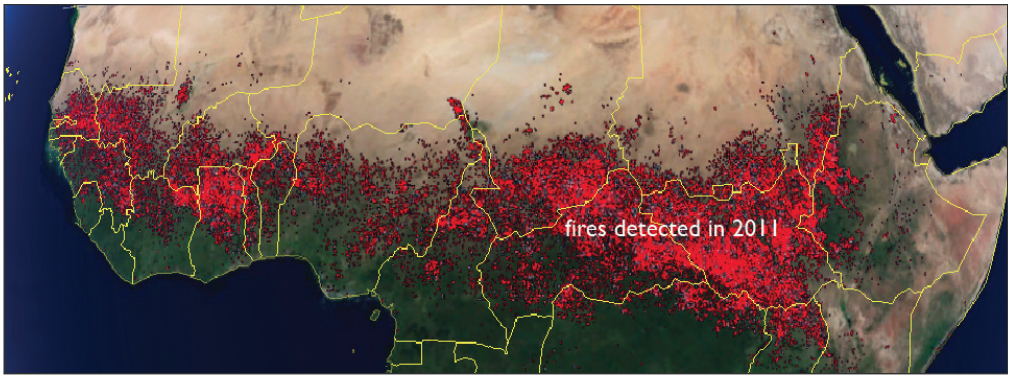
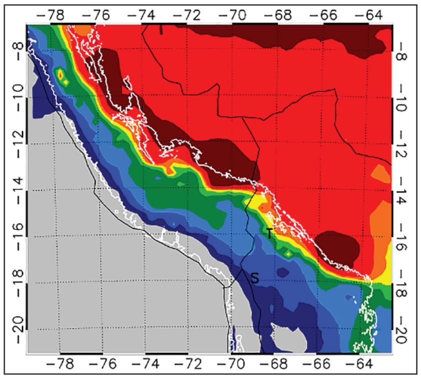
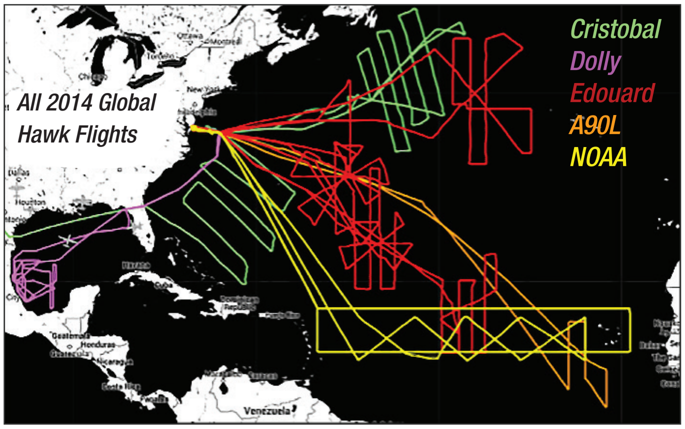
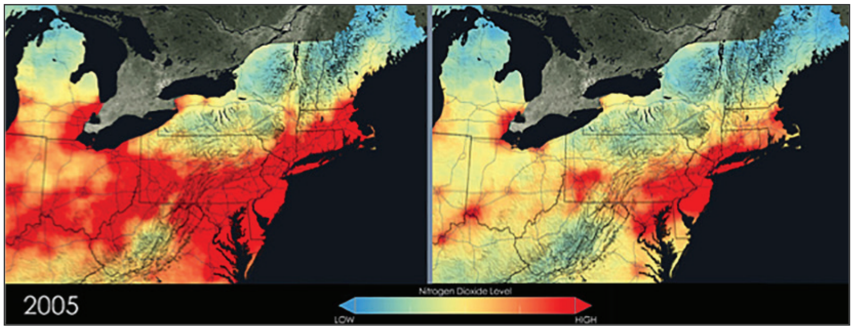
NASA/TM 2015-217530

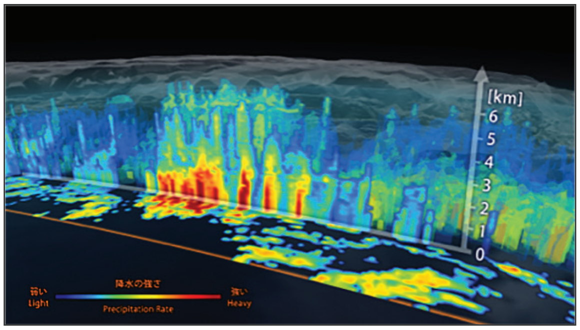
Atmospheric Research 2014 Technical Highlights











March 2015

Cover Photo Captions

UPPER LEFT

Fires detected over northern sub-Saharan Africa in 2011 by Modis on Terra and Aqua satellites. The study demonstrated a method for characterizing and deriving the trajectories of post-fire albedo dynamics from satellite data.

UPPER RIGHT

Area map of mean annual rainfall (1998–2012) in the Central Andes. The legend colors and the breakpoints distinguish between arid (gray to blue), transitional (green to orange), and humid (red to brown) climate zones. The Central Andes precipitation features tended to be smaller and weaker than the precipitation features in dry, mountainous, and dynamically linked regions in the tropics.

CENTER LEFT

Bill and Carol Lau celebrate Bill's retirement after 37 years of service to NASA and the Federal Government. During his Goddard career, Bill served as Senior Research Meteorologist, Head of the Climate and Radiation Branch, Chief of the Laboratory for Atmospheres, and Deputy Director of Earth Sciences for Atmospheres.

CENTER RIGHT

Summary of Global Hawk Flight Tracks for all 2014 flights. These flights included Hurricane Cristobal (green, August 26–27 and 28–29), Tropical Storm Dolly (purple, September 2–3), Invest A90L and the Saharan Air Layer (orange, September 5–6), Hurricane Edouard (red, September 11–12, 14–15, 16–17, 18–19), and two NOAA flights in the Atlantic Main Development Region for tropical cyclones (yellow, September 22–23, 28–29).

BOTTOM LEFT (2 panels)

Decrease in tropospheric NO_2 columns from 2005 to 2011 in the Eastern United States. This was due to technology improvements in response to Federal and state NO_x emissions reduction programs, including the implementation of emission control devices on power plants.

BOTTOM RIGHT

The first image captured by the Global Precipitation Mission (GPM) launched on February 27. The image shows a 3D view inside an extra-tropical cyclone observed off the coast of Japan by the Dual-frequency Precipitation Radar.

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

NASA/TM–2015-217530

Atmospheric Research 2014 Technical Highlights

March 2015

NASA STI Program ... in Profile

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 NASA Aeronautics and Space Database and its public interface, the NASA Technical Report 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.

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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Reader:

Welcome to the Atmospheric Research 2014 Atmospheric Research Highlights report. This report, as before, is intended for a broad audience. Our readers include colleagues within NASA, scientists ouside the Agency, science graduate students, and members of the general public. Inside are descriptions of atmospheric research science highlights and summaries of our education and outreach accomplishments for calendar year 2014.

This report covers research activities from the Mesoscale Atmospheric Processes Laboratory, the Climate and Radiation Laboratory, the Atmospheric Chemistry and Dynamics Laboratory, and the Wallops Field Support Office under the Office of Deputy Director for Atmospheres (610AT), Earth Sciences Division in the Sciences and Exploration Directorate of NASA's Goddard Space Flight Center. The following are some noteworthy events that took place during 2014:

Gail Skofronick Jackson and a team on international scientists began a new era in observations of rain and snow when NASA and the Japan Aerospace Exploration Agency (JAXA) launched the Global Precipitation Measurement mission (GPM) Core Observatory satellite on February 27, 2014. GPM is carrying advanced instruments that will set a new standard for precipitation measurements from space. The mission will advance our understanding of the water and energy cycles, and extend the use of precipitation data to directly benefit society.

Scott Braun, Paul Newman, and the Hurricane and Severe Storm Sentinel (HS3) team began science operations for its third and final field deployment at the Wallops Flight Facility on August 26, 2014. Science flights took place from August 26 to September 29. HS3 used NASA's Global Hawk unmanned aircraft to study how hurricanes form and intensify in the Atlantic basin. In all, HS3 conducted 10 science flightsduring 2014, including two over Hurricane Cristobal, one over Tropical Storm Dolly, and four over Hurricane Edouard.

Code 610AT scientists including Ken Pickering, Scott Janz, Jay Herman, Anne Thompson, and Tom McGee participated in the fourth and final field deployment for the Earth Venture DISCOVER-AQ project in July. NASA aircraft were used to focus on the Front Range region of Colorado from south of Denver to Ft. Collins to examine inflow to and outflow from the Front Range Region, studying the upslope and downslope flow over the mountains, and characterizing various emission sources.

610AT scientists also played key roles in numerous other field campaigns. These included: (1) The Integrated Precipitation and Hydrology Experiment (IPHEx) which was a ground validation campaign focused in the southern Appalachian Mountains. The campaign closely followed the launch of the Global Precipitation Measurement Mission (GPM) Core satellite CONvective TRansport of Active Species in the Tropics in early 2014; (2) Glenn Wolfe (JCET/614), Dan Anderson (graduate student UMD) and Tom Hanisco (NASA/614) participated in the (CONTRAST) campaign in Guam. CONTRAST research objectives were to quantify how large convective clouds redistribute atmospheric gases in the tropical atmosphere; and (3) Dr. Judd Welton as PI of the MPLNET network traveled and met with MPLNET partners to plan additional monitoring sites in Taiwan, Thailand, Vietnam, Indonesia, and Kuala Lumpur. MPLNET results have contributed to studies of dust, biomass, marine, and continental aerosol properties, the effects of soot on cloud formation, aerosol transport processes, and polar clouds and snow.

610AT scientists received many top professional honors and appointments during the year. Gail Skofronick Jackson was elevated to an Institute of Electrical and Electronic Engineers (IEEE) Fellow, Dr. George J. Huffman (612) and Ralph Kahn (613) received an AGU 2013 Editor's Citation for Excellence in Refereeing, W.-K Tao (612) received the award for Most Cited Article Award from the *Terrestrial, Atmospheric and Oceanic Sciences Journal of the Chinese Geoscience Union,* Matt McGill and his team (Code 612) received the 2014 "IRAD Innovators of the Year" Award, and Geoff Bland (610W) received the James Kerley Award awarded for the "Aerodynamically Stabilized Instrument Platform" (AeroPod).

The year was a time to bid farewell to Bill Lau who retired on October 1 after more than 37 years of service to NASA and the Federal government. During his career at Goddard he served as head of the Climate and Radiation Branch, Chief, of the Laboratory for Atmospheres, and Deputy Division Chief for Atmospheres. Bill led these organizations with confidence and authority. Throughout his career Bill received many prestigious awards for his research and scientific leadership. He is continuing his research at ESSIC and will serve as President (2015–2016) of the Atmospheric Sciences Division, American Geophysical Union.

We also said good buy to Bill Heaps and Charlie Jackman. Bill left after 38 years and was one of NASA's leading scientists on the application of Fabry Perot spectrometers and contributed to the NASA Laser Risk Reduction program to address problems in the development of laser transmitter technologies. Charlie leaves after 35 years of service. He was a creative scientist who was recognized as an international authority in the field of the chemistry and transport of the middle atmosphere, the stratosphere, and mesosphere.

Karen Mohr was welcomed as the new Associate Deputy Director for Atmospheres filling the position in February, recently vacated by Jim Irons. Karen joined Goddard as a research scientist in numerical modeling of convection and hydrologic processes. She became the team lead for providing global model inputs to the operational GPM rainfall retrieval algorithm. Karen also served as the science liaison for the NASA Headquarters Applied Science Program, where she has made significant contributions to research planning and program development. Karen's science and leadership skills will enable atmospheric research at Goddard to continue to excel in the years to come.

I am also pleased to welcome Matt Schwaller as Deputy Laboratory Chief for Code 612. Matt will provide a wide range of management services to the Laboratory. In addition, he will continue to serve as a member of the NASA Precipitation Measurement Missions (PMM) Science Team.

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

Steven Platnick

Deputy Director for Atmospheres

Earth Sciences Division, Code 610

March 2015

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1. INTRODUCTION

Atmospheric research in the Earth Sciences Division (610) consists of research and technology development programs dedicated to advancing knowledge and understanding of the atmosphere and its interaction with the climate of Earth. The Division's goals are to improve understanding of the dynamics and physical properties of precipitation, clouds, and aerosols; atmospheric chemistry, including the role of natural and anthropogenic trace species on the ozone balance in the stratosphere and the troposphere; and radiative properties of Earth's atmosphere and the influence of solar variability on the Earth's climate. Major research activities are carried out in the Mesoscale Atmospheric Processes Laboratory, the Climate and Radiation Laboratory, the Atmospheric Chemistry and Dynamics Laboratory, and the Wallops Field Support Office. The overall scope of the research covers an end-to-end process, starting with the identification of scientific problems, leading to observation requirements for remote-sensing platforms, technology and retrieval algorithm development; followed by flight projects and satellite missions; and eventually, resulting in data processing, analyses of measurements, and dissemination from flight projects and missions. Instrument scientists conceive, design, develop, and implement ultraviolet, infrared, optical, radar, laser, and lidar technology to remotely sense the atmosphere. Members of the various Laboratories conduct field measurements for satellite sensor calibration and data validation, and carry out numerous modeling activities. These modeling activities include climate model simulations, modeling the chemistry and transport of trace species on regional-to-global scales, cloud resolving models, and developing the next-generation Earth system models. Satellite missions, field campaigns, peer-reviewed publications, and successful proposals are essential at every stage of the research process to meeting our goals and maintaining leadership of the Earth Sciences Division in atmospheric science research. Figure 1.1 shows the 20-year record of peer-reviewed publications and proposals among the various Laboratories.

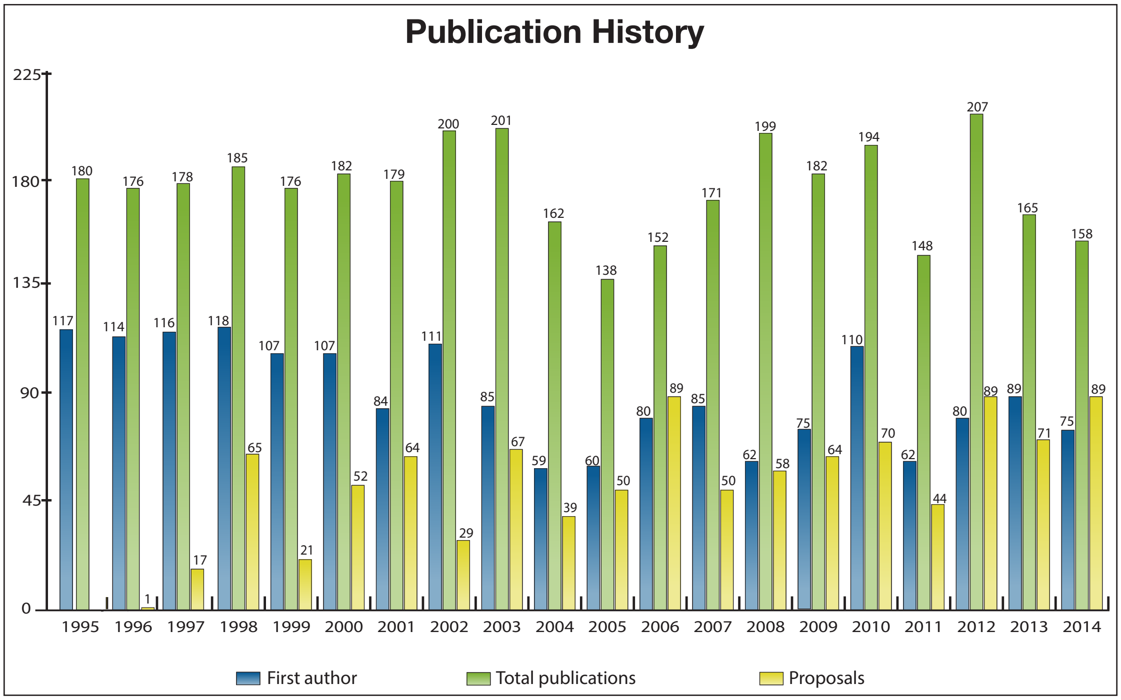


Figure 1.1: Number of proposals and referred publications by Atmospheric Sciences members over the years. The green bars are the total number of publications and the blue bars the number of publications where a Laboratory member is first author. Proposals submitted are shown in yellow.

