Pinatubo in the GOES S2S forecast system: impacts on ENSO
July 25	Anne Thompson/Ryan Stauffer	First Results from the NASA-BOEM SCOAPE (Satellite Coastal Oceanic & Atmospheric Pollution Experiment) Cruise in the Gulf of Mexico, May 2019
August 15	Emma Knowland (USRA)	Overview of the new GEOS Composition Forecast (GOES-CF) system
September 12	Glenn Wolfe	Gossip and Observations from the Aura Science Team Meeting
September 19	Jianping Mao	The Goddard CO_2 Laser Sounder: 2017 Alaska Airborne Demonstration and the Future of CO_2 Remote Sensing from Space
September 26	Dan Anderson (USRA)	Ozone, NOx, Formaldehyde, Air Quality, Biomass Burning, etc.
October 3	Fabrizio Sassi (NRL)	The importance of day-to-day weather for predictions in the upper atmosphere: dynamical variability and coupling with the ionosphere

Date	Speaker	Title
October 10	Mark Schoeberl	Aura Mission
October 17	Ruth Liberman Code 675	The role of inertial instability for interhemispheric coupling
October 31	Jim Irons	Lab Visits by Code 610 Management—Guidance
November 7	Anne Thompson/Ryan Stauffer	SHADOZ at 20 Years: What's Hot? What's Not?
November 14	Bryan Duncan	Changes in the Artic Boreal System (CABS) Working Group Recommendations
November 21	Hiren Jethva	Connecting Crop Productivity, Residue Fires, and Air Quality over Northern India
December 5	SPECIES Group	SPECIES Group AGU practice

7.3.2. AeroCenter Seminars

Aerosol research is one of the nine cross-cutting themes of the Earth Sciences Division at NASA's Goddard Space Flight Center. AeroCenter is an interdisciplinary union of researchers at NASA Goddard and other organizations in the Washington, D.C. metropolitan area (including NOAA, University of Maryland, 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; and the atmospheric correction of aerosol blurring of satellite imagery of the ground. Our regular activities include strong collaborations among aerosol community, informal weekly AeroCenter Forum (seminars, discussions, posters, and paper reviews), and annual aerosol research update. More information on AeroCenter activities can be found at https://aerocenter.gsfc.nasa.gov/.

Table 7.3.2.1: Manic Talks
Seminar series coordinators: David Giles, Jasper Lewis, Ed Nowottnick, and Yingxi Shi

Date	Speaker	Title
February 19	Weidong Yang Code 613, USRA	Cloud properties at the edge of clouds; comparison between land and ocean
March 5	Hiren Jethva Code 614, USRA	Crop Production-Residue Fires-Air Quality over Northern India: An Intriguing Connection Inferred from A-train Satellites and Ground Observations
April 2	Alfonso Delgado-Bonal Code 613	Changes in climatic complexity in the last four decades using MERRA-2 radiation data.

Date	Speaker	Title
April 16	Zhanqing Li UMD	New Approaches in Estimating Surface Air Pollution Indices by Remote Sensing and Understanding Aerosol-PBL Interactions
April 30	Adriana Rocha Lima	Recent Variability of Middle Eastern Dust AOT in Observations and Models
May 7	Alexander Sinyuk	AERONET Version 3 Inversion Update
June 4	Andy Sayer Code 616, GESTAR	How should we aggregate aerosol optical depth data?
June 11	Kerstin Schepanski Leibniz Institute for Tropospheric Research (TROPOS)	Insights into desert dust sources, emission processes and impacts on remote sensing of airborne mineral dust
September 13	Xiquan Dong University of Arizona	Remote Sensing of Low-level and Convective MCS Clouds and Precipitation
September 23	Michael Fromm and Geroge P. Kablick III Naval Research Laboratory	Sulfate Rising: Observational Analysis of Dramatic Diabatic Lofting of the Raikoke Volcanic Cloud
October 1	Rajesh Poudyal	A new data Interface and visualization tool for the Cloud Absorption Radiometer (CAR)
October 3	Benoit Tournadre Mines Paris Tech french school Observation, Impacts, Energy (O.I.E.)	Heliosat-V : a versatile method for estimating downwelling surface solar irradiance with satellite imagery
October 15	Xiaohua Pan Code 614	Six Global Biomass Burning Emission Datasets
October 21	Yoav Schechner Technion in Israel	Scattering as Key to Three dimensional Tomography: from Medical Imaging to Spaceborne Atmospheric Sensing
November 5	Harsh Harshvardhan Purdue University	Severe Arabian Dust Outbreaks as Viewed from Space, the Surface, and as Simulated by Models
December 3	Mian Chin Code 613	Aerosol composition in the UTLS and its connections to the anthropogenic and natural emissions and the Asian summer monsoon convective system

7.3.3. Cloud Precipitation Center

NASA GSFC Cloud-Precipitation Center (CPC), established in 2016, is a cross-laboratory union for cloud-precipitation researchers mainly at NASA GSFC. CPC offers discussions and collaborations across NASA laboratories through interactive seminar series on every other Tuesday at 11am. CPC maintains a member mailing list for seminar announcement, publications, and conference information. Main seminar topics include i) cloud-precipitation processes and interactions with surface process, aerosols, mesoscale dynamics, and large-scale circulations, ii) remote sensing, radiative transfer, and scattering theory of cloud and precipitation particles, iii) cloud microphysics and convection measurements and parameterizations, and iv) satellite missions and field campaigns associated with cloud and precipitation processes. In the 2019 season CPC hosted 7 seminars, and the current CPC member list holds 80 members.

Table 7.3.3.1: Climate and Radiation

Seminar series coordinators: 2019 Seminar Series Coordinators: Yuekui Yang (613) and Jae N. Lee (UMBC)

Date	Speaker	Title
April 23	Liang Liou (NASA GSFC/ MSU)	GPM DPR Retrieval Algorithm, Evaluation and Validation
September 10	Toshi Matsui Code 612, ESSIC UMD	Toward establishing Semi-Permanent Supersite for Cloud Convection and Precipitating processes at Wallops Flight Facility
September 24	Dan Miller Code 613, USRA	Passive shortwave remote sensing of cloud microphysics: lessons from simulators, observations, and new approaches to remote sensing problems
October 8	Chris Kidd Code 612, ESSIC, UMD	Precipitation retrievals: from cross-track sensors to what do we observe?
October 22	Yoav Schechner Technion in Israel	Scattering as Key to Three dimensional Tomography: from Medical Imaging to Space-borne Atmospheric Sensing
November 7	Mikael Witte JPL	Variability of low clouds and drizzle: a tale of two frameworks
November 12	Lauren Zamora Code 613, MSU	Tropical North Atlantic dust decreases the prevalence of deep convective clouds
November 18	Linda Forster JPL	Challenges in passive remote sensing of cloud properties: From remote sensing of ice crystal properties to 3D tomographic cloud reconstruction

7.4. Public Outreach

Science plays and important role in peoples' lives and has a significant (and increasing) impact on humans and the environment. In order to improve links between science and society, Code 610AT scientists donate time to public outreach activities to communicate the importance and benefits of NASA's Earth science research through engagement with local, regional, and national organizations and institutions. Target audiences may include policy makers, resource managers, teachers, students, citizens, and particular professional groups. Outreach activities may include public lectures, field trips for students or adults, community or professional training or education workshops, and service on boards or committees. The following sections summarize many such activities.

7.4.1. Earth Observatory

The Earth Observatory website team is housed in Code 613 and works with scientists and outreach partners from across the agency and other affiliated organizations to publish thousands of images and hundreds of articles about NASA's Earth science and climate change research. Images from the Earth Observatory regularly appear in the mass media, popular science magazines, textbooks, and blogs. The idea for the Earth Observatory was hatched in 1998 as a virtual observatory, where anyone on the internet could see what NASA satellites were seeing and learn what NASA scientists were learning from EOS missions. Over the past 20 years, the Earth Observatory has become a fixture of NASA Earth science outreach and has garnered a dedicated community of subscribers and repeat readers.

In 2019, the Earth Observatory group continued to routinely research, write, produce imagery, and publish its Image of the Day (IOTD) product for every single day of the year. The IOTD series is the only communications product within the Earth Science Division that is published on a daily basis (including weekends) and is regularly featured not only through NASA flagship social media accounts but also by numerous popular media outlets. 2019 marked the 20th anniversary of the launch of the website. The Earth Observatory team celebrated this landmark with a series of blog posts, IOTDs, and a look-back section of the site dedicated to unique IOTDs from previous years: https://earthobservatory.nasa.gov/on-this-day. Also in 2019:

- EO staff participated in the publication of a book and corresponding online photo-essay called Earth. https://earthobservatory.nasa.gov/features/earth-book-2019. The book was produced in collaboration with the NASA Applied Sciences Program.

- EO website was visited by the most visitors ever recorded for a single month. This was due to the viral nature of stories surrounding fires in the Brazilian Amazon forest in August 2019.

- The EO team continued to maintain their archive of nearly 16,000 stories and articles.

For additional information please contact Kevin Ward (kevin.a.ward@nasa.gov, 503-246-1608).

7.4.2. Activities

On January 21, Dorian Janney (612/ADNET) wrote a blog for the GLOBE Program website that focused on using the GLOBE Observer Mosquito Habitat Mapper even when mosquitoes are not active: http://www.globe.gov/web/dorian.w.janney/home/blog/-/blogs/51779107.

On February 6, Stephanie Schollaert Uz (610) and Bryan Duncan (614) presented on the Hyperwall to 15 senior military leaders as part of the Defense Advanced Research Projects Agency (DARPA) Service Chiefs' Fellowship Program. They gave an overview of NASA Earth Sciences and Applied Sciences activities at Goddard, highlighting how NASA data are used to support decisions around water and food security, air quality, hazards to aviation, and vector borne diseases. They also described new and upcoming missions and how the Decadal Survey guides this process.

Brian Campbell (610W/GST) and Geoff Bland (610W) presented a workshop at the 2019 Maryland Association for Environmental and Outdoor Education (MAEOE) Conference in Towson, Maryland, on February 8. The hands-on workshop was entitled, "NASA's Advancing Earth Research Observations with Kites and Atmospheric/Terrestrial Sensors (AEROKATS) Program. An Introduction for Citizen Scientists." Brian presented on the ICESat-2 Mission and the current Trees Around the GLOBE Student Research Campaign and Geoff presented on the AREN project and remote sensing at NASA.

Dorian Janney (612/ADNET) organized and led the GPM 5th Anniversary Sunday Experiment at the GSFC Visitor's Center on February 17. She and Jessica Merzdorf (130/Telophase) shared information about GPM's five Top Achievements in Scientific Research, Engineering, and Applications.