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

Interdisciplinary research is carried out in collaboration with other laboratories and research groups within the Earth Sciences Division, across the Sciences and Exploration Directorate, and with partners in universities and other government agencies. Members of the Laboratories interact with the general public to support a wide range of interests in the atmospheric sciences. Among other activities, the Laboratories raise the public's awareness of atmospheric science by presenting public lectures and demonstrations, by making scientific data available to wide audiences, by teaching, and by mentoring students and teachers. The Atmosphere Laboratories make substantial efforts to attract and recruit new scientists to the various areas of atmospheric research. We strongly encourage the establishment of partnerships with Federal and state agencies that have operational responsibilities to promote the societal application of our science products. This report describes our role in NASA's mission, provides highlights of our research scope and activities, and summarizes our scientists' major accomplishments during calendar year 2014. The composition of the organization is shown in Figure 1.2 for each code. This report is published in a printed version with an electronic version on our atmospheres Web site, http://atmospheres.gsfc.nasa.gov/.

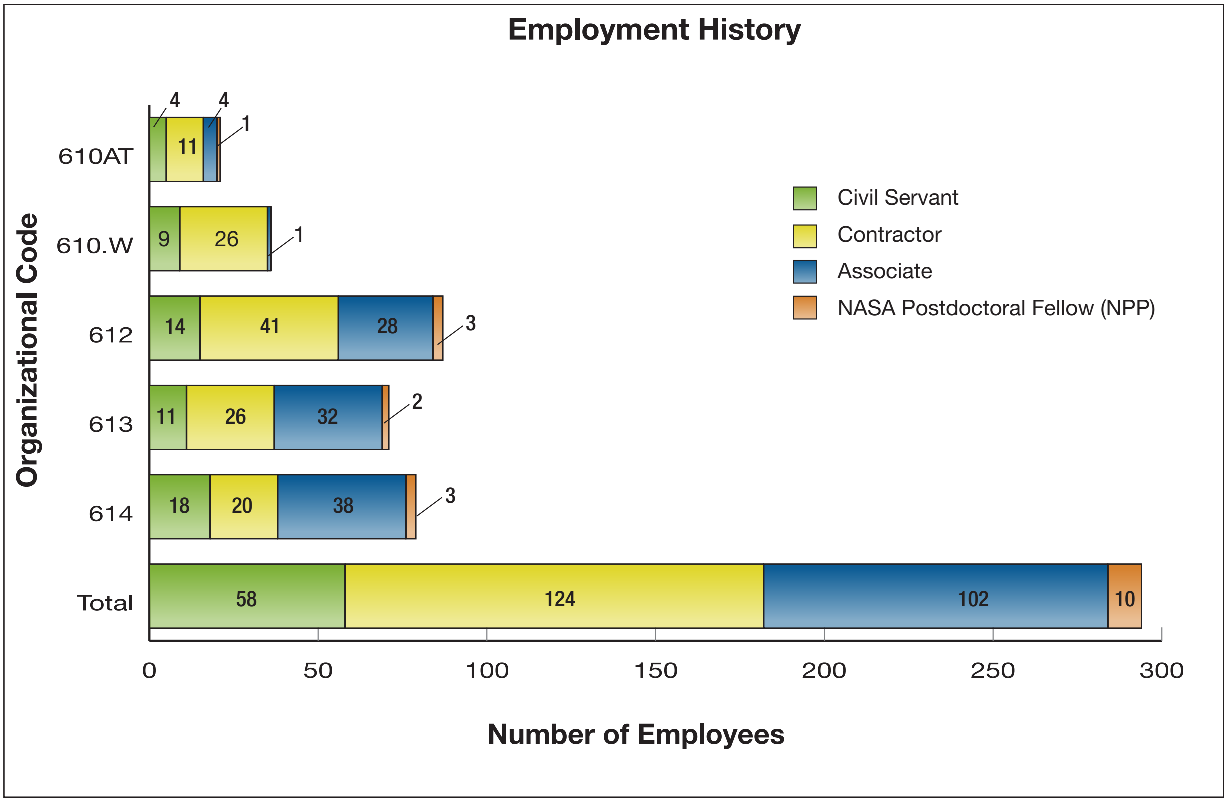


Figure 1.2: Employment composition of the members of Atmospheric Sciences.

2. SCIENTIFIC HIGHLIGHTS

Atmospheric research at Goddard has a long history (more than 40 years) in Earth Science studying the atmospheres of both the Earth and the planets. The early days of the TIROS and Nimbus satellites (1960s–1970s) emphasized ozone monitoring, Earth radiation, and weather forecasting. Planetary atmosphere research was carried out with the Explorer, Pioneer Venus Orbiter, and Galileo missions until around 2000. In the recent years, Earth-orbiting satellite (EOS) missions have provided an abundance of data and information to advance knowledge and understanding of atmospheric and climate processes. Basic and crosscutting research has been conducted using observations, modeling, and analysis. Observation data has been provided from 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 decadal mission recommendations made in the *Decadal Survey* by the National Academy of Sciences in 2007 (http://www.nap.edu/catalog/11820.html) (see Section 3.1.1). The following sections summarize some of the scientific highlights of each Laboratory and the Wallops Field Office for the year 2014. The individual contributors are named at the end of each summary. Additional highlights and other information may be found at the website: atmospheres.gsfc.nasa.gov.

2.1. Mesoscale Atmospheric Processes 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 as well as 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 has been 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 plays a key science leadership role in the Tropical Rainfall Measurement Mission (TRMM), launched in 1997 and still operating, and in developing the Global Precipitation Measurement (GPM) mission concept. 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. An electronic version of the full highlights may be found on the Mesoscale Atmospheric Processes Laboratory Web site, http://atmospheres.gsfc.nasa.gov/meso/science/index.php?year=2014.

2.1.1. Effect of Aerosols on Mesoscale Convective Systems

Mesoscale convective systems (MCS) have large (~10^2 km) cloud anvils extending laterally outward from deep convective cores. MCS impact the climate system by contributing almost half of the total precipitation in the tropics and by their anvils controlling both solar and terrestrial radiation fluxes. We seek observational support of the hypothesis that aerosols, e.g. ice nuclei, indirectly modulate climate by their impact on MCS anvil development.

Two international field campaigns, the African Monsoon Multidisciplinary Analysis (AMMA) and the Tropical Warm Pool–International Cloud Experiment (TWP-ICE), took place in 2006 in West Africa and the Australia tropical coast, respectively.

These field campaigns provided extensive observations of MCS in both polluted and clean environments. Both the field campaign and satellite-based observations were compared to cloud-resolving model (CRM) simulations in order to formulate and validate concepts on aerosols and cloud anvils.

The results demonstrated that cloud anvils are sensitive to aerosol number concentration. The anvil modeled in the polluted environment has a scale of 400 km (Figure 1), close to that observed over AMMA, in contrast to the scale of 100 km in a clean environment typically observed in TWP-ICE. Current climate models usually overlook the indirect effect of ice nuclei (e.g., dust particles,) on climate change. This case study demonstrated that ice nuclei are an important modulator of clouds and radiation and therefore of climate change. The study also provided a quantitative example to accurately represent the ice nuclei effects in climate models. ***(Xiping Zeng, Wei-Kuo Tao, Harold Pierce, and Toshihisa Matsui)***

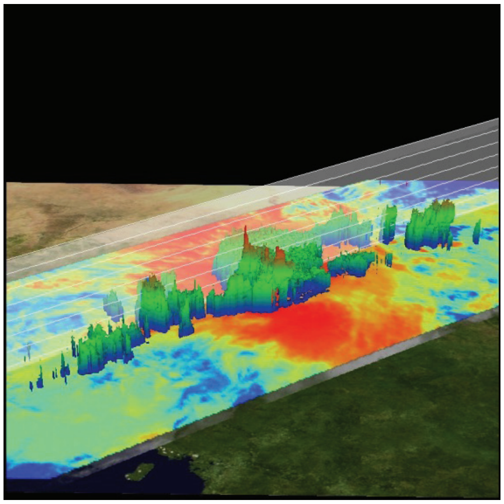


Figure 2.1: This three-dimensional image of AMMA MCS from TRMM satellite Precipitation Radar at ~0433 UTC on August 11, 2006 over west-central Africa, shows the volume of convective clouds (Z >15 dBZ). The image is overlaid on an infrared image from TRMM's VIRS that represents the cloud anvil (red) associated with the convective clouds.

2.1.2. Hurricane and Severe Storm Sentinel: Initial Findings from 2013

The goal of the mission is to improve the understanding of processes that control hurricane formation, intensity change and the relative roles of the large-scale environment and smaller-scale processes in the inner-core region of storms (i.e., the eyewall and rain bands). The Hurricane and Severe Storm Sentinel (HS3) uses two Global Hawk (GH) UASs deployed from the Wallops Flight Facility. One (designated the environmental GH) is designed to sample temperature, humidity, winds, and Saharan dust in the storm environment while the other (designated the over-storm GH) is focused on measuring winds and precipitation within the storm. Nine flights were conducted, seven with the environmental GH and two with the over-storm GH. Over-storm GH flights were limited due to infrequent convectively active targets and two return-to-base flights in which a navigation unit failed. Two of the nine flights explored the structure of the Saharan air layer. Four flights flew into the disturbance associated with Tropical Storm Gabrielle. Two took place prior to formation, one at the time of formation, one prior to redevelopment of the disturbance back to a tropical storm. One flight took place over Hurricane Ingrid with the over-storm GH, but cold fuel temperatures forced an early return to base. One flight into the newly reformed Tropical Storm Humberto and revealed a hybrid tropical/extratropical structure, and one flight over Invest 95L was a non-developer. HS3 has had deployments in 2012 and 2013 and will conduct another deployment in 2014. ***(Scott Braun (612) and Paul Newman (610), NASA GSFC)***

2.1.3. Wind Retrieval Algorithms for the HIWRAP

Atmospheric winds in precipitating systems are one of the most fundamental characteristics of the atmosphere and are crucial for understanding and forecasting high-impact events such as hurricanes. Knowledge of the three-dimensional (3D) distribution of winds in precipitating systems such as hurricanes is crucial for understanding their dynamics and predicting their evolution. A mathematical/computational technique for retrieving 3D winds from a new class of airborne Doppler radar that scans in a cone below the aircraft was developed. The algorithms will allow retrievals of three-dimensional winds at high resolution from a new class of airborne radar that fly on the unmanned Global Hawk aircraft. The new algorithms, radar and aircraft, have the potential for significant improvements in our understanding and monitoring of ocean-based precipitating systems. As an example, the figure below shows HIWRAP horizontal wind vector retrievals overlaid on Ku band reflectivity at 2-km height in Hurricane Karl during the Genesis and Rapid Intensification Processes (GRIP) field experiment conducted in 2010. This figure combines ~12 hours of data and the grid spacing of the retrievals is 1 km. The retrieval of three-dimensional atmospheric winds from space-based instruments has never been done before, and the HIWRAP radar along with the present retrieval algorithms can provide a testing ground for future space instruments and scientific understanding. ***(Stephen Guimond (612), GSFC and UMD/ESSIC)***

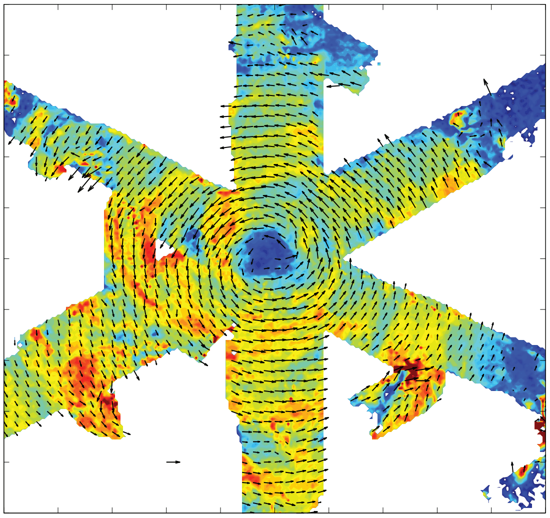


Figure 2.2: HIWRAP wind vector retrievals at 2-km height in Hurricane Karl (2010) using a synthesis of ~12 hours of data.

2.1.4. Characteristics of Precipitation Features in the Central Andes

Climatologically, the Central Andes range (from 7°S to 21°S) covering southern Peru, Bolivia, and northern Chile contains 90 percent of the world's tropical glaciers. TRMM-observed precipitation features and surface observations were used to learn more about the spectra of precipitation features as well as the size, intensity, and rainfall rates of observed features (1998–2012) in the Andean highlands (>1000 m). The majority of annual rainfall in the Central Andes is contributed by precipitation featuring weak, shallow convection (<12 km); short durations (<60 min); and light to light-moderate rainfall rates (0.5–4.0 mm hr-1). Well-organized and intense precipitation features do occur, but there are not enough of them to make an impact on regional rainfall statistics. The Central Andes precipitation features tended to be smaller and weaker than those in comparably dry (West Africa), mountainous (Himalayas), and dynamically linked (Amazon) regions in the tropics.

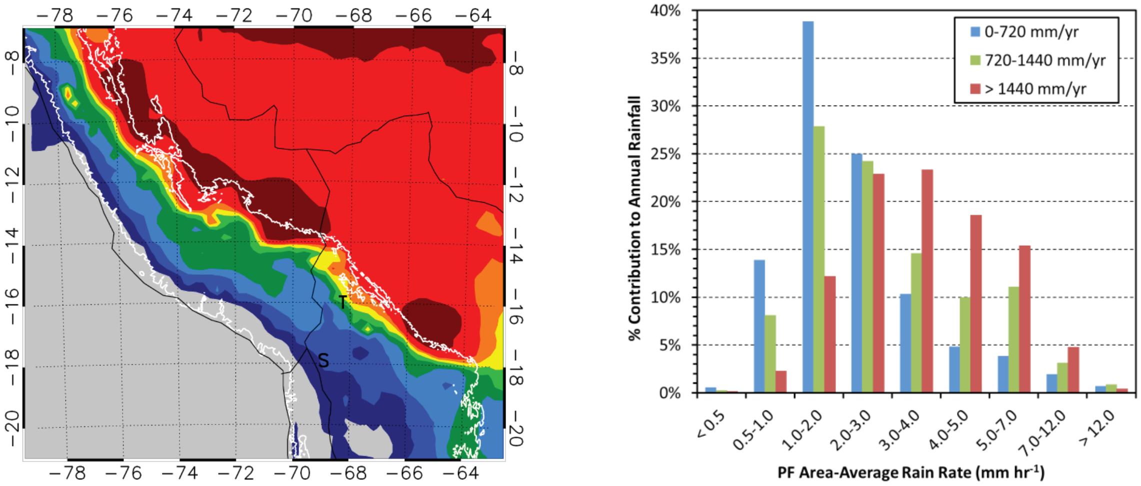


Figure 2.3: (a) Area map of mean annual rainfall (1998–2012). The white contour is the 1000 m elevation line defining the eastern and western boundaries of the study area. (b) TRMM-observed precipitation feature rain rates vs. annual rainfall contribution for arid (blue), humid (red), and transitional (green) climate zones.

Threats to ancient rangelands in the high Andes due to glacier recession and climate change inspired our work to characterize the glacier recession rates, valley hydrology and ecosystem functioning, and regional rainfall regimes from field and remote-sensing data. We have provided strong evidence than rangeland health is closely tied to the light, frequent rainfall events that occur in the present climate, and we will continue to work toward understanding how these rainfall regimes will change in the future using regional climate modeling. ***(Karen Mohr (610), GSFC; Daniel Slayback (618), GSFC and SSAI, Inc; and Karina Yager (618), GSFC and SSAI, Inc)***

2.1.5. Comparison of ECMWF Weather Model Precipitation to TRMM

Numerical weather models are valuable, but they require continued examination to determine the accuracy of their various forecast parameters. Here, the precipitation output of a model is compared to observational products for the years 2004–2011. Use of these nearly global NASA products is crucial to determining the skill of the model. Forecasts from the state-of-the-art European Centre for Medium range Weather Forecasting (ECMWF) model are compared to the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) and the TRMM Precipitation Radar (PR) products. A change in the model physics in late 2007 yielded much better agreement with the satellite products in the large-scale averages.