Scott Braun (612) gave two presentations on the use of TRMM/GPM data to better understand and respond to tropical cyclones. Jacob Reed (612/Telophase) shared 3D printed and LEGO models depicting GPM data taken during various storms and showed the data animations. Trena Ferrell (610) assisted with a hands-on activity that enabled participants to create 3D models of average precipitation. Helen Amos (610/SSAI) assisted with a hands-on activity to engage participants to interact with and better understand the water cycle. Over 200 participants attended this event. https://pmm.nasa.gov/education/current-activities/The-GPM-Sunday-Experiment

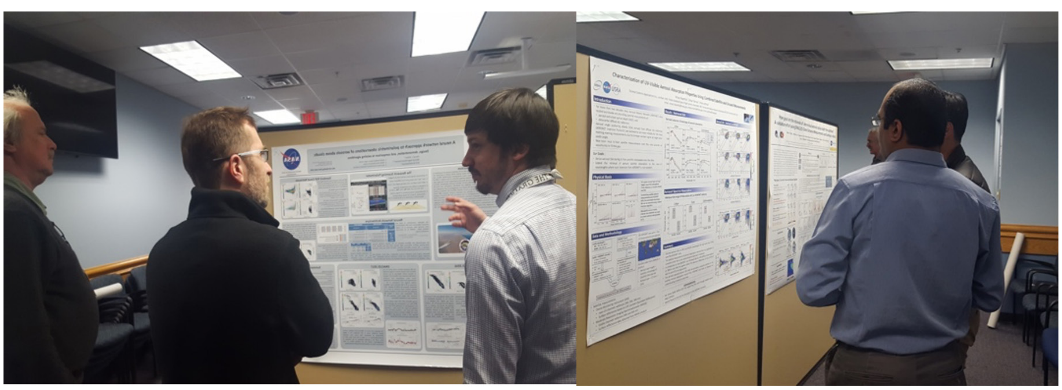
The GPM outreach team coordinated a week of new outreach product releases to celebrate the 5th anniversary of the launch of the GPM Core Observatory. This campaign was managed by GPM web developer Jacob Reed (617/Telophase). Each day of the week a new outreach product was released online and promoted on social media (@NASARain) to highlight a different aspect of the GPM mission. Social media posting was handled by Jacob Reed and Joy Ng (130/USRA).

Dorian Janney (612/ADNET) organized and presented during the March Education GLOBE Mission Mosquito webinar on March 13. This webinar focused on sharing ways in which both educators and citizen scientists can prepare for the upcoming mosquito season and describing how participants could collect environmental data to assist them in predicting the start of active mosquito season. There were 58 participants from all across the United States as well as from 14 countries around the world. http://bit.ly/2FiY4yn.

On March 31, Dorian Janney (612/ADNET) wrote a blog for the GLOBE Program entitled "GLOBE 'Mission Mosquito' Spotlight on New Jersey". Brian Campbell (610W/GST) and Tom Neumann (615) were quoted in a recent press release about the new NASA GLOBE Observer App Trees Tool, a tool that allows citizen scientists to measure tree heights with just their mobile device. The press release, entitled "Help NASA Measure Trees with Your Smartphone" was published on March 26 at https://www.nasa.gov/feature/goddard/2019/help-nasa-measure-trees-with-new-app and discusses the ground-based tree height measurements and their relevance to several NASA Missions likeICESat-2 and GEDI. Brian is the Trees science lead and Tom is the ICESat Project Scientist.

On March 27, Dorian Janney (612/ADNET) presented on the formal education outreach efforts being undertaken during the GLOBE "Mission Mosquito" campaign for the Citizen Science focused webinar which was organized and led by Russanne Low. There were 27 participants from three countries around the world who attended this webinar.

The Annual AeroCenter Poster Bash, organized by David Giles (618/SSAI), Yingxi Shi (613/USRA), Ed Nowottnick (614/USRA) and Jasper Lewis (612/UMBC) was held on March 19th. Scientists and students from GSFC and surrounding universities came together to present their most current work.



AeroCenter Poster Bash, March 19

On March 29, Dorian Janney (612/ADNET) presented on the GLOBE Observer Mosquito Habitat Mapper tool, the GLOBE Mission Mosquito campaign, and the ways that NASA EOS data is being used to predict, monitor, and respond to mosquito-transmitted disease to the 22 foreign nationals who are involved in the Department of State's International Visitor's Leadership Program as well as eight other professionals from the DOS, NASA HQ, and the CRDF Global organization which hosted this event.

International Visitor Leadership Program participants (photo credit: D. Janney)

A new Precipitation Measurement Missions (PMM) story was written by Stephen Lang(612/SSAI), and published and promoted by Jacob Reed (617/Telophase) on the PMM web site, and shared on @NASARain social media: "TMPA Shows El Niño Conditions in the Pacific"(https://pmm.nasa.gov/articles/tmpa-shows-el-nino-conditions-pacific). It was republished on www.nasa.gov (https://www.nasa.gov/feature/goddard/2019/nasa-sees-el-nino-conditions-incentral-pacific/) and shared by the popular @NASAhurricane and @NASAGoddard Twitter accounts.

On April 11, Brian Campbell (610W/GST) gave a virtual talk to the NASA Solar System Ambassadors (SSA) Program. The presentation, entitled, "NASA Trees: Citizen Science, Student Research, and Space-Based Observations" was given to thirty-eight Solar System Ambassadors from around the United States. The Solar System Ambassadors program works with motivated volunteers across the nation to share the latest science and discoveries of NASA's missions through a variety of events that inspire their communities. The Ambassadors will be sharing the Trees information in their regions and bringing more participants into the various NASA Trees programs Brian discussed. On April 17, Dorian Janney (612/ADNET) wrote and distributed the April GLOBE Mission Mosquito newsletter. https://www.globe.gov/web/mission-mosquito/overview/newsletters.

AIRS/GISTEMP paper by Joel Susskind (610) et al. and co-authored by Gavin Schmidt (611), was published and received news release from publisher as well as articles from various news media: Release:

- https://phys.org/news/2019-04-nasa-global-trends.html.
- *Newsweek:* http://www.newsweek.com/nasa-global-warming-climate-change-trendsgavin-schmidt-1397740.
- *US News:* https://www.usnews.com/news/national-news/articles/2019-04-16/nasa-studyconfirms-global-warming-trendso
- *Washington Post:* https://www.washingtonpost.com/climateenvironment/2019/04/17/satellite-confirms-key-nasa-temperature-data-planet-is-warmingfast/?utm_term=.262321c53c47

On April 22-23, Dorian Janney (612/ADNET) organized and staffed the GPM table at NASA's "Earth Day" event at Union Station. Andrea Portier (612/SSAI) and Jacob Reed (612/Telophase) also staffed the table during the two-day event. They used hands-on activities, demonstrations, and virtual reality to engage participants in the science, technology, and applications of the GPM mission.

On April 27, Dorian Janney (612/ADNET) gave a presentation at the Holland Point Civic Association on the ways in which NASA EOS data are used to predict, monitor, and respond to water-related and vector-borne disease and shared information about how to use the GLOBE Observer Mosquito Habitat Mapper. On April 28, she staffed a table featuring hands-on activities and demonstrations, and presented how the GPM is able to measure precipitation from space, and used the GLOBE Observer Mosquito Habitat Mapper to show an example of a real-world application for GPM data.

Dorian Janney (612/ADNET) gave a presentation on the ways in which NASA EOS data are used to predict, monitor, and respond to water-related and vector-borne disease and shared information about how to use the GLOBE Observer Mosquito Habitat Mapper at Holland Point Civic Association on April 27.

NASA ARSET completed an intermediate online training: *Remote Sensing for Disasters Scenarios*, delivered in English and Spanish. Each of the three sessions walked participants through the relevance of NASA data for all phases of a disaster: before, during, and after. The disasters scenarios covered were tropical storms, flooding, landslides, and earthquakes. By the end of the training, attendees were able to identify and access NASA data products to characterize and monitor disasters. This training was led by Erika Podest (JPL). It was supported by Sean McCartney (610/SSAI), Elizabeth Hook (613/SSAI), Brock Blevins (614/SSAI), Selwyn Hudson-Odoi (614/UMBC), and Ana Prados (614/UMBC). There were 1,086 individuals from 87countries and more than 850 organizations. Learn more about the training and access the materials at: https://arset.gsfc.nasa.gov/disasters/webinars/disasters-scenario-2019

Dorian Janney (612/ADNET) gave a large group presentation to share information about the Global Precipitation Measurement's 5 year anniversary and achievements since launch at the Odyssey of the Mind World Finals, May 22-24, Lansing, Michigan. Scott Braun (612) gave a presentation entitled "Hurricane Hunting NASA Style: Using Space-Based and Airborne Measurements to Better Understand and Predict Hurricanes" at the Library of Congress's Earth and Space Science Talks series June 13, at the Pickford Theater.

On June 11, Dorian Janney (612/ADNET) organized and interacted with a group of 40 adults who belong to the Potomac Valley Ski Club on a guided tour and presentations which focused on the GPM mission.

The NASA Earth Science Office of Communications launched an online outreach campaign on how NASA studies Earth's freshwater resources. The campaign began on 10 June with two featured articles published on www.nasa.gov: "NASA Explores Our Changing World" (https://www.nasa.gov/feature/goddard/2019/nasa-investigates-our-changing-water-world) and "Earth's Freshwater Future: Extremes of Flood and Drought" (https://www.nasa.gov/feature/goddard/2019/earth-s-freshwater-future-extremes-of-flood-anddrought/). The first article included mention of GPM's contributions to freshwater monitoring, including a visualization of global freshwater anomalies using GPM and SMAP data. GPM team members Dorian Janney (612/Adnet) and Jacob Reed (617/Telophase) were involved in the planning of the outreach campaign, and the articles were shared on the @NASARain social media accounts.

The Earth Observatory Group (613/SSAI) Image of the Day for July 8, featured research by Goddard atmospheric scientist Tianle Yuan (613/UMBC) et al., who are using machine learning to automate the detection of ship tracks. "Finding Hidden Ship Tracks" https://earthobservatory.nasa.gov/images/145256/finding-hidden-ship-tracks. Paul A. Newman (610) attended the Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer in Bangkok, Thailand, July 1-5. Dr. Newman is one of the four Scientific Assessment Panel (SAP) co-chairs to the Montreal Protocol. At this meeting, the co-chairs gave two presentations. The first concerned the overall science findings on the unexpected increase of emissions of the banned substance chlorofluorocarbon-11 (CFC-11). CFC-11 is a powerful ozone depleted and greenhouse gas. The second presentation was open science topics that should become the terms of reference for the 2022 quadrennial assessment of stratospheric ozone depletion. http://enb.iisd.org/ozone/oewg41.

The following Code 612 lab members participated in the GSFC Science Jamboree held on Thursday, July 11: Mircea Grecu (612/MSU), Mei Han (612/MSU), Andrea Portier (612/SSAI), Toshi Matsui (612/UMD), and Joe Munchak (612).

Dorian Janney (612/ADNET) had multiple science outreach activities in July including a virtual presentation about the Apollo missions for several audiences in Taiwan as part of a larger Apollo 50th anniversary event, presenting a poster "GPM: Celebrating 5 Years of Success!" and demonstrating the GLOBE Observer Mosquito Habitat Mapper at the GLOBE Annual meeting in Detroit, Michigan, and by giving a short presentation about the GPM mission at the Michigan Science Center during the NASA Science Day event.

Santiago Gassó (613/UMD) was recently involved in several public outreach and media activities. He was interviewed by a Netflix production company to provide expertise on dust transport over the North Atlantic for an upcoming documentary. He was also interviewed by Australia's ABC World News after posting notable features of current wildfires in Siberia on Twitter. The published article was then reposted to several well-known media outlets including Forbes.com, UPI, and SmithsonianMag.com. He provided background material for an Earth Observatory article on the same subject prepared by Kasha Patel (613/SSAI). Additionally, he participated in a Wildfires Live Shot organized by the Goddard Office of Communications (130) and was interviewed in English and Spanish for several media outlets. Finally, he provided a live interview to a Seattle television station in which he talked about long-range transport smoke from northern Asia to the Pacific Northwest.

Santiago Gassó (613/UMD-ESSIC) was interviewed by Universo Online (UOL) (www.uol.com.br), one of the largest news portals in Brazil. He provided background information for an article about the current biomass burning in South America, which appears to be particularly active with several instances of poor air quality in major cities. The article is available at https://noticias.uol.com.br/meio-ambiente/ultimas-noticias/redacao/2019/08/20/queimadas-na-amazonia-provocam-corredor-de-fumaca-na-americado-sul.htm

On August 22, Brian Campbell (610W/GST) gave a lecture about the ICESat-2 satellite, yhe ATLAS instrument, laser altimetry, and photon-counting as part of the 2019 What's Up at Wallops Lecture series at the NASA Wallops Flight Facility Visitors Center. Forty-one public participants attended the lecture entitled, "The NASA ICESat-2 Mission: Laser from Space."

Brian Campbell (610W/GST) attended the 2019 California Urban Forests Council Conference in San Luis Obispo, California, September 26-28. During the conference, Brian presented the keynote to 200 urban foresters, arborists, sustainable lumber professionals, and university researchers. Brian's keynote, entitled "NASA Trees: Student Research, Citizen Science, and Space-Based Observations" focused on the ICESat-2 Mission, the Trees Around the GLOBE Student Research Campaign, and the NASA GLOBE Observer Trees Tool, culminating in training the participants how to use the NASA GLOBE Observer Trees Tool, with many taking observations.

On October 5, Dorian Janney (612/ADNET) participated in the "Girls in Aviation" event at the College Park Aviation Museum in College Park, Maryland. There were 38 girls and 28 adults who participated in this event. Dorian ran a table and gave hands-on demonstrations to share information about GPM and the GLOBE Observer Mosquito Habitat Mapper.

On October 5, Trena Ferrell (610) and Kristen Weaver (612/SSAI) supported International Observe the Moon Night at the Goddard Visitor Center with hands-on GLOBE activities for the public. There were about 434 people in attendance.

Kevin Ward and Adam Voiland (613/SSAI) visited the National Space Science Technology Center (MSFC) in Huntsville, Alabama. There they presented to various teams about the Earth Observatory website and how we work with science groups across the agency to craft stories, images, and visualizations about NASA Earth science research.

On October 17, George J. Huffman (612) participated in the GPM IMERG Live Shots campaign, providing Live Shot interviews for KOMO News Radio, Seattle; Indiana Environmental Reporter, Indianapolis; WVXU radio, Cincinnati; WIOD radio, Miami; KHPR radio, Honolulu.

On October 17, Joe Munchak (612) did TV interviews for KENS-5 in San Antonio, Spectrum News 13 in Orlando, FL, and Bay News 9 in St. Petersburg, FL. He also did radio interviews for News Radio 600 WMT in Cedar Rapids, Iowa, and WSLW in White Sulfur Springs, West Virginia.

On October 20, Dorian Janney (612/ADNET) organized and presented during the GSFC "Sunday Experiment", which was held at the Goddard Visitor Center. Kristen Weaver (612/SSAI), Trena Ferrell(610), George Huffman (612), Andrea Portier (612/SSAI), Lauren Antt (618/intern) and Dorian ran hands-on table activities. In addition, George Huffman presented "Why I Became a Meteorologist" and Andrea Portier presented on the applications for IMERG data. There were over 100 participants who attended this event, which focused on GPM's newly released IMERG product.

On October 29, the GPM Outreach Team worked with the Goddard Office of Communications to create and publish a social media story on Snapchat, Instagram and Tumblr highlighting the recent release of IMERG V06 and 19 years of global precipitation data. The stories were supported by posts from @NASARain. https://nasa.tumblr.com/post/188681919944/what-doestwo-decades-of-rain-and-snow-show-us.

On November 7, Dorian Janney (612/ADNET) presented during the GLOBE Mission Mosquito webinar. This webinar focused on the impact of climate change on mosquito populations, and the keynote presenter was Russanne Low. There were 36 participants from all over the U.S. and from several other countries.

On October 29, the GPM Outreach Team worked with the Goddard Office of Communications to create and publish a social media story on Snapchat, Instagram and Tumblr (https://nasa.tumblr.com/post/188681919944/what-does-two-decades-of-rain-and-snow-show-us) highlighting the recent release of IMERG V06 and 19 years of global precipitation data. The stories were supported by posts from @NASARain. The story reached 2,089,946 people on all platforms combined and was watched by 1,236,503 people on Instagram.

The GPM Outreach team hosted an exhibit booth at the 2019 AGU Fall Meeting, in which they provided GPM handouts and displayed LEGO models of Hurricane Irma and the GPM Core Observatory, 3D printed hurricanes, GPM visualizations, and VR videos of "Inside Hurricane Maria".

8. Atmospheric Sciences in the News

The following pages contain links to press releases that describe some of the laboratory's activities during 2019.

2018's biggest volcanic eruption of sulfur dioxide
Science Daily
28 February 2019
https://www.sciencedaily.com/releases/2019/02/190228113547.htm
Source: NASA/Goddard Space Flight Center

NASA study verifies global warming trends
Science Daily
17 April 2019
https://www.sciencedaily.com/releases/2019/04/190417084535.htm
Source: NASA/Goddard Space Flight Center

Weather Geeks podcast
Paul A. Newman (610) gave an interview on the science and policy behind the issue of ozone depletion for Marshal Shepherd's Weather Geeks podcast on Wed,, May 8.
https://weloveweather.tv/weathergeekspodcast

Environmentalists express concerns about air pollution following July 4 fireworks show
WJLA
By Anna-Lysa Gayle, ABC7, Friday, July 5th 2019
https://wjla.com/news/local/environmentalists-concerns-air-pollution-fireworks-show
Source: NASA/Goddard Space Flight Center

'It caught our attention': Air pollution spikes in DC after fireworks
WTOP
By Michelle Basch | @MBaschWTOP , July 5, 2019, 6:51 PM
https://wtop.com/local/2019/07/it-caught-our-attention-air-pollution-spikes-in-dc-after-fireworks
Source: NASA/Goddard Space Flight Center

Suomi-NPP Satellite Instrument Restored After Radiation Damage
By Jenny Marder, NASA's Goddard Space Flight Center, Greenbelt, Maryland.
https://www.nasa.gov/feature/goddard/2019/suomi-npp-satellite-instrument-restored-after-radiation-damage

Hurricane Hunting NASA Style: Using Space-Based and Airborne Measurements to Better Understand and Predict Hurricanes
Library of Congress
June 13, 2019
Video: https://www.loc.gov/item/webcast-8766/

ACRONYMS AND ABBREVIATIONS

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

A

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
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

B

BC	Black Carbon
BESS	Beaufort and East Siberian Sea
BEST	Beginning Engineering Science and Technology
BMKG	Indonesian Agency for Meteorology, Climatology and Geophysics
BRDF	Bidirectional Reflectance-Distribution Functions

C

CALIOP	Cloud-Aerosol LIdar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAR	Cloud Absorption Radiometer
CARAFE	CARbon Airborne Flux Experiment
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

ACRONYMS AND ABBREVIATIONS

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
CPR	Cloud Profiling Radar
CR	Cloud regimes
CrIS	Cross-track Infrared Sounder
CRM	Cloud-resolving Models
CRS	Cloud Radar System

D

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

E

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

F

FMI	Finnish Meteorological Institute
FV	Finite Volume

G

G-IV	Gulfstream IV
GCE	Goddard Cumulus Ensemble
GCM	Global Climate Model
GCPEX	GPM Cold Season Precipitation Experiment
GEMS	Geostationary Environmental Monitoring Sensor
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	Global Modeling and Assimilation 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

H

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
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

I

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
ICESat	Ice, Cloud, and land Elevation Satellite
IGAC	International Global Atmospheric Chemistry
IGP	Indo–Gangetic Plain
IIP	Instrument Incubator Program
IMPACTS	Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms
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
IWRAP	Imaging Wind and Rain Airborne Profiler

J

JAXA	Japanese Aerospace Exploration Agency
JCET	Joint Center for Earth Systems Technology
JPL	Jet Propulsion Laboratory in Pasadena, California
JPSS	Joint Polar Satellite System
JSC	NASA's Johnson Space Center in Houston, Texas
JWST	James Webb Space Telescope

L

LaRC	Langley Research Center in Hampton, Virginia
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	Laser Risk Reduction Program

M

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
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
MRMS	Multi-Radar/Multi-Sensor
MSU	Morgan State University

N

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
NIR	Near-infrared
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

O

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
ONR	Office of Naval Research
ORS	Operationally Responsive Space
OSC	Orbital Sciences Corporation

P

PACE	Pre-Aerosols, Clouds, and Ecology
PAO	Public Affairs Office
PARSIVEL	PARticle Size VELocity
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