Since 2007, the model continues to poorly simulate the average cycle of precipitation over the course of a day. Over land, the model maximizes precipitation near local-noon, whereas the TRMM products correctly place it in the afternoon or evening. The model continues to show biases related to the amount of time since the start of the model forecast. The ECMWF implemented a new convective parameterization in November 2007; this study shows that the change was successful at reducing the overall tropical precipitation bias, but it failed to substantially address the diurnal-cycle problem. It is a matter for future research for other models to address the high bias in the tropics, as the ECMWF has started to do, and for models in general to achieve more-accurate depictions of the diurnal cycle. However, the diurnal cycle issue remains a problem at higher latitudes. ***(Christopher Kidd (612), GSFC and UMD/ESSIC)***

2.1.6. An Experimental Study of Spatial Variability of Rainfall: Influence of Weather Systems in Seasonal Variability

Non-uniform beam filling within the instantaneous field of view is a key uncertainty in satellite-based precipitation estimates. This study investigates the spatial variability of rainfall through a rain gauge network in the Southern Delmarva Peninsula. A continuous record of gauge observations was available from May 2005 to July 2010 at 11 sites where the gauge separation distance varied from 1 km to 150 km, and each site had dual or triple gauges. The correlation distance was 17 km for the entire experiment, but significant variations occurred between seasons, between cold and warm periods, and between years. There was a strong correlation between the seasonal and storm-based spatial variability. The convection dominated the variability during summer while autumn was dominated by tropical cyclones when they occurred. The study intends to quantify the spatial variability of rainfall within the instantaneous field of view of microwave-sensor-based rainfall estimates and within the footprint of spaceborne radars. The dominance of particular weather systems in a given season and warm/cold period is one of the key conclusions of this study. The unique database with a continuous gauge record over five years enabled the investigation of the spatial variability between the years in a given season, warm/cold periods, and year. Interestingly, the spatial variability was noticeably different between the years in the presence and absence of tropical cyclones during autumn. The study showed the importance of long-term collection of precipitation data. ***(Ali Tokay (612), GSFC and JCET/UMBC)***

2.1.7. Scattering Computations of Snow Aggregates from Simple Geometrical Particle Models

Proper interpretation of radar and radiometer measurements from cloud and precipitation requires an understanding of the electromagnetic scattering characteristics of snow aggregates. Because of the complex and irregular shapes of snowflakes, researchers often use numerical techniques to compute their scattering properties. Although particle models using simple geometric shapes with an effective dielectric constant for the ice-air mixture have been used frequently in an attempt to provide approximate results for aggregates, their accuracy in reproducing scattering parameters used for radars and radiometers has not been consistently checked. The primary purpose of this study is to evaluate the accuracy of using simple particle shapes (spherical/spheroidal) with two different mass density assumptions, namely the variable and fixed snow density models, to reproduce the scattering properties of snow aggregates over the range of GPM frequencies from 10 to 183 GHz. Our results indicate that the scattering properties of aggregates can be fairly well reproduced by using a sphere/spheroidal particle model with a fixed mass density and setting the mass of the sphere/spheroid to be the same as that of the aggregate. A mass density of 0.2 g/cm^3 serves the purpose well up to frequencies of about 35 GHz and equivalent ice diameters up to 2.5 mm. At frequencies of 89 GHz and above, however, a higher snow density of 0.3 g/cm^3 provides better overall agreement. Randomly oriented spheroids perform better than spheres by suppressing the strong resonance/anti-resonance oscillations that are manifest in the results from spheres. ***(Liang Liao,GESTAR/MSU; and Robert Meneghini (612), NASA)***

2.1.8. Simulations and Visualizations of Hurricane Sandy as Revealed by the NASA Advanced Global Modeling and Visualization Systems

NASA's Coupled Advanced Modeling and Visulation (CAMVis) systems produced a remarkable seven-day track and intensity forecast of Hurricane Sandy, which was made possible by improved simulation of the interaction of an easterly wave and westerly wind belt, and of the impact of tropical waves associated with a Madden-Julian Oscillation (MJO). Figure 2.4 shows 4D visualizations of Hurricane

Sandy consisting of temporal evolution of 3D visualization at 1200 UTC Oct. 27 and 1200 UTC Oct. 28. One of the major challenges in tropical cyclone genesis prediction is the accurate simulation of the complex interactions across a wide range of scales, from the large-scale environment (deterministic) to mesoscale flows to convective-scale motions (stochastic). Therefore, the improvement in intensity prediction relies on the accurate representation of a tropical cyclone's structure and its interactions with both large-scale environmental processes and small-scale moist processes (such as convection and surface fluxes exchanges). In this study, the role of multiscale processes associated with tropical waves in the predictability of Hurricane Sandy (2012) is studied by the facilitation of the Coupled Advanced global Modeling and Visualization (CAMVis) systems, which brings the multiscale interaction processes into vivid illustration. ***(Bo-Wen Shen (612), ESSIC; Jui-Lin F. Li, Samson Cheung, David Ellsworth and Wu-Ling Wu)***

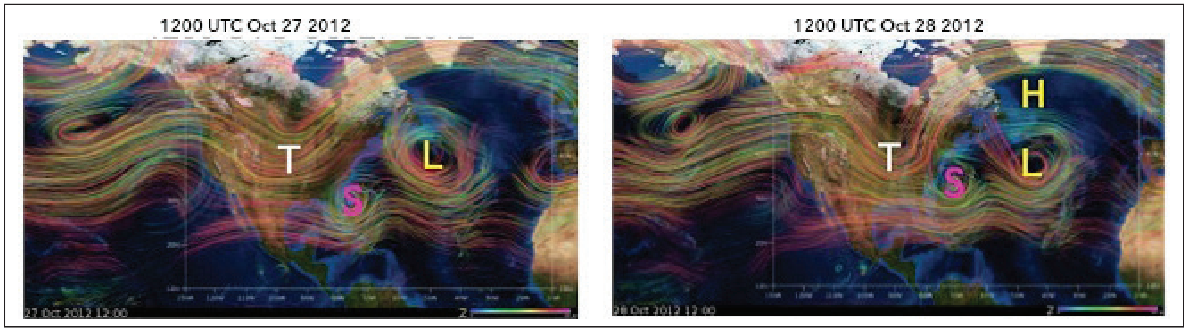


Figure 2.4: The NASA Coupled Advanced Modeling and Visualization (CAMVis) systems is used to produce a remarkable seven-day track and intensity forecast of Hurricane Sandy, which is made possible by improved simulation of the interaction of an easterly wave and westerly wind belt, and of the impact of tropical waves associated with a Madden-Julian Oscillation (MJO).

2.1.9. Upgraded Global Air-Sea Turbulent Fluxes from Goddard's Satellite-based Surface Turbulent Fluxes Datasets and their Climate Applications

About two-thirds of global precipitation falls in the tropics, mainly attributable to air-sea surface latent and sensible heat fluxes. This provides about three-fourths of the energy driving global atmospheric circulation via Hadley cells. Accurate global sea surface fluxes measurements are therefore crucial to understanding the global water and energy cycles. Oceanic evaporation is a major component of the global oceanic fresh water flux and is particularly useful for predicting oceanic circulation and transport. Remote sensing is a valuable tool for global monitoring of these flux measurements. The Goddard Satellite-based Surface Turbulent Fluxes (GSSTF) algorithm has been developed and applied to remote-sensing research and applications for two decades. GSSTF2c and GSSTF3 are two recently improved and upgraded datasets using the corrected SSM/I brightness temperature (TB) by removing artificial temporal trend due to the Earth incidence angle (EIA) decease found among the SSM/I sensors. C.-L. Shie, principal investigator on the GSSTF project, plans to further develop the GSSTF algorithm and extend its application to the GPM mission for producing the associated air-sea turbulent fluxes by using the available related parameters such as TB, SST, surface wind speed (U) and specific humidity (Q) retrieved from GPM. ***(Chung-Lin Shie (612), UMBC/JCET; Long S. Chiu, and Si Gao)***

2.1.10. Multi-sensor Satellite Radiance-Based Evaluation of NASA-Unified WRF

Researchers for the first time used the multi-instrumental Goddard-Satellite Data Simulator Unit (G-SDSU), to compare output from the regional Earth system model, the NASA Unified-Weather

Research and Forecasting (NU-WRF) model, to multi-sensor signals from the A-Train satellites over the West Africa. Figure 2.5 shows MODIS Tb11μm overlaid with AMSR-E $\mathrm{Tb}_{89\mathrm{GHz}\,(V)}$, which revealed detailed storm structure through a view of cloud and precipitation signals. The same satellite signals were simulated from the NU-WRF using the multi-instrumental G-SDSU simulator. CloudSat CPR reflectivity and the CALIPSO CALIOP backscattering signals showed detailed profiles of mineral dust and multi-layer cloud structure. Similar signals were simulated from the NU-WRF via G-SDSU, which revealed strengths and weaknesses of fully coupled aerosol-cloud-precipitation-land simulation.

This Noble multi-sensor radiance-based evaluation for the first time showed detailed aspects of fully coupled aerosol-land-cloud-precipitation processes. The G-SDSU and the comprehensive evaluation framework created a new benchmark for evaluating and developing a complex regional Earth System model. The G-SDSU and multi-instrumental evaluation framework can be applied to various current (A-Train, TRMM, GPM, Suomi NPP) and upcoming (SMAP, ACE) satellite missions. ***(Toshi Matsui (612), GSFC and ESSIC UMD)***

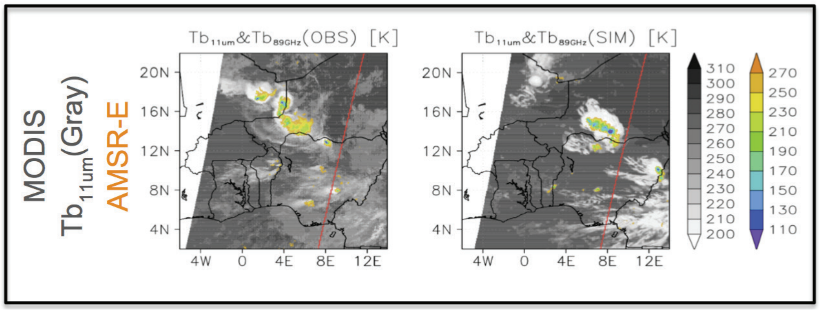


Figure 2.5: For the first time, NASA's multi-instrumental satellite simulator, G-SDSU compared output from the regional Earth system model, NASA-Unified WRF, to multi-sensor signals from the A-Train satellites over the West Africa.

2.1.11. TRMM and GPM Observe a Rare Sahara Desert Storm

On August 6, 2014, the TRMM and GPM satellites captured a swarm of thunderstorms over a portion of the Sahara Desert where rain is particularly rare. Both the TRMM and GPM satellites have a Ku-band radar capable of revealing the three-dimensional structure of precipitation. The GPM satellite flew over the eastern side of the thunderstorm cluster in the early evening (7 p.m. local time) and saw three wide rain features producing lightning. Each of these three features were 50–80 km across, suggesting they each contained multiple rain cells. The World Wide Lightning Location Network (WWLLN) saw a somewhat higher flash rate in the evening storms observed by GPM compared to the WWLLN flash rate for the single-cell storms seen a few hours earlier by TRMM. Almost half of the lightning that the TRMM LIS instrument has observed all year in this very dry portion of the Sahara Desert occurred in connection with the August 6 thunderstorm cluster. Rare thunderstorms, which contribute significantly to the annual rainfall accumulation in the east-central Sahara Desert, can only be studied from space; this part of the Sahara lacks a network of ground radars, and only a handful of location in this large region contribute rain-gauge observations to public data archives. ***(GPM Team, GSFC)***

2.1.12. The Airborne Cloud-Aerosol Transport System

The Airborne Cloud-Aerosol Transport System (ACATS) is a new lidar built at GSFC that can be used to determine horizontal wind speed and direction, directly retrieve of cloud/aerosol extinction, and capture radiative/optical properties of dust, smoke, and clouds. ACATS data products consist of three levels: Level 1A includes the total backscatter data computed similar to CALIPSO and the Cloud Physics Lidar (CPL); Level 1B data includes particulate and molecular backscatter computed using the high spectral resolution lidar (HSRL) technique; and Level 2 data includes HSRL derived optical properties such as extinction. As currently configured, the ACATS instrument houses a telescope that collects the backscattered light at a 45-degree view angle and passes it through to the receiver subsystem. A Fabry-Perot interferometer located in the receiver provides ACATS with the spectral resolution needed to resolve the HSRL extinction measurement and wind velocity.

Obtaining an accurate assessment of cloud and aerosol properties and their transport remains a major challenge in understanding and predicting the climate system. The ACATS data products have a large range of applications to significant climate system issues, such as examining cirrus optical properties and convective outflow in tropical storms, assessing dust and smoke transport, and investigating cloud-aerosol interactions and radiative effects. Figure 2.6 shows an example of the retrieved ACATS total backscatter ($km^{-1}sr^{-1}$) from September 26, 2012 shows water and ice clouds between 5 and 10 km, as well as a smoke plume below 5 km as the ER-2 flew over the state of Montana. ACATS operates at 532 nm with an off-nadir view angle of 45 degrees and a telescope that rotates to 4 different look-angles. This image is from the forward direction (0-degree look-angle).

ACATS also advances component technologies and algorithm development by producing an airborne instrument directly applicable to prototyping and validation for NASA's Cloud-Aerosol Transport System (CATS) instrument for the ISS. ***(John Yorks (612), GSFC and SSAI)***

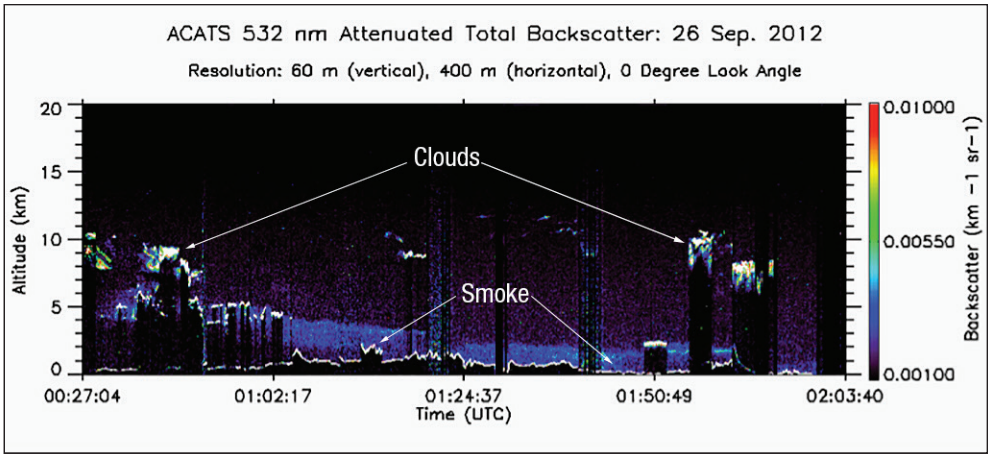


Figure 2.6: This ACATS lidar image was captured by the ER-2 as it flew over Montana. Using 532 nm with an off-nadir view angle of 0 degrees, the retrieved total backscatter ($km^{-1}sr^{-1}$) shows water and ice clouds between 5 and 10 km, as well as a smoke plume below 5 km.

2.1.13. Hurricane and Severe Storm Sentinel (HS3)—2014 Highlights

Using the NASA Global Hawk and WB-57, the HS_3 mission successfully overflew four Atlantic tropical cyclones in 2014, including two major hurricanes (four Global Hawk flights over Hurricane Edouard, three WB-57 flights over Hurricane Gonzalo). Data from the HS_3 2014 field campaign included information from the Cloud Physics Lidar (CPL), Scanning High-resolution Interferometer Sounder (S-HIS), dropsondes from the Airborne Vertical Atmospheric Profiling System (AVAPS), and the Hurricane Imaging Radiometer (HIRAD). For example, CPL and S-HIS data gathered on September 14–15 when Edouard was undergoing rapid intensification into a strong Cat-2 hurricane are shown in Figure 2.7, below. CPL data showed the cloud tops over the eyewall and outer rain regions, but a sharp drop in cloud heights during passage over the eye. A dropsonde released into the eye and lower eyewall measured the surface pressure at 967 hPa with a wind speed of 40 ms^{-1} (77 kt); this suggested that the center's minimum pressure was probably closer to 960 hPa. The values were ~10 hPa and ~10 kt greater than measured four hours earlier by a NOAA P-3.

The Global Hawk provides a valuable capability for mapping out large regions of the storm and its environment. Despite being a relatively quiet season, HS3 was able to take measurements in four named storms, including two major hurricanes. The Hurricane Edouard flights sampled the majority of Edouard's life cycle, from initial tropical storm, through rapid intensification, and eventual rapid weakening. The Gonzalo flights with the WB-57 (the "over-storm" Global Hawk failed to make it to Wallops for a second year, forcing HS3 to move HIRAD and HIWRAP to the WB-57) provided HS3's first good over-storm measurements for a hurricane and will provide valuable information on concentric eyewall structure. This work provides a significant set of observations for understanding how the large-scale environment (including Saharan air) impacts developing storms and can provide important information for the analysis of data in hurricanes from satellite data such as from TRMM, GPM, Aqua, CALIPSO, and NPP. ***(Scott Braun (612) GSFC)***

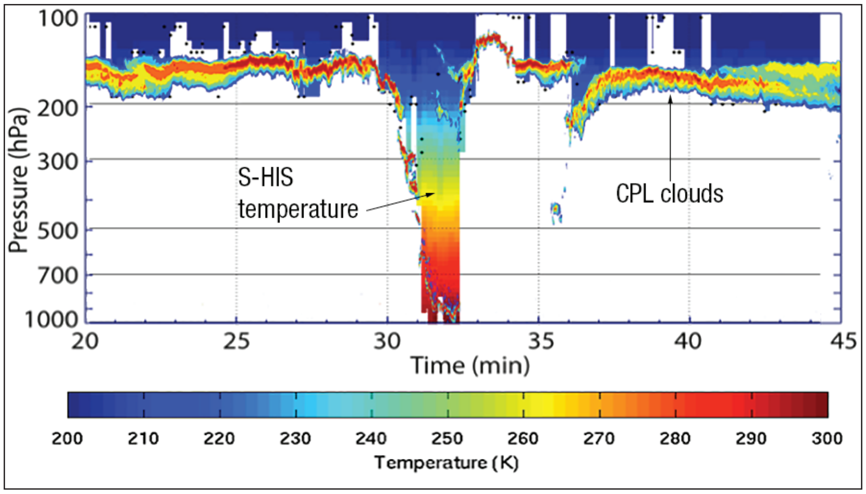


Figure 2.7: CPL and S-HIS measured the eye of Hurricane Edouard during rapid intensification on September 14–15.

2.1.14. Assimilating Data from the Global Hawk Improves Hurricane Forecast

Assimilating data from NASA's HIWRAP radar, which was on the Global Hawk during the GRIP experiment in 2010, significantly improved forecasts of Hurricane Karl. The image below shows the evolution of observed maximum winds compared to those in forecasts, with and without assimilation. All six assimilation experiments show large improvements over the experiments without assimilation. The results show that data from unmanned aircraft can potentially be used to improve hurricane forecasting in the future. Since the Global Hawk has a maximum flight duration of about 26 hours, which is two to three times that of other hurricane-observing aircraft, there are several significant advantages to using the plane as a hurricane reconnaissance system. For example, it can reach tropical cyclones much farther from land than other aircraft. For cyclones close to land, the Global Hawk can remain on station much longer, which could provide near-constant monitoring. This advancement would be most beneficial forecasting tropical cyclones in data-sparse locations or during periods of large forecast uncertainty and intensity changes. Currently NOAA plans to use the Global Hawks for hurricane reconnaissance in 2015 and 2016**.** ***(Jason Sippel, Lin Tian, Gerry Heymsfield, and Scott Braun (612) GSFC and GESTAR)***

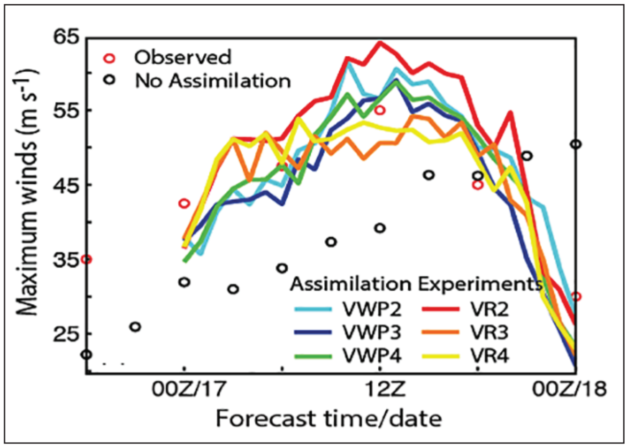


Figure 2.8: The FEER emissions product has good global coverage. Major burning regions are clearly in Central and Southern African regions, Central South America and Southeast Asia.

2.2. Climate and Radiation Laboratory

One of the most pressing issues humans face is to understand the Earth's climate system and how it is affected by human activities now and in the future. This has been the driving force behind many of the activities in the Climate and Radiation Laboratory. Accordingly, the Laboratory has made major scientific contributions in five key areas: hydrologic processes and climate, aerosol-climate interaction, clouds and radiation, model physics improvement, and technology development. Examples of these contributions may be found in the list of refereed articles in Appendix II and in the material updated regularly on the Code 613 Laboratory Web site: http://atmospheres.gsfc.nasa.gov/climate/.

Key satellite observational efforts in the Laboratory include MODIS and MISR algorithm development and data analysis, SORCE solar irradiance (both total and spectral) data analysis and modeling, and TRMM and ISCCP data analysis. Leadership and participation in science and validation field campaigns provide key measurements as well as publications and presentations. Laboratory scientists serve in key leadership positions on international programs, panels, and committees, serve as project scientists on NASA missions and principal investigators 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 2014 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 Web site contains recent significant findings in these and other areas.

The study of aerosols is important to Laboratory scientists for many reasons: (1) Their direct and indirect effects on climate are complicated and not well-quantified; (2) Poor air quality due to high aerosol loadings in urban areas has adverse effects on human health; (3) Transported aerosols provide nutrients such as iron (from mineral dust and volcanic ash), important for fertilizing 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 are summarized are below. An electronic version of the full highlight may be found on the Atmospheric Chemistry and Dynamics Laboratory Web site, http://atmospheres.gsfc.nasa.gov/acd/science/index.php?year=2014.

2.2.1. Effects of Antarctic Blowing Snow on Outgoing Thermal Infrared Radiation

Blowing snow is a common phenomenon over the Polar Regions. Over large areas of East Antarctica, blowing snow occurs over 60 percent of the time during the winter months. Previous studies have shown that it has significant impacts on the ice-sheet-mass balance and hydrological processes. Recently, Goddard scientists found the first observational evidence that blowing snow substantially affects the outgoing, long-wave radiation (OLR) over the Antarctic ice sheet. These results followed from the study that combined observations from three NASA sensors: CERES, which measures the Earth's radiation budget; MODIS, which observes the Earth in 36 spectral bands; and the CALIOP lidar, which provides the vertical profile needed for blowing snow detection.

Under cloud-free conditions, if OLR with blowing snow is greater than OLR without it then the presence of blowing snow leads to more radiation leaving the Earth; hence, blowing snow cools the surface-atmosphere system. In opposite case, blowing snow warms the system. This study shows that blowing snow events can cause significant perturbations in top of atmosphere long-wave radiation. These perturbations may affect climate in the regional and even global scale, which is currently unaccounted for in climate models. In the future, lidar systems on board of future missions (such as the Aerosol-Cloud-Ecosystems (ACE) and the Ice, Cloud, and land Elevation Satellite-2 (ICESat-2)) could help to extend the blowing snow record, which will enable the annual variation and long term trend studies of blowing snow radiative effects. ***(Yuekui Yang, Stephen Palm, Alexander Marshak, Dong Wu, Hongbin Yu, and Qiang Fu, (613) GSFC)***

2.2.2. New Biomass-Burning Smoke Emissions Dataset Fills Gap between Previous Estimations and Expected Values

Fires burn extensively in most vegetated parts of the world. Smoke from biomass burning contributes a major portion of the annual carbon emissions to the atmosphere. Thus, an accurate smoke emissions inventory is imperative to correctly understand the impacts of biomass burning on the global climate system and regional environmental dynamics. Smoke emissions have long been calculated by bottom-up approaches, using burned area, fuel content or biomass density, and burn efficiency data, along with experimentally determined emission factors to estimate smoke emissions for any given area. A major effort to create a new emissions dataset was undertaken during the past several years. The result is the Fire Energetics and Emissions Research (FEER) emissions product, available at http://feer.gsfc.nasa.gov/data/emissions/. This globally gridded product at 1°×1° resolution was derived from satellite measurements of FRP and aerosol optical depth (AOD), in conjunction with model-assimilated wind fields. The building blocks for the product are emission coefficients that relate FRP directly to the smoke emission rate. The FEER emissions product is unique in that it directly relates the two quantitative datasets of interest: fire radiative power (FRP) and smoke emissions, and it provides emission coefficients at a comparatively high spatial resolution that is easily amenable to verification and validation. Figure 2.9 shows FEER.v1 estimates of aerosol total particulate matter (TPM) for all of 2010 plotted on a global grid with 0.5°×0.5° resolution. These values were generated by multiplying the coefficients of emission (C_e) with fire radiative power (FRP) using the FEER.v1 Ce product combined with the GFASv1.0 FRP monthly data. Major burning regions are clearly seen in Central and Southern African regions, Central South America and Southeast Asia.

Fire is a major contributor of carbon emissions to the climate system, and at a time when climate change is of high scientific significance, an accurate representation of biomass burning emissions is desperately needed. FEER emissions product is currently being used in a major interdisciplinary study on how fires impact the devastating droughts in sub-Saharan Africa. ***(Luke Ellison and Charles Ichoku, (613, GSFC and SSAI))***

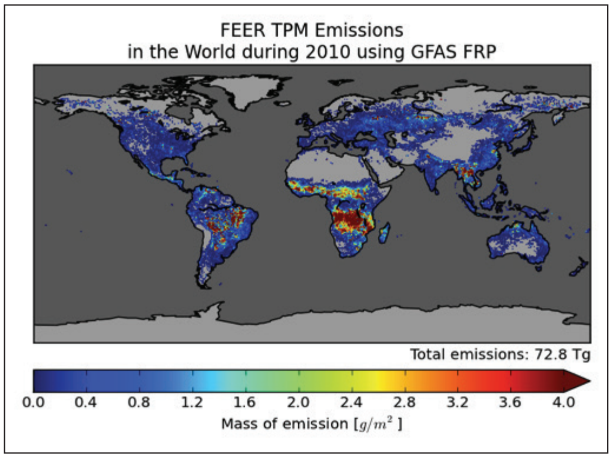


Figure 2.9: The FEER emissions product has good global coverage. Major burning regions are clearly in Central and Southern African regions, Central South America and Southeast Asia.

2.2.3. Detection of Mountain Lee Waves in MODIS NIR Column Water Vapor

Mountain gravity (lee) waves are caused by airflow over mountain ridges within a stably stratified atmosphere. Breaking waves and small-scale waves can be a source of turbulence, and strong vertical air currents can be an aviation hazard. Atmospheric gravity waves have been widely studied using high-resolution temperature observations from space [e.g., *Alexander & Teitelbaum*, 2011]. Mountain-generated waves have been observed using the MODIS 6.7-µm channel which has peak sensitivity at altitudes ~550hPa. Using the MAIAC algorithm [*Lyapustin et al.*, 2011], we have discovered mountain lee waves in the total column water vapor (CWV) derived from MODIS near-IR measurements (0.94 µm). In contrast to previous studies based on sounding data that reported gravity waves at altitudes of the midtroposphere and stratosphere, the CWV shows perhaps the lowest near-surface waves (~1 to 3 km above the surface) that can be detected from remote-sensing data over land. Remote-sensing measurements of greenhouse gases, such as CO_2 and CH_4, will also benefit from improved characterization of CWV variability because such information allows for more accurate representation of the line broadening by water vapor and potential error reduction. ***(A. Lyapustin, M. J. Alexander, L. Ott, A. Molod, Y. Wang, B. Holben, J. Susskind (613) GSFC, NWRA-CoRA Office, UMCP, and UMBC)***

2.2.4. An Innovative Approach to Separate Thin Cirrus from Aerosols Using High-Resolution Ground Spectra

For years, the principles of derivative spectroscopy have been widely applied in the field of analytical chemistry for fingerprinting the composition of materials. Hansell et al. (2014) applied these techniques using hyperspectral remote-sensing data (http://smartlabs.gsfc.nasa.gov/) from BASE-ASIA 2006 (Tsay et al. 2013) to discern subtle changes in the spectral signatures of aerosols and cirrus clouds. Differences in spectral slopes are highly dependent on the refractive indices of the medium as well as particle size. Moreover, the aerosol's affinity for water, which changes both the size and composition of particles, can also affect the shape of the spectrum. An algorithm employing a two-model fit of derivative spectra was developed to determine the relative contributions of aerosols/clouds to measured solar spectra from a ground-based spectroradiometer. When aerosols and cirrus clouds (particularly thin cirrus) coexist, the cloud optical thickness can be separated from retrieved aerosol optical thickness measurements. The peaks coincide with maximum changes in spectral flux, while the magnitude and phase differences in the derivatives are related to the physical and chemical properties in the media. Applications of this approach using hyperspectral, remote-sensing data can provide valuable insight into the aerosol and cloud properties of Earth's atmosphere. This is a valuable tool that can help reveal more detailed structural features in the spectral data. ***(R.A. Hansell (613, UMD-ESSIC), S.-C. Tsay (613); P. Pantina (613, SSAI), J. R. Lewis, Q. Ji., J.R. Herman)***

2.2.5. Accounting for Snow Darkening over Land Surfaces in NASA's GEOS-5 Model

Dust, black carbon, and organic carbon depositions on snow can reduce its reflectance (albedo), possibly accelerating snow melting (called, snow-darkening effect (SDE); see the references in Yasunari et al., 2014). Understanding the feedbacks between land and atmosphere due to the SDE is one of the important topics in climate science. Yasunari et al. (2014) summarized the developed GOddard SnoW Impurity Module (GOSWIM) implemented in GSFC's system for Earth System Modeling (called GEOS-5) to account for dust, black carbon, and organic carbon SDE over the land surface. With a 1-D off-line simulation, reasonable seasonal migrations of snow-covered surface albedos and snow depth were simulated by the catchment land surface model (LSM) for GEOS-5 Model with GOSWIM. However, it underestimated dust and black carbon in the snow surface except for the black carbon in the early winter. This could be explained by the underestimates of dust and black carbon depositions. Another sensitivity off-line simulation increased these depositions (Exp 2). Before the development of GOSWIM, there was no way to calculate SDE using the Light Absorbing Aerosol (LAA) depositions from the chemical transport module, GOCART, in NASA's GEOS-5. This capability allows GEOS-5 to simulate climate feedbacks between the land surface and atmosphere caused by SDE. ***(Teppei J. Yasunari (613, GESTAR/USRA) and K.-M. Lau (610, GSFC)***