R

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

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
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.
SPARC — Stratosphere-troposphere Processes And their Role in Climate
SPARRO — Self-Piloted Aircraft Rescuing Remotely Over Wilderness
SPE — Solar Proton Event
SSA — Single Scattering Albedo
SSAI — Science Systems and Applications, Inc.
SSC — Scientific Steering Committee
SSI — Solar Spectral Irradiance
SST — Sea Surface Temperature
STEM — Science, Technology, Engineering, and Mathematics
SWG — Science Working Group
SWOT — Surface Water Ocean Topography

T

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

U

UARS — Upper Atmosphere Research Satellite
UAS — Unmanned Aircraft Systems
UAVs — Unmanned Aerial Vehicles
UMBC — University of Maryland, Baltimore County
UMSA — Universidad Mayor San Andres
UNCG — University of North Carolina - Greensboro
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

V

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

W

WAVES — Water Vapor Validation Experiments Satellite and sondes
WFF — Wallops Flight Facility
WMO — World Meteorological Organization
WRF — Weather Research and Forecasting

APPENDIX 1: REFEREED ARTICLES

Airapetian, V. S., R. Barnes, O. Cohen, G. A. Collinson, W. C. Danchi, C. F. Dong, A. D. Del Genio, K. France, K. Garcia-Sage, A. Glocer, N. Gopalswamy, J. L. Grenfell, G. Gronoff, M. Güdel, K. Herbst, W. G. Henning, C. H. Jackman, M. Jin, C. P. Johnstone, L. Kaltenegger, C. D. Kay, K. Kobayashi, W. Kuang, G. Li, B. J. Lynch, T. Lüftinger, J. G. Luhmann, H. Maehara, M. G. Mlynczak, Y. Notsu, R. A. Osten, R. M. Ramirez, S. Rugheimer, M. Scheucher, J. E. Schlieder, K. Shibata, C. Sousa-Silva, V. Stamenković, R. J. Strangeway, A. V. Usmanov, P. Vergados, O. P. Verkhoglyadova, A. A. Vidotto, M. Voytek, M. J. Way, G. P. Zank, and Y. Yamashiki. 2019: Impact of space weather on climate and habitability of terrestrial-type exoplanets. *Int. J. Astrobiol.*, **1-59** (In Press) [10.1017/s1473550419000132].

Bacour, C., F. Maignan, P. Peylin, N. MacBean, V. Bastrikov, J. Joiner, P. Köhler, L. Guanter, and C. Frankenberg. 2019: Differences between OCO-2 and GOME-2 SIF products from a model-data fusion perspective. *J. Geophys. Res.: Biogeosci.*, **124**, 3143-3157 [10.1029/2018jg004938].

Beck, H. E., M. Pan, T. Roy, G. P. Weedon, F. Pappenberger, A. I. van Dijk, G. J. Huffman, R. F. Adler, and E. F. Wood. 2019: Daily evaluation of 26 precipitation datasets using Stage-IV gauge-radar data for the CONUS. *Hydrol. Earth Syst. Sci.*, **23** (1), 207-224 [10.5194/hess-23-207-2019].

Bian, H., K. Froyd, D. M. Murphy, J. Dibb, M. Chin, P. R. Colarco, A. Darmenov, A. da Silva, T. L. Kucsera, G. Schill, H. Yu, P. Bui, M. Dollner, B. Weinzierl, and A. Smirnov. 2019: Observationally constrained analysis of sea salt aerosol in the marine atmosphere. *Atmos. Chem. Phys.*, **19**, 10773-10785 [10.5194/acp-2019-18].

Carlson, B., A. Lacis, C. Colose, A. Marshak, W. Su, and S. Lorentz, 2019: "Spectral Signature of the Biosphere: NISTAR Finds It in Our Solar System From the Lagrangian L-1 Point. *Geophys. Res. Lett.*, **46** (17-18), 10679-10686 [10.1029/2019gl083736].

Carr, J. L., D. L. Wu, R. E. Wolfe, H. Madani, G. Lin, and B. Tan. 2019: Joint 3D-Wind Retrievals with Stereoscopic Views from MODIS and GOES. *Remote Sens.*, **11** (18), 2100 [10.3390/rs11182100].

Chang, K.-L., O. R. Cooper, J. J. West, M. L. Serre, M. G. Schultz, M. Lin, V. Marécal, B. Josse, M. Deushi, K. Sudo, J. Liu, and C. A. Keller. 2019: A new method (M3Fusion-v1) for combining observations and multiple model output for an improved estimate of the global surface ozone distribution. *Geosci. Model Dev.*, **12** (3), 955-978 [10.5194/gmd-12-955-2019].

Cromar, K. R., B. N. Duncan, A. Bartonova, K. Benedict, M. Brauer, R. Habre, G. S. Hagler, J. A. Haynes, S. Khan, V. Kilaru, Y. Liu, S. Pawson, D. B. Peden, J. K. Quint, M. B. Rice, E. N. Sasser, E. Seto, S. L. Stone, G. D. Thurston, and J. Volckens. 2019: Air Pollution Monitoring for Health Research and Patient Care. An Official American Thoracic Society Workshop Report. *Ann. Am. Thorac. Soc.*, **16** (10), 1207-1214 [10.1513/annalsats.201906-477st].

Dacic, N., J. T. Sullivan, K. E. Knowland, G. M. Wolfe, L. D. Oman, T. A. Berkoff, and G. P. Gronoff. 2019: Evaluation of NASA's high-resolution global composition simulations: Understanding a pollution event in the Chesapeake Bay during the summer 2017 OWLETS campaign. *Atmos. Environ.*, 117133 (In Press) [10.1016/j.atmosenv.2019.117133].

DeLand, M. T., and G. E. Thomas. 2019: Extending the SBUV polar mesospheric cloud data record with the OMPS NP. *Atmos. Chem. Phys.*, **19** (11), 7913-7925 [10.5194/acp-19-7913-2019].

Delgado-Bonal, A., and A. Marshak. 2019: Approximate Entropy and Sample Entropy: A Comprehensive Tutorial. Entropy, **21** (6), 541 [10.3390/e21060541].

Ding, J., P. Yang, M. D. King, S. Platnick, X. Liu, K. G. Meyer, and C. Wang. 2019: A Fast Vector Radiative Transfer Model for the Atmosphere-Ocean Coupled System. *J. Quant. Spectrosc. Radiat. Transfer*, **239**, 106667 [10.1016/j.jqsrt.2019.106667].

Dubovik, O., Z. Li, M. I. Mishchenko, D. Tanré, Y. Karol, B. Bojkov, B. Cairns, D. J. Diner, W. R. Espinosa, P. Goloub, X. Gu, O. Hasekamp, J. Hong, W. Hou, K. D. Knobelspiesse, J. Landgraf, L. Li, P. Litvinov, Y. Liu, A. Lopatin, T. Marbach, H. Maring, V. Martins, Y. Meijer, G. Milinevsky, S. Mukai, F. Parol, Y. Qiao, L. Remer, J. Rietjens, I. Sano, P. Stammes, S. Stamnes, X. Sun, P. Tabary, L. D. Travis, F. Waquet, F. Xu, C. Yan, and D. Yin. 2019: Polarimetric remote sensing of atmospheric aerosols: Instruments, methodologies, results, and perspectives. *J. Quant. Spectrosc. Radiat. Transfer*, **224,** 474-511 [10.1016/j.jqsrt.2018.11.024].

Espinosa, W. R., J. V. Martins, L. A. Remer, O. Dubovik, L. Tatyana, F. David, A. Puthukkudy, F. D. Orozco, L. Ziemba, K. L. Thornhill, and R. C. Levy. 2019: Retrievals of aerosol size distribution, spherical fraction and complex refractive index from airborne in situ angular light scattering and absorption measurements. *J. Geophys. Res.: Atmos.*, **124** (14), 7997-8024 [https://doi.org/10.1029/2018JD030009].

Fasnacht, Z., A. Vasilkov, D. Haffner, W. Qin, J. Joiner, N. Krotkov, A. M. Sayer, and R. Spurr. 2019: A geometry-dependent surface Lambertian-equivalent reflectivity product for UV-Vis retrievals–Part 2: Evaluation over open ocean. *Atmos. Meas. Tech.*, **12** (12), 6749-6769 [10.5194/amt-12-6749-2019].

Fedkin, N. M., C. Li, R. R. Dickerson, T. Canty, and N. A. Krotkov. 2019: Linking improvements in sulfur dioxide emissions to decreasing sulfate wet deposition by combining satellite and surface observations with trajectory analysis. *Atmos. Environ.*, **199**, 210-223 [10.1016/j.atmosenv.2018.11.039].

Gadelha, A. N., V. H. Coelho, A. C. Xavier, L. R. Barbosa, D. C. Melo, Y. Xuan, G. J. Huffman, W. A. Petersen, and C. D. Almeida. 2019: Grid box-level evaluation of IMERG over Brazil at various space and time scales. *Atmos. Res.*, **218**, 231-244 [10.1016/j.atmosres.2018.12.001].

Ganeshan, M., and Y. Yang. 2019: Evaluation of the Antarctic boundary layer thermodynamic structure in MERRA2 using dropsonde observations from the Concordiasi campaign. Earth Space Sci., 6 (612), 2397-2409 [10.1029/2019ea000890].

Gao, B.-C., R.-R. Li, and Y. Yang. 2019: Remote Sensing of Daytime Water Leaving Reflectances of Oceans and Large Inland Lakes from EPIC onboard the DSCOVR Spacecraft at Lagrange-1 Point. *Sensors*, **19** (5), 1243 [10.3390/s19051243].

Gao, M., P.-W. Zhai, Y. Yang, and Y. Hu. 2019: Cloud remote sensing with EPIC/DSCOVR observations: A sensitivity study with radiative transfer simulations. *J. Quant. Spectrosc. Radiat. Transfer*, **230**, 56-60 [10.1016/j.jqsrt.2019.03.022].

Garfinkel, C., I. Weinberger, I. P. White, L. D. Oman, V. Aquila, and Y.-K. Lim. 2019: The salience of nonlinearities in the boreal winter response to ENSO; North Pacific and North America. *Clim Dyn.*, **52** (7-8), 4429-4446 [10.1007/s00382-018-4386-x].

Gassó, S., and O. Torres, 2019: Temporal Characterization of Dust Activity in the Central Patagonia Desert (Years 1964-2017). *J. Geophys. Res.: Atmos.*, **124**, 3417-34342018JD030209 [10.1029/2018jd030209].

Goldberg, D. L., Z. Lu, T. Oda, L. N. Lamsal, F. Liu, D. Griffin, C. A. McLinden, N. A. Krotkov, B. N. Duncan, and D. G. Streets, 2019: Exploiting OMI NO_2 satellite observations to infer fossil-fuel CO_2 emissions from U.S. megacities. *Sci. Total Environ.*, **695**, 133805 [10.1016/j.scitotenv.2019.133805].

Gonzalez-Alonso, L., M. Val Martin, and R. A. Kahn, 2019: Biomass-burning smoke heights over the Amazon observed from space. *Atmos. Chem. Phys.*, **19** (3), 1685-1702 [10.5194/acp-19-1685-2019].

Gouw, J. A., D. D. Parrish, S. S. Brown, P. Edwards, J. B. Gilman, M. Graus, T. F. Hanisco, J. Kaiser, F. N. Keutsch, S. Kim, B. M. Lerner, J. A. Neuman, J. B. Nowak, I. B. Pollack, J. M. Roberts, T. B. Ryerson, P. R. Veres, C. Warneke, and G. M. Wolfe, 2019: Hydrocarbon Removal in Power Plant Plumes Shows Nitrogen Oxide Dependence of Hydroxyl Radicals. *Geophys. Res. Lett.*, **46** (13), 7752-7760 [10.1029/2019gl083044].

Griffin, D., X. Zhao, C. A. McLinden, F. Boersma, A. Bourassa, E. Dammers, D. Degenstein, H. Eskes, L. Fehr, V. Fioletov, K. Hayden, S. K. Kharol, S.-M. Li, P. Makar, R. V. Martin, C. Mihele, R. L. Mittermeier, N. Krotkov, M. Sneep, L. N. Lamsal, M. T. Linden, J. V. Geffen, P. Veefkind, and M. Wolde, 2019: High-Resolution Mapping of Nitrogen Dioxide With TROPOMI: First Results and Validation Over the Canadian Oil Sands. *Geophys. Res. Lett.*, **46** (2), 1049-1060 [10.1029/2018gl081095].

Guimond, S. R., 2019: Papers of Note: Coherent turbulence in Hurricane Rita (2005) during an eyewall replacement cycle. *Bull. Am. Meteorol. Soc.*, **100**, 18-20. [Magazine]

He, L., J. M. Chen, J. Liu, T. Zheng, R. Wang, J. Joiner, S. Chou, B. Chen, Y. Liu, R. Liu, and C. Rogers, 2019: Diverse photosynthetic capacity of global ecosystems mapped by satellite chlorophyll fluorescence measurements. *Rem. Sens. Environ.*, **232**, 111344 [10.1016/j.rse.2019.111344].

Hooper, J., P. Mayewski, S. Marx, S. Henson, M. Potocki, S. Sneed, M. Handley, S. Gassó, M. Fischer, and K. M. Saunders, 2019: Examining links between dust deposition and phytoplankton response using ice cores. *Aeolian Res.*, **36**, 45-60 [10.1016/j.aeolia.2018.11.001].

Hsu, N. C., J. Lee, A. M. Sayer, W. Kim, C. Bettenhausen, and S. Tsay, 2019: VIIRS Deep Blue Aerosol Products Over Land: Extending the EOS Long-Term Aerosol Data Records. *J. Geophys. Res.: Atmos.*, **124** (7), 4026-4053 [10.1029/2018jd029688].

Jamet, C., A. Ibrahim, Z. Ahmad, F. Angelini, M. Babin, M. J. Behrenfeld, E. Boss, B. Cairns, J. Churnside, J. Chowdhary, A. B. Davis, D. Dionisi, L. Duforêt-Gaurier, B. Franz, R. Frouin, M. Gao, D. Gray, O. Hasekamp, X. He, C. Hostetler, O. V. Kalashnikova, K. Knobelspiesse, L. Lacour, H. Loisel, V. Martins, E. Rehm, L. Remer, I. Sanhaj, K. Stamnes, S. Stamnes, S. Victori, J. Werdell, and P.-W. Zhai, 2019: Going Beyond Standard Ocean Color Observations: Lidar and Polarimetry. *Frontiers Mar. Sci*., **6**, [10.3389/fmars.2019.00251].

Jasinski, M. F., J. D. Stoll, D. W. Hancock, J. W. Robbins, and J. Nattala, 2019: ATLAS/ICESat-2 L3A Inland Water Surface Height Data Products, ATL13, Version 2. NASA National Snow and Ice Data Center Distributed Active Archive Center, Boulder CO. Version 2: [10.5067/ATLAS/ATL13.002] [Dataset]

Jasinski, M. F., J. D. Stoll, D. W. Hancock, J. W. Robbins, J. Nattala, T. Pavelsky, J. Morrison, B. Jones, and C. Parrish, 2019: Algorithm Theoretical Basis Document (ATBD) for Inland Water Data Products, ATL13, Version 002. ICESat-2 Data Products. https://icesat-2.gsfc.nasa.gov/sites/default/files/page_files/ICESat2ATL13ATBDr002mj12202019.pdf. Version 2: 99 [10.5067/3H94RJ271O0C] [Report] [Ocean Dynamics, Hydrology / Water Cycle]

Jeong, D., R. Seco, D. Gu, Y. Lee, B. A. Nault, C. J. Knote, T. Mcgee, J. T. Sullivan, J. L. Jimenez, P. Campuzano-Jost, D. R. Blake, D. Sanchez, A. B. Guenther, D. Tanner, L. G. Huey, R. Long, B. E. Anderson, S. R. Hall, K. Ullmann, H.-J. Shin, S. C. Herndon, Y. Lee, D. Kim, J. Ahn, and S. Kim, 2019: Integration of Airborne and Ground Observations of Nitryl Chloride in the Seoul Metropolitan Area and the Implications on Regional Oxidation Capacity During KORUS-AQ 2016. *Atmos. Chem. Phys.*, **19**, 12779-12795 [10.5194/acp-19-12779-2019].

Jethva, H., and O. Torres, 2019: A comparative evaluation of Aura-OMI and SKYNET near-UV single-scattering albedo products. *Atmos. Meas. Tech.*, **12** (12), 6489-6503 [10.5194/amt-12-6489-2019].

Jethva, H., O. Torres, and Y. Yoshida, 2019: Accuracy assessment of MODIS land aerosol optical thickness algorithms using AERONET measurements over North America. *Atmos. Meas. Tech.*, **12** (8), 4291-4307 [10.5194/amt-12-4291-2019].

Jethva, H., O. Torres, R. D. Field, A. Lyapustin, R. Gautam, and V. Kayetha, 2019: Connecting Crop Productivity, Residue Fires, and Air Quality over Northern India. *Scientific Reports*, **9** (1), 16594 [10.1038/s41598-019-52799-x].

Jiang, Y., L. Zhou, C. J. Tucker, A. Raghavendra, W. Hua, Y. Y. Liu, and J. Joiner, 2019: Widespread increase of boreal summer dry season length over the Congo rainforest. *Nat. Clim. Change*, **9**, 617-622 [10.1038/s41558-019-0512-y].

Jin, X., A. M. Fiore, G. Curci, A. Lyapustin, K. Civerolo, M. Ku, A. van Donkelaar, and R. V. Martin, 2019: Assessing uncertainties of a geophysical approach to estimate surface fine particulate matter distributions from satellite-observed aerosol optical depth. *Atmos. Chem. Phys.*, **19** (1), 295-313 [10.5194/acp-19-295-2019].

Jung, Y., G. González Abad, C. R. Nowlan, K. Chance, X. Liu, O. Torres, and C. Ahn, 2019: Explicit Aerosol Correction of OMI Formaldehyde Retrievals. *Earth Space Sci.*, **6** (11), 2087-2105 [10.1029/2019ea000702].

Karagulian, F., M. Temimi, D. Ghebreyesus, M. Weston, N. K. Kondapalli, V. K. Valappil, A. Aldababesh, A. I. Lyapustin, N. Chaouch, F. Al Hammadi, and A. Al Abdooli, 2019: Analysis of a severe dust storm and its impact on air quality conditions using WRF-Chem modelling, satellite imagery, and ground observations. *Air Qual., Atmos. Health*, **12** (4), 453-470.

Kim, D., M. Chin, H. Yu, X. Pan, H. Bian, Q. Tan, R. A. Kahn, K. Tsigaridis, S. E. Bauer, T. Takemura, L. Pozzoli, N. Bellouin, and M. Schulz, 2019: Asian and Trans-Pacific Dust: A Multimodel and Multiremote Sensing Observation Analysis. *J. Geophys. Res.: Atmos.*, **124**, 13534-13559, 2019JD030822 [10.1029/2019jd030822].

Kim, S., S. Jung, S. Yang, J. Han, B. Lee, J. Lee, and S. W. Han, 2019: "Vision-Based Deep Q-Learning Network Models to Predict Particulate Matter Concentration Levels Using Temporal Digital Image Data. *J. Sensors*, 2019, 9673047 1-10 [10.1155/2019/9673047].

Korkin, S., and A. Lyapustin, 2019: Matrix exponential in C/C++ version of vector radiative transfer code IPOL. *J. Quant. Spectrosc. Radiat. Transfer*, **227**, 106-110 [10.1016/j.jqsrt.2019.02.009].

Kramer, R. J., A. V. Matus, B. J. Soden, and T. S. L'Ecuyer, 2019: Observation-Based Radiative Kernels From CloudSat/CALIPSO. *J. Geophys. Res.: Atmos.*, **124**, 5431-5444 [10.1029/2018jd029021].

Kramer, R. J., B. J. Soden, and A. G. Pendergrass, 2019: Evaluating climate model simulations of the radiative forcing and radiative response at the Earth's surface. *J. Clim.*, **3**2, 4089-4102 [10.1175/jcli-d-18-0137.1].

Lee, L., J. Zhang, J. S. Reid, and J. E. Yorks, 2019: Investigation of CATS aerosol products and application toward global diurnal variation of aerosols. *Atmos. Chem. Phys.*, **19**, 12687-12707 [10.5194/acp-19-12687-2019].

Liao, J., T. F. Hanisco, G. M. Wolfe, J. St. Clair, J. L. Jimenez, P. Campuzano-Jost, B. A. Nault, A. Fried, E. A. Marais, G. Gonzalez Abad, K. Chance, H. T. Jethva, T. B. Ryerson, C. Warneke, and A. Wisthaler, 2019: Towards a satellite formaldehyde – in situ hybrid estimate for organic aerosol abundance. *Atmos. Chem. Phys.*, **19** (5), 2765-2785 [10.5194/acp-19-2765-2019].

Lim, Y.-K., R. I. Cullather, S. M. Crooks Nowicki, and K.-M. Kim, 2019: Inter-relationship between subtropical Pacific sea surface temperature, Arctic sea ice concentration, and North Atlantic Oscillation in recent summers. *Scientific Reports*, **9**, 3481 [10.1038/s41598-019-39896-7].