2.2.6. MCRS: A Novel Tool for Simulating Radiometer Observations From Model Data

The Multi-Cloud Retrieval System (MCRS) simulator allows users to create a synthetic scene as if a spacecraft actually passed over. The output can be directly fed into operational remote-sensing retrieval processing chain such as MODAPS or PEATE. The system allows anyone to do a detailed, low cost analysis of retrieval algorithms that are either operational or under development. It also allows for prototyping of new instruments and comparison to existing ones. It may never replace the need for direct *in situ* measurements for algorithm validation, but it provides ability to do algorithm closure studies, basically answer the question, "Do you get back what you've put in?" on a large scale rather than only in places where a ground station exists, for example. It can also be used in reverse to validate model performance and aid in model development. Currently, GEOS-5 does not assimilate any MODIS pixel that contains cloud. We hope that the MCRS system may aid in developing GEOS-5 and other models further to allow them to make use of cloud-containing data. Figure 2.10 is an example of a simulation result from GEOS-5 model date and time identical to the time of the Terra MODIS overpass. MODIS geolocation was combined with model fields of pressure, temperature, water vapor, ozone, surface parameters, and cloud layer information in order to produce equivalent MODIS radiances in 24 MODIS channels. The figure shows two commonly used MODIS composites: (a) standard RGB (channels 1, 4 and 3) and (b) SWIR false color (channels 2, 6, and 7 in order). Geographic cloud locations and cloud thermodynamic phase appear very similar between the simulation and actual sensor data. In the SWIR composites ice clouds appear red and liquid water clouds yellow and white. Other research groups with instruments under development have already expressed desire to conduct experiments with the MCRS system in order to estimate the instrument's future ability to perform retrievals of various parameters and receive error estimates. ***(G.Wind, A. da Silva, P. Norris, S. Platnick, Code 613, 610, 610.1, NASA GSFC, SSAI, Inc, USRA)***

a) Actual SWIR composite

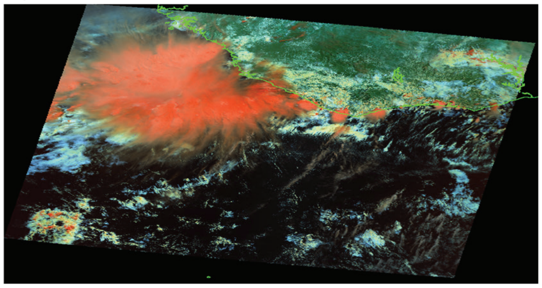
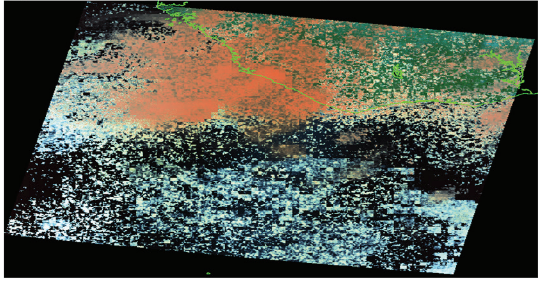


Figure 2.10: (a) MCRS with GEOS-5 and Terra MODIS on May 31, 2013 at 11:15 UTC.

b) Simulated SWIR composite



(b) SWIR composite of real and simulated granule

2.2.7. Surface Albedo Changes from Wildfires in Northern Sub-Saharan Africa

This study demonstrates simple methods for characterizing and deriving the trajectories of post-fire albedo dynamics from satellite data that is consistent and widely available. Results show that savannas accounted for >86% of the total MODIS fire count between 2003 and 2011 in Northern sub-Saharan Africa. That only a small fraction of the savanna pixels (≤10%) displayed burn in two successive years and about 47% had any fire recurrence in nine years. The evergreen broadleaf shows a different pattern, where there is a peak between the third and fourth year, and a second peak after the eighth year. A total of 15% of the evergreen broad leaf pixels that burned in 2003 had burned again by 2011. Furthermore, we find that the persistence of surface albedo darkening in most land cover types in the NSSA region is limited to about 6–7 years, after which at least 99% of the burnt pixels recover to their pre-fire albedo. As an example, Figure 2.11 shows fires detected over northern sub-Saharan Africa in 2011 by Modis on Terra and Aqua satellites. These results will provide critical information for deriving necessary input to various models used in determining the effects of albedo change due to wild fires in sub-Saharan Africa region. ***(C.K. Gatebe (613, USRA), C. M. Ichoku (GSFC), R. Poudyal (613, SSAI), M. Román (619, GSFC), and E.M. Wilcox (DRI)*****)**

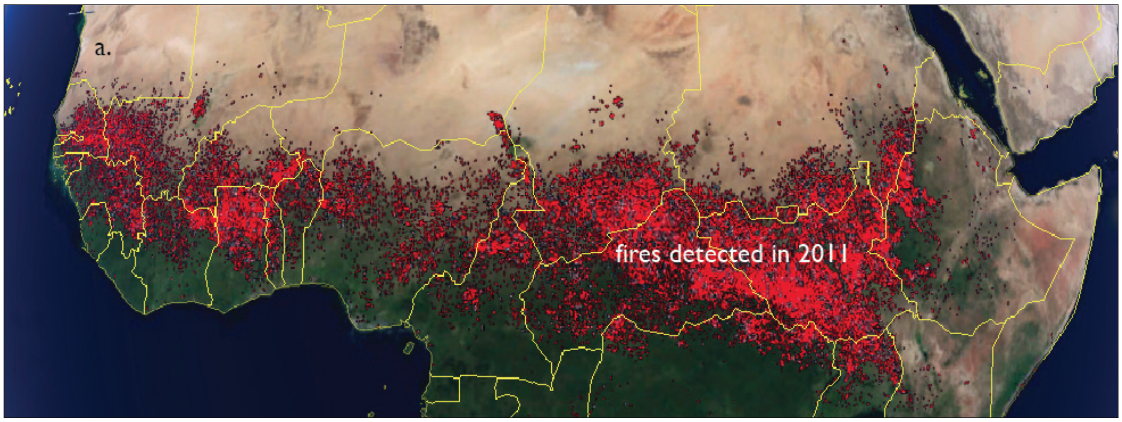


Figure 2.11: Fires detected over northern sub-Saharan Africa in 2011 by Modis on Terra and Aqua satellites were used to study post-fire albedo dynamics.

2.2.8. Application of Airborne HSRL Remote-sensing Measurements to $PM_{2.5}$ Air Quality during DISCOVER-AQ

Satellite remote sensing can cover a large area. The application of satellite retrieval products has become an important tool to evaluate public heath effects by air pollutants. DISCOVER-AQ is a NASA Earth Venture-class mission designed to better understand the scientific challenges associated with the use of Earth-observing satellites for measuring air quality. Thus far, three field deployments were completed in BWC (Baltimore-Washington Corridor, Maryland) in July 2011, SJV (San Joaquin Valley, California) in January–February 2013), and HMR (Houston Metropolitan Region) in September 2013. The last field deployment took place in the Denver Metropolitan in August–September 2014. The results showed part of the comparative study of estimated $PM_{2.5}$ over DISCOVER-AQ campaigns with airborne High-Spectral Resolution Lidar (HSRL) measurements by linear approximations. HSRL is one of the core sensors deployed in DISCOVER-AQ field campaigns to measure optical depth (AOD) and extension profiles. Haze layer height (HLH) is developed based upon PBLH and scale height assuming exponential decrease in extinction with altitude above PBLH. While PBLH is derived by wavelet analysis, maximum gradient height (MGH) is determined based upon maximum gradient extinction with height. The results were presented in 2013 AGU Fall Meeting (Chu, D. A. et al., 2013. *Multi-sensor Approach on Air Quality Application and Assessment Using Measurements in DISCOVER-AQ as a Test Bed*, A24C-7). The results are applicable to the development of future satellite mission, such as GEO-CAPE of the *Decadal Survey*. ***(Allen Chu, JCET/UMBC, GSFC and HSRL Teams, NASA LaRC)***

2.2.9. North African Dust Reaching the Americans Varies Greatly by Season and Year

Dust cycle has become an emerging core theme of Earth system science. The trans-Atlantic dust transport has important implications for human and ecosystem health, the terrestrial and oceanic biogeochemical cycle, weather systems, and climate. Satellites provide a unique platform for studying aerosol intercontinental transport because of their inherent advantages for routine sampling and for large spatial and temporal coverage. This study provides a first observation-based, multiyear estimate of vertically-resolved trans-Atlantic dust transport based on the CALIPSO all-sky aerosol measurements, which can be used to evaluate and constrain highly uncertain model simulations. Vertically resolved trans-Atlantic dust transport was quantified from a seven-year (2007–2013) record of CALIPSO lidar measurements in both *cloud-free* and *above-cloud* conditions. Large seasonal and interannual variations were observed. The interannual variation of yearly dust transport is anti-correlated with the prior-year Sahel rainfall. The also suggests that the prior-year drought condition in Sahel is a good indicator for the amount of trans-Atlantic dust transport. A future aerosol-cloud-ecosystem mission would provide more accurate measurements of the three-dimensional distributions and particle properties of aerosols, which would further improve our ability to assess the implications of dust and other aerosols on the Earth's climate through large-scale transport. ***(Hongbin Yu, (613), GSFC and ESSIC/University of Maryland)***

2.2.10. Aerosols from Degassing Volcanoes Affect Cloud Properties

Satellite data show modifications of cloud properties downwind of volcanoes in pristine oceanic regions due to aerosols formed by passive volcanic degassing. Comparisons against non-volcanic control islands provide evidence that volcanogenic aerosols induce cloud changes. Analysis of clouds near volcanic and non-volcanic islands, in pristine environments where the background aerosol optical depth (AOD) is low, allows examination of the effects of volcanic aerosols on water clouds. We compared cloud properties upwind and downwind of these islands, using 10 years of satellite data (Figure 2.12a). Clouds that have interacted with volcanic aerosols (downwind) tend to have smaller droplets than those that have not (upwind). For example, Figure 2.12b shows the data for Kilauea, Hawaii.

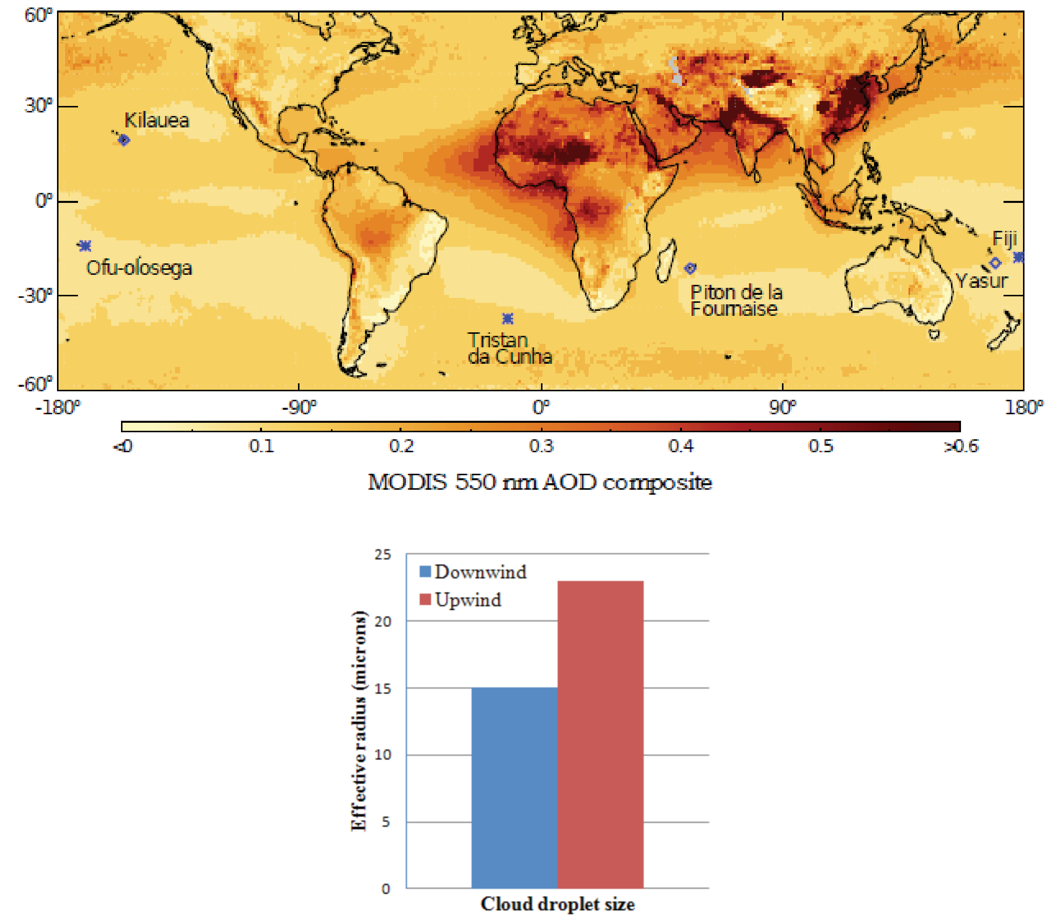


Figure 2.12: Analysis of clouds near volcanic and non-volcanic islands.

Changes in cloud droplet size affect weather and climate atmospheric aerosols (small particles suspended in the atmosphere) have important (climate, ecological, and other) effects on the Earth system. Among these are their interactions with clouds, which can lead to changes in cloud properties such as brightness, droplet size, water content, rainfall occurrence, and lifetime—often known collectively as “indirect radiative effects.” These indirect effects are among the less well-understood factors affecting the global radiation budget.

Volcanoes provide a natural laboratory for studying aerosol indirect effects, since they often emit sulfur dioxide passively, which reacts in the atmosphere to form sulfate aerosols that may modify clouds. This study provides a quantification of the magnitude of volcanic aerosol indirect effects, tying to NASA’s goals for understanding the various factors affecting the Earth’s radiation budget. The synergy achieved by using three satellite sensors increases the robustness of the conclusions, which can be drawn in this type of analysis. ***(S. K. Ebmeier, (University of Bristol, UK); A. M. Sayer, (613 and GESTAR/USRA); R. G. Grainger, T. A. Mather, and E. Carboni,(University of Oxford, UK))***

2.2.11. Using MODIS Could Regimes for Understanding Radiation and Rainfall Budgets

About 10 years of daily MODIS (Terra and Aqua) Level-3, 1-degree cloud optical properties from Collection 5.1 were used in an examination of the nature of global MODIS cloud regimes (mainly joint histograms of cloud optical thickness and cloud top pressure). For the same time period, we used spatiotemporally matched CERES radiative fluxes (SYN1deg) to derive cloud radiative effects and GPCP daily 1-degree surface precipitation estimates. Our analysis elucidated the amount that different mixtures of cloud types (as represented within MODIS cloud regimes) contribute to radiative fluxes and precipitation. The concept of cloud regimes as defined in the current work is now about 10 years old. The ever-growing body of work built around the regime demonstrates its acceptance as a promising approach for making sense of a wide range of processes affecting and being affected by clouds. The present study serves as one more affirmation that cloud regimes derived from cluster analysis of passive satellite retrievals at scales around 100 km are an appropriate foundation for decomposing the Earth's water and energy budget in a meaningful way. By examining, with the aid of satellite simulators, the extent to which GCMs can replicate these regimes, we can identify model deficiencies and ultimately improve cloud representations. The regimes also provide an appropriate framework to meaningfully compare the consistency between passive and active cloud observations, guiding thus decisions on measurement capabilities for future cloud-oriented satellite missions. ***(L. Oreopoulos, N. Cho, D. Lee (613), G. J. Huffman (612), and S. Kato (LARC))***

2.3. Atmospheric Chemistry and Dynamics Laboratory

The Laboratory conducts research including both the gas-phase and aerosol composition of the atmosphere. Both areas of research involve extensive measurements from space to assess the current composition and to validate the parameterized processes that are used in chemical and climate prediction models. This area of chemical research dates back to the first satellite ozone missions and the Division has had a strong satellite instrument, aircraft instrument, and modeling presence in the community. Both the EOS Aura satellite and the OMI instrument U.S. Science team come from this group. The Laboratory also is a leader in the integration and execution of the NPP mission, and is also providing leadership for the former NPOESS—now the newly reorganized Joint Polar Satellite System (JPSS). This group has also developed a state-of-the-art 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 below.

2.3.1. Volcanic and Anthropogenic Contributions to Stratospheric Aerosol Trends

Volcanic emissions can be the major source of stratospheric aerosol, but there is a persistent "background" aerosol layer even without major volcanic eruptions. Recent observations seem to suggest that this "background" aerosol has been increasing in the past decade, and anthropogenic emission increase in Asia was proposed to be the cause of this increase. However, even without a large volcanic eruption (i.e., at the magnitude of El Chichon or Pinatubo) in the last decade, there have been numerous smaller volcanic eruptions that put SO_2 into the upper troposphere or stratosphere.