Limbacher, J. A., and R. A. Kahn, 2019: Updated MISR over-water research aerosol retrieval algorithm – Part 2: A multi-angle aerosol retrieval algorithm for shallow, turbid, oligotrophic, and eutrophic waters. *Atmos. Meas. Tech.*, **12** (1), 675-689 [10.5194/amt-12-675-2019].

Loughner, C. P., M. B. Follette-Cook, B. N. Duncan, J. Hains, K. E. Pickering, J. Moy, and M. Tzortziou, 2019: The benefits of lower ozone due to air pollution emissions reductions (2002-2011) in the Eastern US during extreme heat. *J. Air Waste Manage. Assoc.*, **70** (2), 193-205 [10.1080/10962247.2019.1694089].

Lyapustin, A., Y. Wang, S. Korkin, R. Kahn, and D. Winker, 2019: MAIAC Thermal Technique for Smoke Injection Height From MODIS. *IEEE Geoscience and Remote Sensing Letters.*, **1-517** (5), 730-734; [10.1109/lgrs.2019.2936332].

Mallet, M., P. Nabat, P. Zuidema, J. Redemann, A. M. Sayer, M. Stengel, S. Schmidt, S. Cochrane, S. Burton, R. Ferrare, K. Meyer, P. Saide, H. Jethva, O. Torres, R. Wood, D. Saint Martin, R. Roehrig, C. Hsu, and P. Formenti, 2019: Simulation of the transport, vertical distribution, optical properties and radiative impact of smoke aerosols with the ALADIN regional climate model during the ORACLES-2016 and LASIC experiments. *Atmos. Chem. Phys.*, **19** (7), 4963-4990 [10.5194/acp-19-4963-2019].

Marshak, A., and M. D. Alexandrov, 2019: Cellular Statistical Models of Broken Cloud Fields. Part IV: Effects of Pixel Size on Idealized Satellite Observations. *J. Atmos. Sci.*, **76** (5), 1329-1348 [10.1175/jas-d-18-0345.1].

McPeters, R., S. Frith, N. Kramarova, J. Ziemke, and G. Labow, 2019: Trend quality ozone from NPP OMPS: the version 2 processing. *Atmos. Meas. Tech.*, **12** (2), 977-985 [10.5194/amt-12-977-2019].

Mhawish, A., T. Banerjee, M. Sorek-Hamer, A. I. Lyapustin, D. M. Broday, and R. Chatfield, 2019: Comparison and evaluation of MODIS Multi-Angle Implementation of Atmospheric Correction (MAIAC) aerosol product over South Asia. *Rem. Sens. Environ.*, **224**, 12-28 [10.1016/j.rse.2019.01.033].

Mohammed, G. H., R. Colombo, E. M. Middleton, U. Rascher, C. van der Tol, L. Nedbal, Y. Goulas, O. Pérez-Priego, A. Damm, M. Meroni, J. Joiner, S. Cogliati, W. Verhoef, Z. Malenovský, J.-P. Gastellu-Etchegorry, J. R. Miller, L. Guanter, J. Moreno, I. Moya, J. A. Berry, C. Frankenberg, and P. J. Zarco-Tejada, 2019: Remote sensing of solar-induced chlorophyll fluorescence (SIF) in vegetation: 50 years of progress. *Rem. Sens. Environ.*, **231**, 111177 [10.1016/j.rse.2019.04.030].

Morison, J., D. W. Hancock, S. Dickinson, J. W. Robbins, L. Roberts, R. Kwok, S. P. Palm, B. Smith, M. F. Jasinski, B. Plant, and T. Urban, 2019: Algorithm Theoretical Basis Document (ATBD) for Ocean Surface Height, Version 2. ICESat-2 Data Products, https://icesat-2.gsfc.nasa.gov/sites/default/files/page_files/ICESat2ATL13ATBDr002mj12202019.pdf. 129 [Full Text (Link)] [10.5067/O0KKOL752IM8] [Report] [Remote Sensing]

Moutier, W., S. Thomalla, S. Bernard, G. Wind, T. Ryan-Keogh, and M. Smith, 2019: Evaluation of Chlorophyll-a and POC MODIS Aqua Products in the Southern *Ocean. Remote Sens.*, **11** (15), 1793 [10.3390/rs11151793].

Neumann, T. A., A. J. Martino, T. Markus, S. Bae, M. R. Bock, A. C. Brenner, K. M. Brunt, J. Cavanaugh, S. T. Fernandes, D. W. Hancock, K. Harbeck, J. Lee, N. T. Kurtz, P. J. Luers, S. B. Luthcke, L. Magruder, T. A. Pennington, L. Ramos-Izquierdo, T. Rebold, J. Skoog, and T. C. Thomas, 2019: The Ice, Cloud, and Land Elevation Satellite – 2 mission: A global geolocated photon product derived from the Advanced Topographic Laser Altimeter System. *Rem. Sens. Environ.*, **233**, 111325 [10.1016/j.rse.2019.111325].

Nicholls, S. D., and K. I. Mohr, 2019: An automated detection methodology for dry well-mixed layers. *J. Atmos. Oceanic Techno.*, **36** (5), 761-779 [10.1175/jtech-d-18-0149.1].

Olsen, M. A., G. L. Manney, and J. Liu, 2019: The ENSO and QBO Impact on Ozone Variability and Stratosphere-Troposphere Exchange Relative to the Subtropical Jets. *J. Geophys. Res.: Atmos.*, **124**, 7379-7392, 2019JD030435 [10.1029/2019jd030435].

Oltmans, S. J., L. C. Cheadle, B. J. Johnson, R. C. Schnell, D. Helmig, A. M. Thompson, P. Cullis, E. Hall, A. Jordan, C. Sterling, A. McClure-Begley, J. T. Sullivan, T. J. McGee, and D. Wolfe, 2019: Boundary layer ozone in the Northern Colorado Front Range in July-August 2014 during FRAPPE and DISCOVER-AQ from vertical profile measurements. *Elem Sci Anth.*, **7** (1), 6 [10.1525/elementa.345].

Palmer, P. I., E. L. Wilson, G. L. Villanueva, G. Liuzzi, L. Feng, A. J. DiGregorio, J. Mao, L. Ott, and B. Duncan, 2019: Potential improvements in global carbon flux estimates from a network of laser heterodyne radiometer measurements of column carbon dioxide. Atmos. Meas. Tech., 12 (4), 2579-2594 [10.5194/amt-12-2579-2019].

Parazoo, N. C., C. Frankenberg, P. Köhler, J. Joiner, Y. Yoshida, T. Magney, Y. Sun, and V. Yadav, 2019: Towards a harmonized long-term spaceborne record of far-red solar induced fluorescence. *J. Geophys. Res.: Biogeosci.*, **124** (8), 2518-2539 [10.1029/2019jg005289].

Peers, F., P. Francis, C. Fox, S. J. Abel, K. Szpek, M. I. Cotterell, N. W. Davies, J. M. Langridge, K. G. Meyer, S. E. Platnick, and J. M. Haywood, 2019: Observation of absorbing aerosols above clouds over the south-east Atlantic Ocean from the geostationary satellite SEVIRI – Part 1: Method description and sensitivity. *Atmos. Chem. Phys.,* **19** (14), 9595-9611 [10.5194/acp-19-9595-2019].

Pérez-Ramírez, D., D. N. Whiteman, I. Veselovskii, P. Colarco, M. Korenski, and A. da Silva, 2019: Retrievals of aerosol single scattering albedo by multiwavelength lidar measurements: Evaluations with NASA Langley HSRL-2 during discover-AQ field campaigns. *Rem. Sens. Environ.*, **222**, 144-164 [10.1016/j.rse.2018.12.022].

Policelli, F., A. Hubbard, H. C. Jung, B. Zaitchik, and C. Ichoku, 2019: A predictive model for Lake Chad total surface water area using remotely sensed and modeled hydrological and meteorological parameters and multivariate regression analysis. *J. Hydrol.*, **568**, 1071-1080 [10.1016/j.jhydrol.2018.11.037].

Proestakis, E., V. Amiridis, E. Marinou, I. Binietoglou, A. Ansmann, U. Wandinger, J. Hofer, J. Yorks, E. Nowottnick, A. Makhmudov, A. Papayannis, A. Pietruczuk, A. Gialitaki, A. Apituley, A. Szkop, C. Muñoz Porcar, D. Bortoli, D. Dionisi, D. Althausen, D. Mamali, D. Balis, D. Nicolae, E. Tetoni, G. L. Liberti, H. Baars, I. Mattis, I. S. Stachlewska, K. A. Voudouri, L. Mona, M. Mylonaki, M. R. Perrone, M. J. Costa, M. Sicard, N. Papagiannopoulos, N. Siomos, P. Burlizzi, R. Pauly, R. Engelmann, S. Abdullaev, and G. Pappalardo, 2019: EARLINET evaluation of the CATS Level 2 aerosol backscatter coefficient product. *Atmos. Chem. Phys.*, **19** (18), 11743-11764 [10.5194/acp-19-11743-2019].

Qin, W., Z. Fasnacht, D. Haffner, A. Vasilkov, J. Joiner, N. Krotkov, B. Fisher, and R. Spurr, 2019: A geometry-dependent surface Lambertian-equivalent reflectivity product for UV–Vis retrievals – Part 1: Evaluation over land surfaces using measurements from OMI at 466nm. *Atmos. Meas. Tech.*, **1**2 (7), 3997-4017 [10.5194/amt-12-3997-2019].

Remer, L. A., A. B. Davis, S. Mattoo, R. C. Levy, O. V. Kalashnikova, O. Coddington, J. Chowdhary, K. Knobelspiesse, X. Xu, Z. Ahmad, E. Boss, B. Cairns, H. M. Dierssen, D. J. Diner, B. Franz, R. Frouin, B.-C. Gao, A. Ibrahim, J. V. Martins, A. H. Omar, O. Torres, F. Xu, and P.-W. Zhai, 2019: Retrieving Aerosol Characteristics From the PACE Mission, Part 1: Ocean Color Instrument. *Frontiers in Earth Science.,* **7**, [10.3389/feart.2019.00152].

Remer, L. A., K. Knobelspiesse, P.-W. Zhai, F. Xu, O. V. Kalashnikova, J. Chowdhary, O. Hasekamp, O. Dubovik, L. Wu, Z. Ahmad, E. Boss, B. Cairns, O. Coddington, A. B. Davis, H. M. Dierssen, D. J. Diner, B. Franz, R. Frouin, B.-C. Gao, A. Ibrahim, R. C. Levy, J. V. Martins, A. H. Omar, and O. Torres, 2019: Retrieving Aerosol Characteristics From the PACE Mission, Part 2: Multi-Angle and Polarimetry. *Frontiers in Environ. Sci.*, **7**, [10.3389/fenvs.2019.00094].

Rigby, M., S. Park, T. Saito, L. M. Western, A. L. Redington, X. Fang, S. Henne, A. J. Manning, R. G. Prinn, G. S. Dutton, P. J. Fraser, A. L. Ganesan, B. D. Hall, C. M. Harth, J. Kim, K.-R. Kim, P. B. Krummel, T. Lee, S. Li, Q. Liang, M. F. Lunt, S. A. Montzka, J. Mühle, S. O'Doherty, M.-K. Park, S. Reimann, P. K. Salameh, P. Simmonds, R. L. Tunnicliffe, R. F. Weiss, Y. Yokouchi, and D. Young, 2019: Increase in CFC-11 emissions from eastern China based on atmospheric observations. *Nature*, **569** (7757), 546-550 [10.1038/s41586-019-1193-4].

Riris, H., K. Numata, S. Wu, and M. Fahey, 2019: The challenges of measuring methane from space with a LIDAR. *CEAS Space Journal*, **11** (4), 475-483 [10.1007/s12567-019-00274-8].

Sayer, A. M., N. C. Hsu, J. Lee, W. V. Kim, and S. T. Dutcher, 2019: Validation, Stability, and Consistency of MODIS Collection 6.1 and VIIRS Version 1 Deep Blue Aerosol Data Over Land. *J. Geophys. Res.: Atmos.*, **124** (8), 4658-4688 [10.1029/2018jd029598].

Sayer, A. M., N. C. Hsu, J. Lee, W. V. Kim, S. Burton, M. A. Fenn, R. A. Ferrare, M. Kacenelenbogen, S. LeBlanc, K. Pistone, J. Redemann, M. Segal-Rozenhaimer, Y. Shinozuka, and S.-C. Tsay, 2019: Two decades observing smoke above clouds in the south-eastern Atlantic Ocean: Deep Blue algorithm updates and validation with ORACLES field campaign data. *Atmos. Meas. Tech.*, **12** (7), 3595-3627 [10.5194/amt-12-3595-2019].

Scafetta, N., R. C. Willson, J. N. Lee, and D. L. Wu, 2019: Modeling Quiet Solar Luminosity Variability from TSI Satellite Measurements and Proxy Models during 1980–2018. *Remote Sens.*, **11** (21), 2569 [10.3390/rs11212569].

Schollaert Uz, S., A. C. Ruane, B. N. Duncan, C. J. Tucker, G. J. Huffman, I. E. Mladenova, B. Osmanoglu, T. R. Holmes, A. McNally, C. Peters-Lidard, J. D. Bolten, N. Das, M. Rodell, S. McCartney, M. C. Anderson, and B. Doorn, 2019: Earth Observations and Integrative Models in Support of Food and Water Security. *Remote Sens. Earth Sys. Sci.*, **2**, 18-38 [10.1007/s41976-019-0008-6].

Seo, E., M.-I. Lee, D. Kim, Y.-K. Lim, S. D. Schubert, and K.-M. Kim, 2019: Interannual variation of tropical cyclones simulated by GEOS-5 AGCM with modified convection scheme. *Int.l J. Climatol.*, **39**, 4041-4057 [10.1002/joc.6058].

Shen, J., A. Huete, X. Ma, N. N. Tran, J. Joiner, J. Beringer, D. Eamus, and Q. Yu, 2019: Spatial pattern and seasonal dynamics of the photosynthesis activity across Australian rainfed croplands. *Ecological Indicators*, **108**, 105669 [10.1016/j.ecolind.2019.105669].

Shi, Y. R., R. C. Levy, T. F. Eck, B. Fisher, S. Mattoo, L. A. Remer, I. Slutsker, and J. Zhang, 2019: Characterizing the 2015 Indonesia fire event using modified MODIS aerosol retrievals. *Atmos. Chem. Phys.*, **19** (1), 259-274 [10.5194/acp-19-259-2019].

Silvern, R. F., D. J. Jacob, L. J. Mickley, M. P. Sulprizio, K. R. Travis, E. A. Marais, R. C. Cohen, J. L. Laughner, S. Choi, J. Joiner, and L. N. Lamsal, 2019: Using satellite observations of tropospheric NO_2 columns to infer long-term trends in US NOx emissions: the importance of accounting for the free tropospheric NO_2 background. *Atmos. Chem. Phys.*, **19** (13), 8863-8878 [10.5194/acp-19-8863-2019].

Spencer, R. S., R. C. Levy, L. A. Remer, S. Mattoo, G. T. Arnold, D. L. Hlavka, K. G. Meyer, A. Marshak, E. M. Wilcox, and S. E. Platnick, 2019: Exploring aerosols near clouds with high-spatial-resolution aircraft remote sensing during SEAC4RS. *J. Geophys. Res.: Atmos.*, **124**, 2148-2173 [10.1029/2018jd028989].

St. Clair, J. M., A. K. Swanson, S. A. Bailey, and T. F. Hanisco, 2019:"CAFE: a new, improved nonresonant laser-induced fluorescence instrument for airborne in situ measurement of formaldehyde. *Atmos. Meas. Tech.*, **12** (8), 4581-4590 [10.5194/amt-12-4581-2019].

Stafoggia, M., T. Bellander, S. Bucci, M. Davoli, K. de Hoogh, F. de' Donato, C. Gariazzo, A. Lyapustin, P. Michelozzi, M. Renzi, M. Scortichini, A. Shtein, G. Viegi, I. Kloog, and J. Schwartz, 2019: Estimation of daily PM10 and PM2.5 concentrations in Italy, 2013-2015, using a spatiotemporal land-use random-forest model. *Environ, Int.*, **124**, 170-179 [10.1016/j.envint.2019.01.016].

Stauffer, R. M., A. M. Thompson, L. D. Oman, and S. E. Strahan, 2019: The Effects of a 1998 Observing System Change on MERRA-2-based Ozone Profile Simulations. *J. Geophys. Res.: Atmos.*, **124**, 7429-7441 [10.1029/2019jd030257].

Strode, S. A., J. R. Ziemke, L. D. Oman, L. N. Lamsal, M. A. Olsen, and J. Liu, 2019: Global changes in the diurnal cycle of surface ozone. *Atmos. Environ.*, **199**, 323-333 [10.1016/j.atmosenv.2018.11.028].

Sullivan, J. T., T. Berkoff, G. Gronoff, T. Knepp, M. Pippin, D. Allen, L. Twigg, R. Swap, M. Tzortziou, A. M. Thompson, R. M. Stauffer, G. M. Wolfe, J. Flynn, S. E. Pusede, L. Judd, W. Moore, B. D. Baker, J. Al-Saadi, and T. J. McGee, 2019: The Ozone Water-Land Environmental Transition Study (OWLETS): An Innovative Strategy for Understanding Chesapeake Bay Pollution Events. *Bull. Am. Meteorol. Soc.*, **100** (2), 291-306 [10.1175/BAMS-D-18-0025.1].

Sullivan, J. T., T. J. McGee, R. M. Stauffer, A. M. Thompson, A. Weinheimer, C. Knote, S. Janz, A. Wisthaler, R. Long, J. Szykman, J. Park, Y. Lee, S. Kim, D. Jeong, D. Sanchez, L. Twigg, G. Sumnicht, T. Knepp, and J. R. Schroeder, 2019: Taehwa Research Forest: a receptor site for severe domestic pollution events in Korea during 2016. *Atmos. Chem. Phys.*, **19**, 5051-5067 [https://doi.org/10.5194/acp-19-5051-2019].

Suntharalingam, P., L. M. Zamora, H. W. Bange, S. Bikkina, E. Buitenhuis, M. Kanakidou, J.-F. Lamarque, A. Landolfi, L. Resplandy, M. M. Sarin, S. Seitzinger, and A. Singh, 2019: Anthropogenic nitrogen inputs and impacts on oceanic N2O fluxes in the northern Indian Ocean: The need for an integrated observation and modelling approach. *Deep Sea Research Part II: Topical Studies in Oceanography*, **166**, 104-113 [10.1016/j.dsr2.2019.03.007].

Susskind, J., G. A. Schmidt, J. N. Lee, and L. Iredell, 2019: Recent global warming as confirmed by AIRS. *Environ. Res. Lett.*, **14** (4), 044030 [10.1088/1748-9326/aafd4e].

Tan, I., and T. Storelvmo, 2019: Evidence of Strong Contributions From Mixed-Phase Clouds to Arctic Climate Change. *Geophys. Res. Lett.*, **46** (5), 2894-2902 [10.1029/2018gl081871].

Tan, I., L. Oreopoulos, and N. Cho, 2019: The Role of Thermodynamic Phase Shifts in Cloud Optical Depth Variations With Temperature. *Geophys. Res. Lett.*, **46** (8), 4502-4511 [10.1029/2018gl081590].

Tan, J., and L. Oreopoulos, 2019: Subgrid Precipitation Properties of Mesoscale Atmospheric Systems Represented by MODIS Cloud Regimes. *J. Climate*, **32** (6), 1797-1812 [10.1175/jcli-d-18-0570.1].

Tao, W.-K., J.-D. Chern, T. Iguchi, S. E. Lang, M.-I. Lee, X. Li, A. M. Loftus, T. Matsui, K. I. Mohr, S. Nicholls, C. D. Peters-Lidard, D. Posselt, and G. Skofronick-Jackson, 2019: Microphysics in Goddard multi-scale modeling systems: A Review. Current Trends in the Representation of Physical Processes in Weather and Climate Models. Singapore: Springer, 253-316, ISBN: 978-981-13-3395-8.[10.1007/978-981-13-3396-5_14] [Article in Book]

Thompson, A. M., H. G. Smit, J. C. Witte, R. M. Stauffer, B. J. Johnson, G. Morris, P. von der Gathen, R. Van Malderen, J. Davies, A. Piters, M. Allaart, F. Posny, R. Kivi, P. Cullis, N. Thi Hoang Anh, E. Corrales, T. Machinini, F. R. da Silva, G. Paiman, K. Thiong'o, Z. Zainal, G. B. Brothers, K. R. Wolff, T. Nakano, R. Stübi, G. Romanens, G. J. Coetzee, J. A. Diaz, S. Mitro, M. Mohamad, and S.-Y. Ogino, 2019: Ozonesonde Quality Assurance: The JOSIE-SHADOZ (2017) Experience. *Bull. Am. Meteorol. Soc.*, **100** (1), 155-171 [10.1175/bams-d-17-0311.1].