Incorporating the satellite-based estimation of SO_2 from volcanic eruptions and most recent anthropogenic emission inventories, the GOCART model was used to simulate the stratospheric aerosols and separate the sources. Figure 2:13 shows the volcanic SO_2 plume evolution from the Kasatochi eruption from OMI and GOCART simulation. Both satellite data and models have shown that even without major explosive volcanic eruptions, volcanic emissions frequently perturb the stratospheric "background" aerosols, making it difficult to define non-volcanic background aerosol values in the stratosphere. The model implies that the increase of Asian pollution does contribute to the stratospheric aerosol, but it is mostly confined in the lower stratosphere with organized seasonal cycles and is much less than volcanic aerosols. The study will help understand the impact of stratospheric aerosol on radiative forcing and is relevant to the future NASA missions, such as ACE and CATS. ***(Mian Chin, (614) GSFC)***

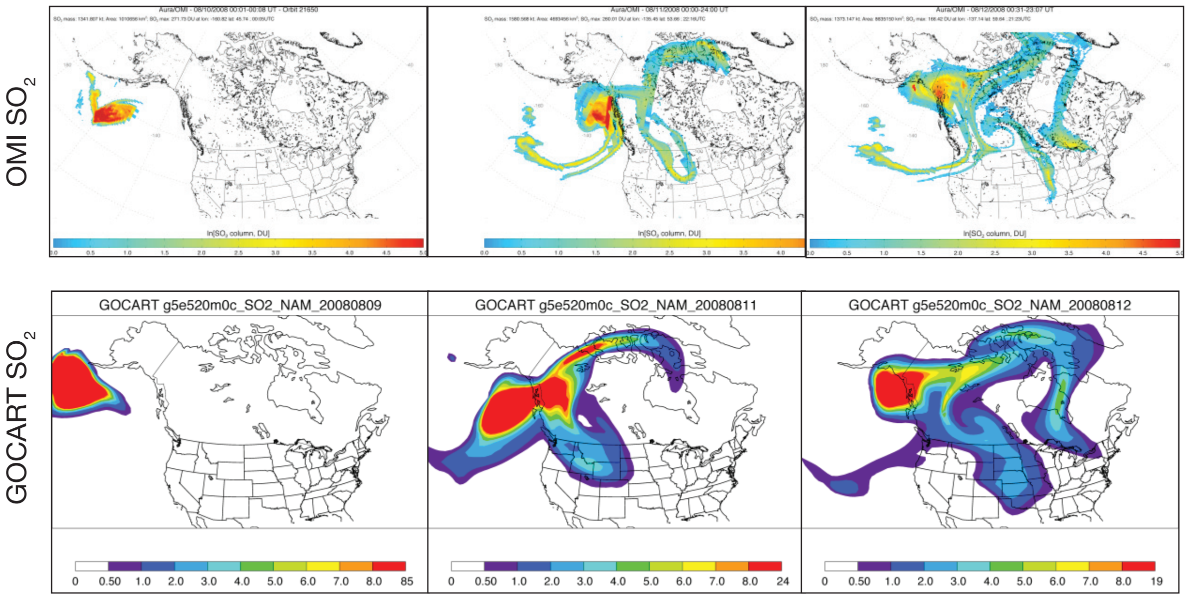


Figure 2.13: Column SO_2 from Kasatochi eruption, August 2008.
Top row: OMI retrieval. Bottom row: GOCART simulation.

2.3.2. The First Global Free-Tropospheric NO_2 Concentrations Derived Using a Cloud-Slicing Technique on Observations from the Aura Ozone-Monitoring Instrument

Measurements of tropospheric NO_2 from space-based sensors are of interest to the atmospheric chemistry and air quality communities because it is an important pollutant as well as a radiative forcing agent. NO_2 is produced in the troposphere by lightning, soil, and combustion. Estimates of NO_2 concentrations are severely lacking for the free-troposphere, where lifetimes are longer and the radiative impact through ozone formation is larger. Such information is critical to evaluate chemistry-climate and air quality models that are used for prediction of the evolution of tropospheric ozone and its impact on climate and air quality. Free-tropospheric NO_2 VMR is retrieved using a cloud slicing technique, which utilizes the fact that the slope of the cloudy NO_2 column versus the cloud optical centroid pressure is proportional to the NO_2 VMR for a given altitude range. This provides a global seasonal climatology of free-tropospheric NO_2 VMR in cloudy conditions and also produces estimates of stratospheric column NO_2 amounts. Enhanced NO_2 in the free troposphere commonly appears near polluted urban locations where NO_2 produced near the surface may be transported vertically out of the boundary layer and then horizontally away from the source. Signatures of lightning NO_2 were shown at low and middle latitude regions in summer months (June–August in the northern hemisphere and December–February in southern hemisphere). This technique will enable new evaluations of chemistry transport models, including lightning NO_x parameterizations and transport of boundary layer pollution. ***(S. Choi, J. Joiner, Y. Choi, B. N. Duncan, E. Bucsela)***

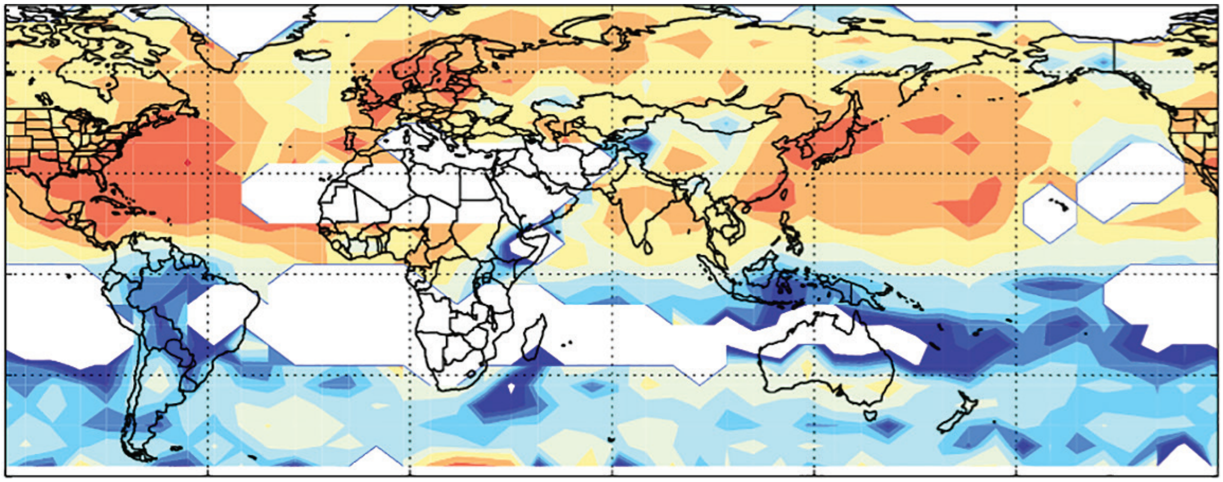


Figure 2.14: June, July, and August OMI cloud-slicing free tropospheric NO_2 VMR.

2.3.3. The Quasi-Biennial Oscillation is Disrupted by Geoengineering Aerosols

The quasi-biennial oscillation (QBO) is a phenomenon whereby stratospheric tropical zonal winds switch from westerly to easterly with a period of about two years. The QBO affects temperatures and the transport of air into and out of the tropics; it is the main source of variability in the tropical stratosphere. Geoengineering is the deliberate modification of the Earth's climate to counteract global warming. One method recreates the cooling effect of large volcanic eruptions by continuously injecting of sulfate aerosol particles into the stratosphere. The effects of this geoengineering method were quantified by simulating different sulfate injections into the Goddard Earth Observing System's chemistry-climate model. Injected sulfate aerosols warm the lower stratosphere, prolonging the phase of westerly winds. High sulfate aerosol burdens completely eliminate the wind oscillation. The QBO impacts the composition of the troposphere and stratosphere, monsoon precipitation, and the polar vortex strength. Hence, a QBO disruption would have effects well beyond the tropical stratosphere. We showed how the stratospheric warming due to the absorption of largely long-wave radiation by the aerosol particles would increase the stratospheric vertical residual velocities, strengthen the westerly winds, and dramatically change stratospheric dynamics, possibly disrupting the QBO.

Figure 2.15 shows vertical profiles of the zonal winds, averaged between 2°S and 2°N. The geoengineering aerosol is introduced in the simulation by continuously injecting 5 Tg SO_2/year at on the Equator at 0° longitude between 16km–25km (middle panel) and 22km–25km (lower panel) altitude. GEOSCCM calculates the transformation of SO_2 into sulfate aerosol. The higher injection height leads to a larger aerosol equilibrium burden.

Long-term observations of the stratospheric aerosol layer, such as the ones provided by the NPP-Suomi satellite, are required to gain knowledge of the stratospheric background aerosol and its importance in the climate system. ***(V. Aquila (614, GSFC; GESTAR/Johns Hopkins University), C. I. Garfinkel (Hebrew University), P. A. Newman(614, GSFC), L. D. Oman (614, GSFC), D. W. Waugh (GESTAR/Johns Hopkins University))***

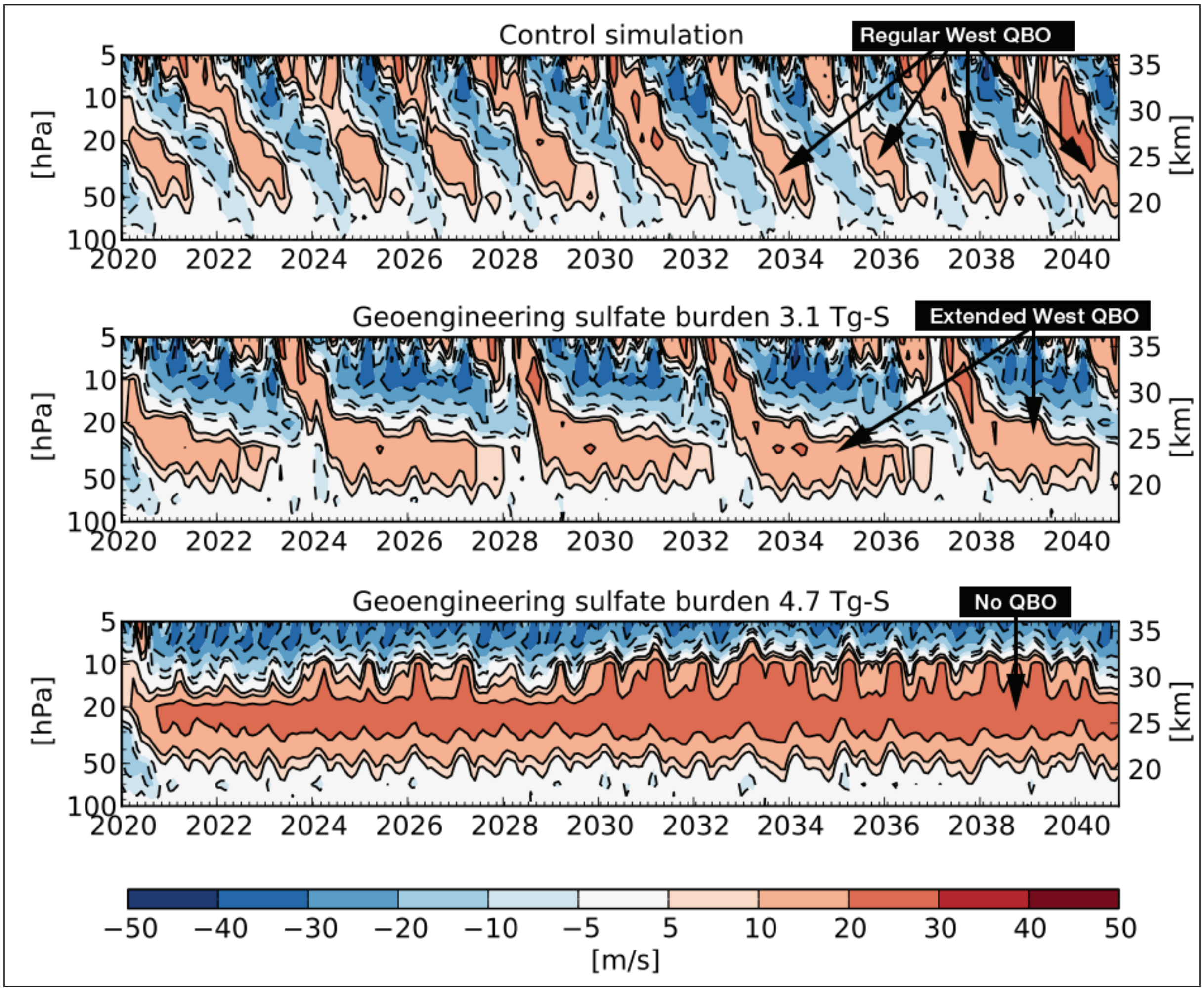


Figure 2.15: This shows the simulated vertical profiles of equatorial stratospheric zonal winds from the start of the geoengineering injection in January 2020 to December 2040. Red shaded areas mark westerly (or eastward blowing) winds, blue shaded areas easterly (or westward blowing) winds. The upper panel shows the control simulation with no sulfate aerosol. The middle and lower panels show the simulations with geoengineering sulfate burdens of 3.1 Tg-sulfate (middle) and 4.7 Tg-sulfate (bottom).

2.3.4. Aura OMI Reveals Solar Variability in the On-Going Cycle 24

Determining long-term solar variations at wavelengths greater than 300 nm requires very accurate satellite measurements and is needed to quantify natural forcing of Earth's climate. The excellent stability of Aura's Ozone Monitoring Instrument (OMI) allows us to determine short-term (solar rotation) and long-term (solar cycle) solar irradiance variability between 265–500 nm. The difference between solar maximum (2012–2013) and solar minimum (2007–2009) is shown for Cycle 24. For the first time, we can confirm that the magnitude and spectral dependence of short-term and long-term solar irradiance variations are consistent to within derived uncertainties. Variations in solar absorption features closely follow the well-known Mg II index of solar activity, as expected. These new results from OMI are more accurate than previous observations from UARS SUSIM and SOLSTICE during Cycles 22–23. OMI *short-term* solar variations agree with concurrent results from the GOME-2 instrument on the ESA MetOp satellite and with results observed during previous solar cycles. OMI *long-term* solar variations agree with calculated changes from the NRLSSI model, but they disagree with Cycle 23 results from SORCE SIM and SORCE SOLSTICE. Our results provide the first direct demonstration that the spectral dependence of long-term and short-term solar irradiance variability is in good agreement. By combining our data with previous results and GOME-2 data, we can also provide a consistent representation of short-term solar variability over the extended spectral range 170–795 nm. ***(Sergey Marchenko and Matthew DeLand, SSAI, NASA GSFC/Code 614)***

2.3.5. Destruction of Mesospheric Ozone Caused by Solar Proton in March

Solar eruptions in 2012 led to a substantial barrage of charged particles on the Earth's polar atmosphere during the March 7–11 period. Most of these charged particles were protons, thus the term "Solar Proton Event (SPE)" has been used to describe this phenomenon. These solar protons created hydrogen-containing compounds that led to the polar ozone destruction. We have used the Aura Microwave Limb Sounder (MLS) observations and a global model simulation to quantify the changes in ozone due to this SPE. The MLS measured atmospheric changes in ozone for the latitude bands 60–82.5°N and 60–82.5°S were all relative to the quiet March 2–6, 2012 time period, which contained no SPEs. Predicted results were obtained from the Goddard Space Flight Center (GSFC) two-dimensional (2-D) model. The SPE-caused mesospheric and upper stratospheric ozone decreases (up to 80% in the 60–82.5°N band and over 40% in the 60–82.5°S band). The ozone changes at pressure levels >2 hPa in the 60–82.5°N band, below the large ozone decreases, are mostly seasonal variations and are not connected to the SPEs. SPEs cause a prompt, predictable perturbation to the atmosphere and can be used to test the chemistry and transport in global models. SPEs, also, can influence Polar Regions where their impact on ozone needs to be measured and better predicted so that humankind-caused ozone variations can be more reliably quantified. It will be important to carry out further measurements of HO_x and NO_x constituents as well as ozone in order to understand the variations in middle atmospheric gases. Thus, measurements of the proposed *Decadal Survey's* Global Atmospheric Composition Mission (GACM) are necessary to continue the work on the influence of solar protons on the mesosphere and stratosphere. ***(Charles Jackman (614, GSFC) and Eric Fleming (614, GSFC; and SSAI)***