Tokay, A., L. P. D'Adderio, D. B. Wolff, and W. A. Petersen, 2019: Development and Evaluation of the Raindrop Size Distribution Parameters for the NASA Global Precipitation Measurement Mission Ground Validation Program. *J. Atmos. Oceanic Techno.*, JTECH-D-18-00711 (In Press) [10.1175/jtech-d-18-0071.1].

Varnai, T., A. B. Kostinski, and A. Marshak, 2019: Deep Space Observations of Sun Glints from Marine Ice Clouds. *IEEE Geoscience and Remote Sensing Letters*, 1-5 (In Press) [10.1109/lgrs.2019.2930866].

Várnai, T., C. Gatebe, R. Gautam, R. Poudyal, and W. Su, 2019: Developing an Aircraft-Based Angular Distribution Model of Solar Reflection from Wildfire Smoke to Aid Satellite-Based Radiative Flux Estimation. *Remote Sens.*, **11** (13), 1509 [10.3390/rs11131509].

Wang, C., S. Platnick, T. Fauchez, K. Meyer, Z. Zhang, H. Iwabuchi, and B. H. Kahn, 2019: An Assessment of the Impacts of Cloud Vertical Heterogeneity on Global Ice Cloud Data Records From Passive Satellite Retrievals. *J. Geophys. Res.: Atmos.*, **12**4, 1578-1595 [10.1029/2018jd029681].

Wang, S., R. S. Hornbrook, A. Hills, L. K. Emmons, S. Tilmes, J. Lamarque, J. L. Jimenez, P. Campuzano-Jost, B. A. Nault, J. D. Crounse, P. O. Wennberg, M. Kim, H. Allen, T. B. Ryerson, C. R. Thompson, J. Peischl, F. Moore, D. Nance, B. Hall, J. Elkins, D. Tanner, L. G. Huey, S. R. Hall, K. Ullmann, J. J. Orlando, G. S. Tyndall, F. M. Flocke, E. Ray, T. F. Hanisco, G. M. Wolfe, J. St. Clair, R. Commane, B. Daube, B. Barletta, D. R. Blake, B. Weinzierl, M. Dollner, A. Conley, F. Vitt, S. C. Wofsy, D. D. Riemer, and E. C. Apel, 2019: Atmospheric Acetaldehyde: Importance of Air-Sea Exchange and a Missing Source in the Remote Troposphere. *Geophys. Res. Lett.*, **46** (10), 5601-5613 [10.1029/2019gl082034].

Wang, T., D. L. Wu, J. Gong, and V. Tsai, 2019: Tropopause Laminar Cirrus and Its Role in the Lower Stratosphere Total Water Budget. *J. Geophys. Res.: Atmos.*, **124**, 7034-70522018JD029845 [10.1029/2018jd029845].

Wen, G., A. Marshak, W. Song, Y. Knyazikhin, M. Mõttus, and D. Wu, 2019: A Relationship between Blue and Near-IR Global Spectral Reflectance and the Response of Global Average Reflectance to Change in Cloud Cover Observed from DSCOVR EPIC. *Earth Space Sci.*, **6**, 1416-1429 [10.1029/2019ea000664].

Werdell, P. J., M. J. Behrenfeld, P. S. Bontempi, E. Boss, B. Cairns, G. T. Davis, B. A. Franz, U. B. Gliese, E. T. Gorman, O. Hasekamp, K. D. Knobelspiesse, A. Mannino, J. V. Martins, C. R. McClain, G. Meister, and L. A. Remer, 2019: The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission: Status, science, advances. *Bull. Am. Meteorol. Soc.*, **100** (9), 1775-1794 [10.1175/bams-d-18-0056.1].

Westberry, T., Y. Shi, H. Yu, M. Behrenfeld, and L. Remer, 2019: Satellite-Detected Ocean Ecosystem Response to Volcanic Eruptions in the Subarctic Northeast Pacific Ocean. *Geophys. Res. Lett.*, **46**, 2019GL083977 [10.1029/2019gl083977].

Wind, G., S. Platnick, K. Meyer, T. Arnold, N. Amarasinghe, B. Marchant, and C. Wang, 2019: The CHIMAERA system for retrievals of cloud top, optical and microphysical properties from imaging sensors. *Computers & Geosciences*, **134**, 104345 [10.1016/j.cageo.2019.104345].

Wolfe, G. M., J. M. Nicely, J. M. St. Clair, T. F. Hanisco, J. Liao, L. D. Oman, W. B. Brune, D. Miller, A. Thames, G. González Abad, T. B. Ryerson, C. R. Thompson, J. Peischl, K. McKain, C. Sweeney, P. O. Wennberg, M. Kim, J. D. Crounse, S. R. Hall, K. Ullmann, G. Diskin, P. Bui, C. Chang, and J. Dean-Day, 2019: Mapping hydroxyl variability throughout the global remote troposphere via synthesis of airborne and satellite formaldehyde observations. *Proceedings of the National Academy of Sciences*, *116* (23), 11171-11180 [10.1073/pnas.1821661116].

Wu, M., X. Liu, K. Yang, T. Luo, Z. Wang, C. Wu, K. Zhang, H. Yu, and A. Darmenov, 2019: Modeling Dust in East Asia by CESM and Sources of Biases. *J. Geophys. Res.: Atmos.*, **124**, 8043-8064 [10.1029/2019jd030799].

Xian, P., J. S. Reid, E. J. Hyer, C. R. Sampson, J. I. Rubin, M. Ades, N. Asencio, S. Basart, A. Benedetti, P. Bhattacharjee, M. E. Brooks, P. R. Colarco, A. Da Silva, T. F. Eck, J. Guth, O. Jorba, R. Kouznetsov, Z. Kipling, M. Sofiev, C. P. Carcia-Pando, Y. Pradhan, T. Tanaka, J. Wang, D. L. Westphal, K. Yumimoto, and J. Zhang, 2019: Current State of the global operational aerosol multi-model ensemble: an update from the International Cooperative for Aerosol Prediction (ICAP). *Q. J. R. Meteorol. Soc.*, **145** (S1), 176-209 [10.1002/qj.3497].

Xie, Y., M. Sengupta, and C. Wang, 2019: A Fast All-sky Radiation Model for Solar applications with Narrowband Irradiances on Tilted surfaces (FARMS-NIT): Part II. The cloudy-sky model. *Solar Energy*, **188**, 799-812 [10.1016/j.solener.2019.06.058].

Xu, X., J. Wang, Y. Wang, J. Zeng, O. Torres, J. S. Reid, S. D. Miller, J. V. Martins, and L. A. Remer, 2019: Detecting layer height of smoke aerosols over vegetated land and water surfaces via oxygen absorption bands: hourly results from EPIC/DSCOVR in deep space. *Atmos. Meas. Tech.*, **12** (6), 3269-3288 [10.5194/amt-12-3269-2019].

Yang, W., A. Marshak, and G. Wen, 2019: Cloud Edge Properties Measured by the ARM Shortwave Spectrometer Over Ocean and Land. *J. Geophys. Res.: Atmos.*, 2019JD030622 **124**, 8707-8721 [10.1029/2019jd030622].

Yang, Y., K. Meyer, G. Wind, Y. Zhou, A. Marshak, S. Platnick, Q. Min, A. B. Davis, J. Joiner, A. Vasilkov, D. Duda, and W. Su, 2019: Cloud products from the Earth Polychromatic Imaging Camera (EPIC): algorithms and initial evaluation. *Atmos. Meas. Tech.*, **12** (3), 2019-2031 [10.5194/amt-12-2019-2019].

Yu, H., Q. Tan, M. Chin, L. A. Remer, R. A. Kahn, H. Bian, D. Kim, Z. Zhang, T. L. Yuan, A. H. Omar, D. M. Winker, R. C. Levy, O. Kalashnikova, L. Crepeau, V. Capelle, and A. Chédin, 2019: Estimates of African Dust Deposition Along the Trans-Atlantic Transit Using the Decadelong Record of Aerosol Measurements from CALIOP, MODIS, MISR, and IASI. *J. Geophys. Res.: Atmos.*, **124** (14), 7975-7996 [10.1029/2019jd030574].

Yuan, T., C. Wang, H. Song, S. Platnick, K. Meyer, and L. Oreopoulos, 2019: Automatically Finding Ship-tracks to Enable Large-scale Analysis of Aerosol-Cloud Interactions. *Geophys. Res. Lett.*, **46**, 7726-7733 [10.1029/2019gl083441].

Yue, J., Y. Jian, W. Wang, R. Meier, A. Burns, L. Qian, M. Jones, D. L. Wu, and M. Mlynczak, 2019: Annual and Semiannual Oscillations of Thermospheric Composition in TIMED/GUVI Limb Measurements. *J. Geophys. Res.: Space Phys.*, **124**, 3067-30822019JA026544 [10.1029/2019ja026544].

Zhang, B., R. J. Kramer, and B. J. Soden, 2019: Radiative Feedbacks Associated with the Madden-Julian Oscillation. *J. Clim.*, **32** (20), 7055-7065 [10.1175/jcli-d-19-0144.1].

Zhang, H., J. Wang, L. Castro García, J. Zeng, C. Dennhardt, Y. Liu, and N. A. Krotkov, 2019: Surface erythemal UV irradiance in the continental United States derived from ground-based and OMI observations: quality assessment, trend analysis and sampling issues. *Atmos. Chem. Phys.*, **19** (4), 2165-2181 [10.5194/acp-19-2165-2019].

Zhou, Y, 2019: Extreme precipitation: theory, trends and monitoring. Research on Weather and Climate Variabilities and Their Mechanisms—Collected Essays in Commemoration of Academician Li Chongyin's 60 Years' Research in Atmospheric Sciences. Beijing: China Meteorological Press, ISBN: 978-7-5029-6969-1. [Article in Book] [Global Warming]

Zhou, Y., K. Nelson, K. I. Mohr, G. J. Huffman, R. C. Levy, and M. Grecu, 2019: A spatial-temporal extreme precipitation database from GPM IMERG. *J. Geophys. Res.: Atmos.*, **124**, 10344-103632019JD030449 [10.1029/2019jd030449].

Ziemke, J. R., L. D. Oman, S. A. Strode, A. R. Douglass, M. A. Olsen, R. D. McPeters, P. K. Bhartia, L. Froidevaux, G. J. Labow, J. C. Witte, A. M. Thompson, D. P. Haffner, N. A. Kramarova, S. M. Frith, L.-K. Huang, G. R. Jaross, C. J. Seftor, M. T. Deland, and S. L. Taylor, 2019: Trends in global tropospheric ozone inferred from a composite record of TOMS/OMI/MLS/OMPS satellite measurements and the MERRA-2 GMI simulation. *Atmos. Chem. Phys.*, **19** (5), 3257-3269 [10.5194/acp-19-3257-2019].