2.3.6. The Effect of Dust Absorption on its Transport and Lifecycle

Airborne Saharan dust particles absorb solar and infrared radiation, affecting the weather and climate. These impacts were explored in the NASA GEOS-5 Earth System Model. Dust is emitted from barren land surfaces, where high winds start loose soil particles bouncing along the ground, ultimately breaking them up into tiny fragments that can remain suspended in the atmosphere. The dominant source of dust on Earth is the Sahara Desert in North Africa. Dust is important to Earth's climate system because it reflects and absorbs solar and thermal radiation, changing the energy balance of the atmosphere, and so literally changing the weather. Dust also interacts with and changes the properties of clouds, and is a contributor to poor air quality when emitted near urban areas. We modeled the emission and transport of dust on Earth using a climate model. Because we were interested in how the radiative properties of dust impact its lifecycle and transport, we tested different assumptions of the dust particle shape and absorption, allowing those effects to feed back on our model. We found for Saharan dust that the more strongly absorbing it is assumed to be, the further north and west and at higher altitudes the dust is transported, in best agreement with observations. Better treatment of dust aerosols in climate and weather models will improve climate forcing simulations and weather and air quality forecasting. Figure 1 shows a vertical profile of dust, temperature, and zonal wind speed differences for a climatological June–July–August mean between a model simulation with moderate dust absorption and a simulation in which dust is not active radiatively. The average is taken from 15°W to 0° (over the Western Sahara). The colored shading indicates differences in atmospheric temperature caused by the radiative heating of dust. The solid (dashed) contours show increases in easterly (westerly) flow associated with the dust heating (in units of ms^{-1}). The thick solid contour is the 100-μgm^{-3} dust concentration isosurface for the experiment with dust heating. ***(P. Colarco (614, GSFC), E. Nowottnick (614, GSFC; NASA Postdoctoral Program), C. Randles (614, GSFC; GESTAR/Morgan State University), B. Yi (Texas A&M University), P. Yang4, K.-M. Kim (613, GSFC; GESTAR/Morgan State University), J. Smith (University of Colorado), C. Bardeen (National Center for Atmospheric Research)***

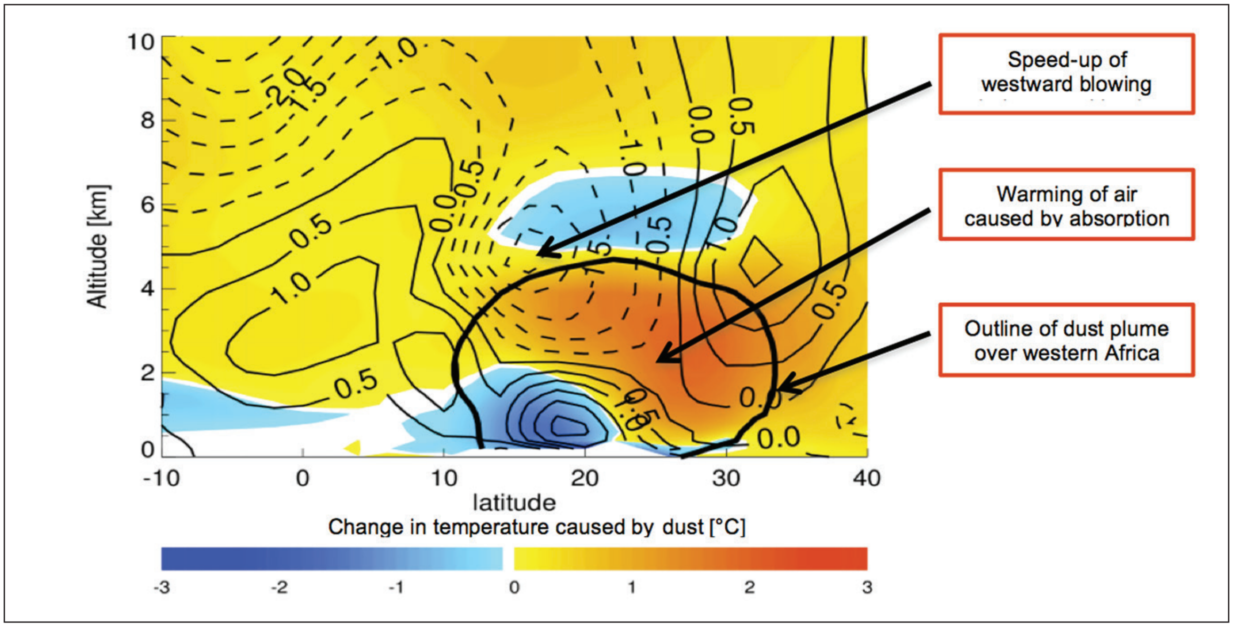


Figure 2.16: June, July, and August OMI cloud-slicing free tropospheric NO_2 VMR.

2.3.7. U.S. Air Quality Improvement

Emission of nitrogen oxides (NO_x) is changing across the United States due to environmental regulations and technological change. Observations of tropospheric NO_2 from the Ozone Monitoring Instrument (OMI) onboard the AURA satellite were used to examine NO_x emission reductions and their impact on U.S. air quality. Nitrogen dioxide pollution, averaged yearly for 2005 and 2011, has shown a dramatic decrease across the country, more notably in the east. The overall decrease in NO_2 columns is about 40%. OMI observations show that Atlanta, Georgia, has seen a 42% decrease in nitrogen dioxide between the 2005–2007 and 2009–2011 periods. Technological improvements, such as emission control devices installed on power plants, have meant that residents here now breathe cleaner air. Denver has seen a 22% decrease in nitrogen dioxide between the 2005–2007 and 2009–2011 periods. NASA's Discover-AQ, a multi-year airborne mission, was flown during the 2014 summer in Denver to learn more about the region's wide range of air pollutants.

The impact of technology to reduce emissions of nitrogen dioxide and sulfur dioxide from coal-fired power plants is apparent in satellite imagery. NO_x emissions are reducing and air quality is improving in the United States. In addition to satellites, NASA's DISCOVER-AQ missions over: Baltimore-Washington region in 2011; Houston, Texas, in 2013; San Joaquin Valley, California, in 2013; and Denver, Colorado in 2014 help to better understand air quality. ***(NASA OMI NO_2 Team (614), GSFC Scientific Visualization Studio (606.4))***

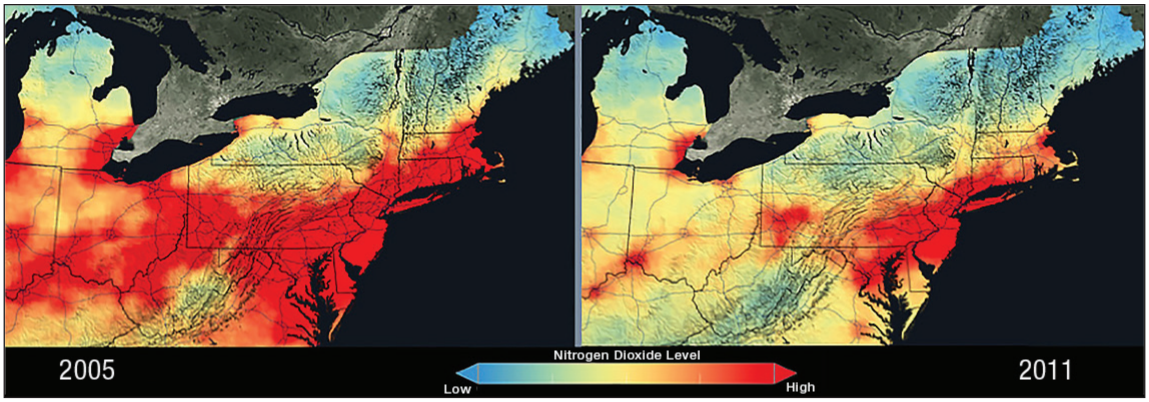


Figure 2.17: Nitrogen dioxide pollution, averaged yearly for 2005 and 2011, has shown a dramatic NO_2 column decrease of approximately 40%.

2.3.8. Solving the CCl_4 budget mystery using surface observations

The near-zero CCl_4 emissions from UNEP reported production and feedstock and the 25-year lifetime do not match the observed decline and inter-hemispheric gradient (IHG). CCl_4 is a major anthropogenic ozone-depleting substance and greenhouse gas that is regulated under the Montreal Protocol. Current bottom-up emissions, estimated based on reported production and feedstock usage, were zero after 2007. The near-zero, bottom-up emissions cannot be reconciled with the observed slow decline of atmospheric concentrations (~1% per year) and the inter-hemispheric gradient for CCl4. Our 3D model simulations suggest that the observed inter-hemispheric gradient (1.5±0.2 ppt for 2000–2012) is caused primarily by ongoing, current emissions, while ocean and soil losses and stratosphere-troposphere exchange together contribute a small negative gradient (~0 to -0.3 ppt). Using the observed CCl_4 global trend and inter-hemispheric gradient, we deduced the mean global emissions for the 2000–2012 period were 39 (34–45) Gg/yr (~30% of the peak 1980s emissions) with a corresponding total lifetime of 35 (32–37) years. Results from this work point to the need for a more accurate bottom-up estimate of CCl_4 emissions as well as re-evaluation of the current CCl_4 best estimate lifetime of 25 years to a needed much longer lifetime of 35 years. ***(Qing Liang (614) and Paul Newman (610), GSFC and USRA/GESTAR)***

2.3.9. Impact of Satellite Viewing-Swath Width on Global and Regional Aerosol Optical Thickness Statistics and Trends

Spatial coverage is an important design consideration for future space-based aerosol remote-sensing measurements. We explored the impact of reduced spatial coverage on the statistics of the amount of aerosol detected, as well as on our ability to confidently measure how aerosol loading is changing in time. Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments onboard the Terra and Aqua spacecraft were used in this study, as were results from the NASA Goddard Earth Observing System (GEOS-5) Earth system model. The full swath of MODIS Aqua aerosol observations were sub-sampled along candidate narrower and single-pixel wide swaths in order to investigate the impact of reduced spatial coverage on the statistics of aerosol loading (i.e., aerosol optical thickness, or AOT) and trends in aerosols. AOT data derived from both MODIS instruments were also assimilated into the GEOS-5 simulation in order to correct errors in the simulated aerosol fields. Figure 2.18a shows the year 2010 annual average AOT derived from the MODIS Aqua observations. The left portion shows the annual average AOT if the full swath of the MODIS observations is used. The right panel shows the annual average AOT limited to a subset of the observations along a single-pixel wide stripe of the full swath observations.

Gaps in the observations and different magnitudes of the AOT at certain geographic locations are evident when the single-pixel-wide observations are compared to the full swath observations.

Because of the reduced spatial coverage of the single-pixel-wide sampling, the trends shown for that case are not found to be statistically significant at sub-continental spatial scales, whereas regions of statistically significant trends are more pronounced for the full swath viewing conditions. Our study was aimed at understanding how our estimate of aerosol loading, as well as our ability to confidently detect changes in aerosol loading, is impacted if we reduce the spatial coverage of our satellite observing system. ***(P. R. Colarco (614, GSFC), R. A. Kahn (613, GSFC), L. A. Remer (JCET, University of Maryland-Baltimore County), R. C. Levy (613, GSFC))***

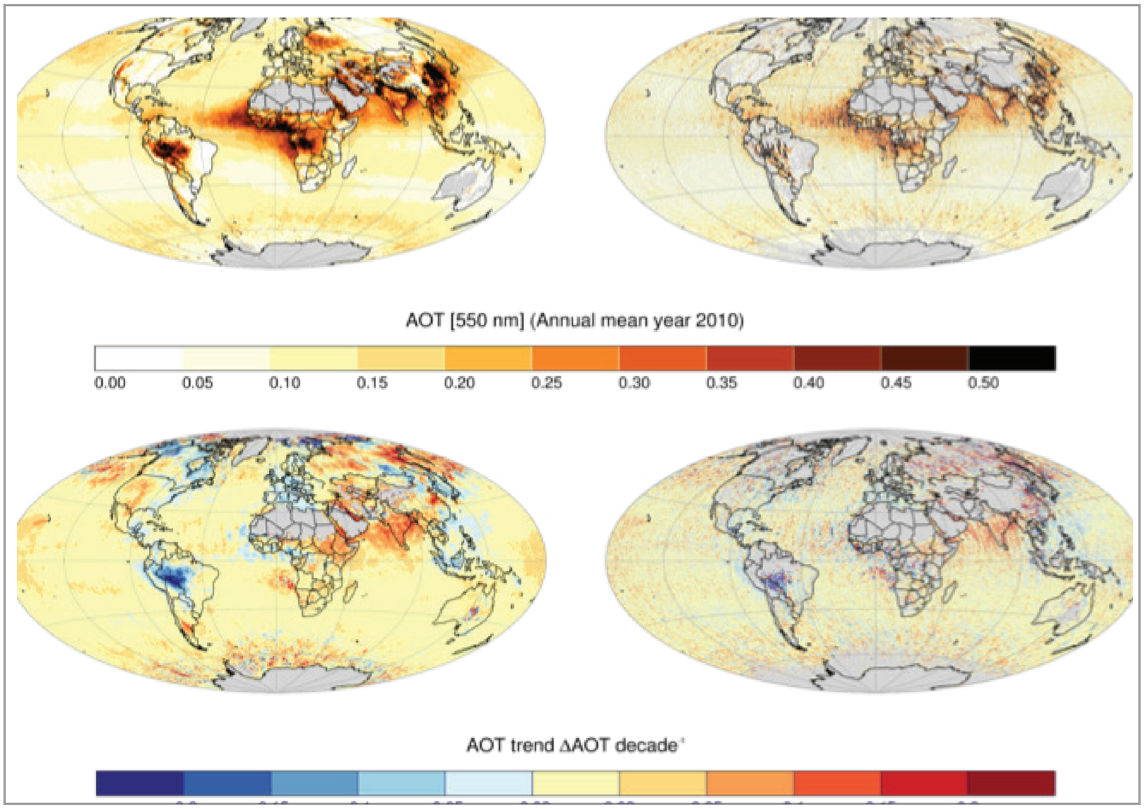


Figure 2.18: Top: Aerosol loading (the aerosol optical thickness, or AOT) from MODIS Aqua for the year 2010. Bottom: Decadal trend in aerosol loading for the MODIS Aqua instrument over the years 2003–2012.

2.3.10. Are Tropospheric Ozone Increases in the Southern African Region a Bellwether for Large Pollution Growth in the Southern Hemisphere?

From 1992 through 2011, ozonesonde profiles show a large increase, up to 50 percent per decade, over Réunion Island, located 3000 km east of southern Africa (Figure 2.19, shown in red brown). The largest change takes place between July and August (winter), not during the biomass-burning season that spans September and October. What is causing these ozone increases? In the upper troposphere, above 11 km, dynamical changes could play a role. In the middle troposphere (from about 6–10 km), however, we hypothesize that long-range transport of pollution ozone is contributing to the buildup over time. To test the plausibility of this mechanism, we ran a reverse trajectory model to follows air parcels backward to discover where the ozone originates. Results showed that some of the air comes from southern Africa and the Atlantic, regions that are well known to be high in pollution ozone. However, air also arrived from as far away as South America and southern Asia, where rapid economic growth may be adding to pollution in the middle troposphere. To better define the ozone's origins, we are studying ozone data from satellite and outputs from chemical-transport models that attempt to simulate growth in southern hemisphere emissions. A number of ozonesonde stations are operating in the tropics and subtropics; however, they have differing frequency and reporting procedures. The Southern Hemisphere ADditional OZonesondes (SHADOZ) is designed to remedy this data discrepancy by coordinating launches, by supplying additional sondes in some cases, and by providing a central archive location http://croc.gsfc.nasa.gov/shadoz/. ***(Anne M. Thompson (614, GSFC), Nikolai Balashov (Penn State University))***

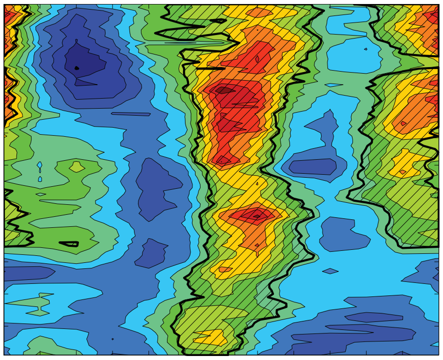


Figure 2.19: Ozone trends over Reunion Island peak between June and August, shown in reddish brown.

2.3.11. Summer Surface Ozone Reduced by NO_x Emission Reductions

Simulations confirm that pollution reductions caused the decrease in summer ozone levels over the eastern U.S. and altered the seasonal cycle of ozone in the Mid-Atlantic. As shown in Figure 1, summertime surface ozone over the eastern United States decreased over the period from 1991-2010, with many sites showing statistically significant negative trends in July. The observed trends (left panel) are well captured by a GMI model simulation (right panel) driven by time-dependent emissions of NO_x and other pollutants. Statistically significant trends are plotted in circles, while trends that are not significant are shown in triangles. Surface ozone pollution is harmful to human health and a major contributor to air quality violations. Demonstrating that models can reproduce the observed decreases in eastern U.S. ozone and NO_2 is important for establishing the link between decreases in ozone and reductions in the emissions of ozone-forming pollutants. By demonstrating skill in simulating the historic trends and year-to-year variability of surface ozone, our study increases confidence in model projections of how ozone pollution may change in the future. Future missions that provide space-based measurements of NO_2 and other pollutants could further improve our ability to simulate and interpret changes in ozone pollution. ***(Sarah Strode (GSFC, GESTAR), Jose Rodriguez (GSFC), Lok Lamsal (614, GSFC and GESTAR))***

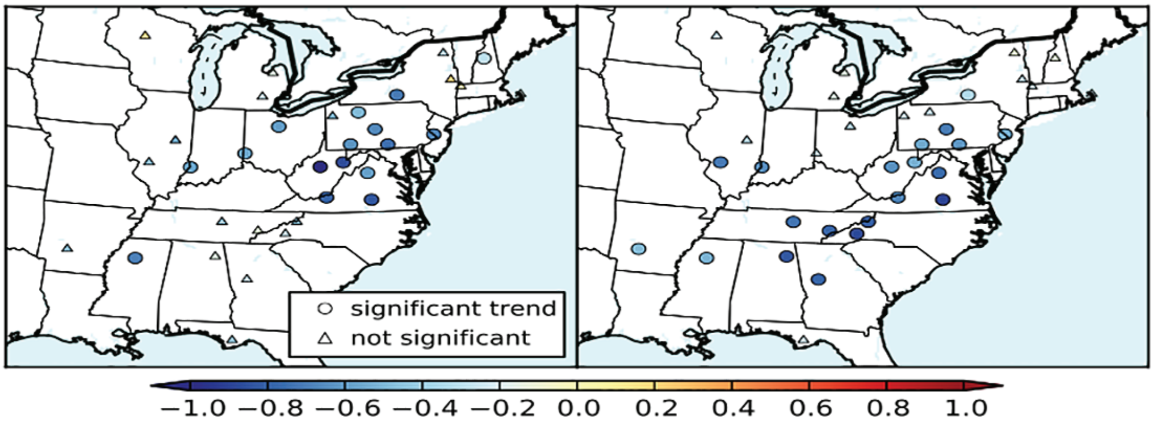


Figure 2.20: Trends in July surface ozone, 1991–2010.

2.3.12. Excellent Agreement of Total Column Ozone Retrievals from the Pandora Spectrometer System and Dobson Spectrophotometer in Boulder, Colorado

A NASA-developed Pandora spectrometer system was installed on the roof of the NOAA building in Boulder, Colorado, to compare measured total column ozone amounts (TCO) with a well-calibrated, classic Dobson spectrophotometer system. The Dobson system has set the worldwide standard among ozone measuring devices for more than 50 years; however, it requires manual operation a few times per day for each measurement taken. The Pandora system is automatic, for both data acquisition and data processing. It can make measurements every 40 seconds for ozone as well as other atmospheric trace gases. The results of our comparison, December 17, 2013 through September 24, 2014, showed excellent agreement for all-sky conditions (within 2%) and for clear-sky days (within 1%). The day-to-day variation measured by the two systems also showed excellent statistical correlation.

The results imply that the Pandora system could be an inexpensive alternative to the labor-intensive Dobson instrument. The first graph in Figure 2.21 compares Pandora TCO with Dobson TCO under Dobson AD-DSGQP clear-sky criteria; the ozone time series shows Pandora TCO averaged over +/-8 minutes of the Dobson retrieval time. The second graph uses a scatter plot Pandora-Dobson TCO comparison under Dobson AD-DSGQP clear-sky criteria, which shows the degree of agreement, with a correlation of 0.97 and a slope of 1.007.

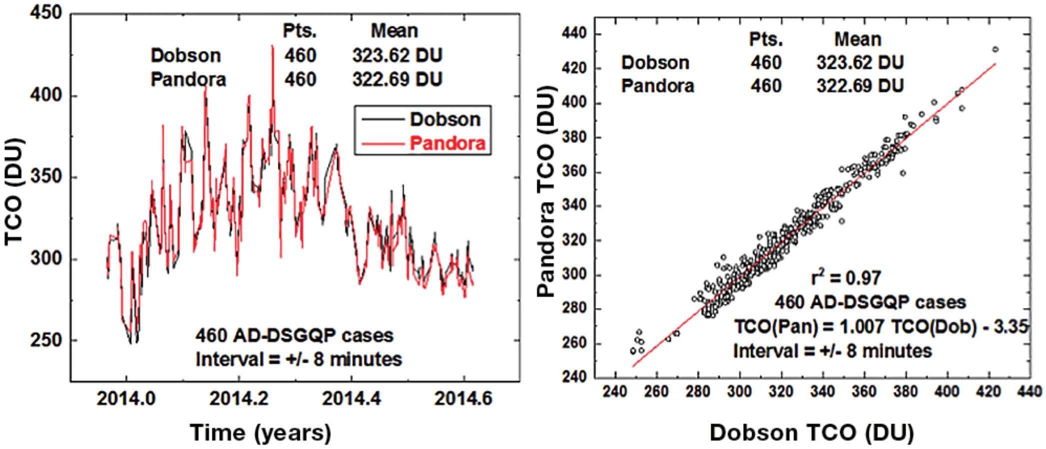


Figure 2.21: Pandora TCO results indicate that it is but more capable instrument than the traditional Dobson Spectrophotometer or Brewer Spectrometer. It is also much less expensive,

A set of 37 Pandora instruments are located at various places in the United States, Asia, and Europe, which can be used to validate satellite data for ozone and NO_2 as well as determine local air quality. These Pandora spectrometers are more capable than the traditional Brewer and Dobson instruments, operate autonomously, and are much less expensive. In addition to total column measurements, the Pandora also provide altitude profiles throughout the day. The Pandora network is rapidly growing as NASA and non-NASA institutions acquire instruments. Current locations include: Korea, Finland, Austria, Spain, New Zealand, Canada, and the United States (Harvard, GSFC, NASA-HQ, Wallops Island, Langley, New Mexico, St. Louis, Hawaii-Mauna Loa Observatory). A shipboard version has also been developed, which was deployed in the Chesapeake Bay and in the Gulf of Mexico during the DISCOVER-AQ campaigns to help determine airborne nitrification of coastal waters. The Pandora instrument has been used to validate AURA/OMI and NPOESS/OMPS and will be used for the future TEMPO and DSCOVR missions. ***(Jay Herman (GSFC, UMBC-JCET), Robert Evans (NOAA), Alexander Cede, Nader Abuhassan (GSFC, UMBC-JCET), Irina Petropavlovskikh (University of Colorado), Glen McConville (University of Colorado; GSFC, UMBC-JCET))***

2.4. Wallops Field Support Office

The Wallops Field Support Office (Code 610.W) supports the Earth science research activities of GSFC Code 600 scientists at the Wallops Flight Facility. The Office conceives, builds, tests, and operates ground and airborne research sensors and instruments, both at Wallops and at remote sites. Scientists in the Office use radars, aircraft, balloons, and satellite platforms to participate in the full complement of Earth science research activities, including measurements, retrievals, data analysis, model simulations, calibration, and validation. Office personnel collaborate with other scientists and engineers at Goddard Space Flight Center, other NASA centers, and at universities and other government agencies, both nationally and internationally.

2.4.1. Wallops Precipitation Research Facility

Home based at Wallops Flight Facility (WFF), the Precipitation Research Facility (PRF) is designed to provide multi-scale, referenced ground-based radar, disdrometer, and rain gauge-based measurements of hydrometeor properties including size, number concentration, shapes, fall speeds, and water contents for both liquid (e.g., rain) and frozen (e.g., snow) hydrometeors. The resultant PRF network supports fundamental NASA Precipitation Measurement Mission (PMM) science by providing ground validation of precipitation's physical characteristics in the context of testing and improving Tropical Rainfall Measurement Mission (TRMM) and Global Precipitation Measurement Mission (GPM) precipitation remote-sensing algorithms. PRF instrument assets include the NASA S-band dual-polarimetric radar (NPOL), the Dual-Frequency Ka–Ku band Dual-Polarimetric Doppler Radar (D3R), the TOGA C-band radar, a plethora of video, impact and laser disdrometers, high-density autonomous rain gauge networks, a dual-pit gauge reference site located at WFF, vertically-pointing micro rain radars (K-band; MRR), snowfall particle imaging, and liquid water content measurement systems. When not deployed in remote field campaigns, PRF instruments are stationed regionally in a network around the WFF as a means to support GPM Ground Validation, test instrumentation performance, develop new sampling methodologies, and conduct new PMM science.

2.4.1.1. GPM Ground Validation Operations

During 2014 home-based operations at WFF, the NASA D3R Ka–Ku Band radar was relocated from its original operating location on the Wallops main base and installed at the NPOL radar site in Newark, Maryland. Both radars were operated in tandem (co-scanning) to collect precipitation data in support of GPM ground validation and precipitation science research. After launch of the GPM Core satellite platform in late February, the NPOL and D3R radars conducted numerous coordinated data collections during GPM Core satellite overpasses in precipitation systems producing both rain and snow. When possible, ground-based disdrometer and PRF dense-rain-gauge network data within the GPM overpass coverage swaths were used to complete the calibration loop between precipitation rate- and size-distribution measurements made at the Earth's surface, upward through the atmospheric column via the NPOL and D3R radars, and by instruments onboard the GPM spacecraft looking downward from their space-based vantage point. Collectively, the data obtained in PRF radar and supporting instrument operations during GPM overpasses enabled direct comparisons between ground-based attenuated (D3R) and unattenuated (NPOL) radar measurements, and GPM radar and radiometer views from space. Moreover, the data provide high-resolution precipitation information to physical validate GPM's precipitation retrieval algorithms.

As a spinoff to PMM/GPM radar operations, the NPOL radar also collected several months of unique mid-Atlantic regional bird migration data during periods of clear-air/no-weather a collaborative effort with The Nature Conservancy.

2.4.1.2. PRF Deployment and Leadership in the NASA GPM Integrated Precipitation and Hydrology Experiment (IPHEx) Field Campaign

The Wallops Field support office played a critical role in the GPM Integrated Precipitation and Hydrology Experiment (IPHEx), which began May 1, 2014. The Integrated Precipitation and Hydrology Experiment (IPHEx) was centered in the Southern Appalachians and extended into the Piedmont and Coastal Plain regions of North Carolina. The campaign objectives were to characterize warm-season orographic precipitation and the relationship between these precipitation regimes and hydrologic processes in regions of complex terrain. Dr. Walt Petersen, 610.W, was the NASA principal investigator on the experiment. IHPEx made use of airborne assets, such as the NASA ER-2, as well as cloud-penetrating aircraft, such as the University of North Dakota Citation. The Wallops PRF deployed the NPOL and D3R radars, 24 Parsivel, 6 Joss-Waldvogel, and 5 2D-video disdrometers, 4 Micro Rain Radars, and more than 50 rain gauges. Contact: walt.petersen@nasa.gov ***(Walt Petersen)***

Figure 2.22: Airborne and ground-based measurements of precipitation and storms during IPHEx. Upper panel: The NPOL and D3R radars sampling an approaching thunderstorm. Lower left: View from the cockpit of the NASA ER-2 of a severe thunderstorm being sampled during a GPM overpass (D. Broce, NASA/AFRC). Lower right: View from the cockpit of the University of North Dakota Citation during sampling of cloud and precipitation hydrometeors.

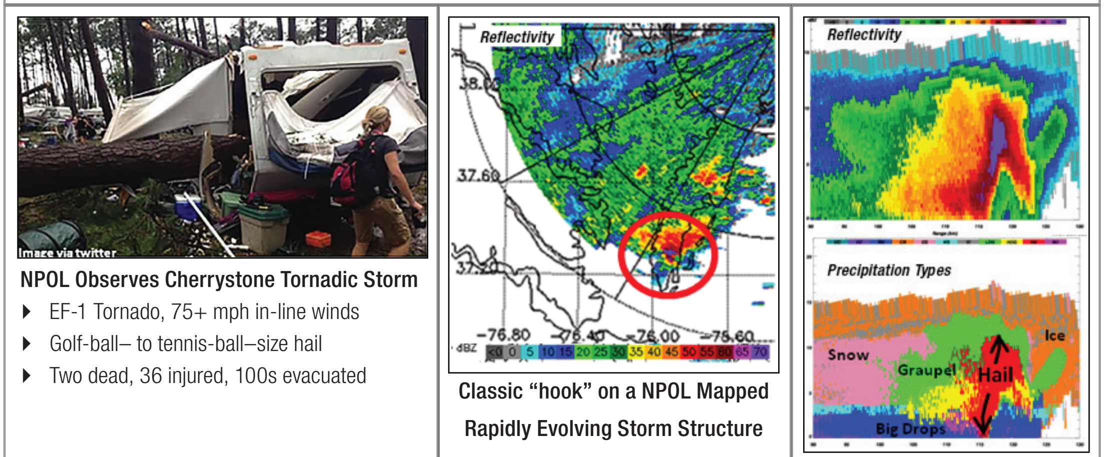
2.4.1.3. Operations with the 613 SMART/ACHIEVE Platforms

A 100-foot radar calibration tower was completed for radar calibration operations of the ACHIEVE 94-GHz radar in collaboration with the WFF Precipitation Research Facility. The 100-foot telescoping tower configuration carries frequency-appropriate corner reflectors and can be used by virtually any radar with a line of site view of the tower. Use of the tower for regular instrument calibration will assure quality data collections during planned combined multi-frequency radar (e.g., ACHIEVE and D3R) studies of the aerosol-cloud and precipitation process at WFF, and a baseline calibration prior to external field deployments. Contact: walt.petersen@nasa.gov (Walt Petersen) si-chee.tsay-1@nasa.gov ***(Si-Chee Tsay)***

2.4.1.4. PRF Radar Operations Capture the Cherrystone Campground Tornado

During routine precipitation data collections on July 24, 2014, the NPOL radar coincidentally sampled a rare tornado in the Mid-Atlantic/Chesapeake Bay region as it translated across the Eastern Shore of the Delmarva Peninsula (120 km south of the NPOL radar site). The severe storm and associated tornado hit the Cherrystone RV campground in the early morning hours, producing 75+ mph straight-line winds and golf-ball– to tennis-ball–sized hail, which caught hundreds of people unaware. As a result, two people were killed, 76 people were injured, and 100's were evacuated. As it crossed the Chesapeake Bay and Delmarva Peninsula, the evolving storm circulation was scanned in the horizontal at high temporal resolution, and then scanned in the vertical to reveal its deep damaging core of large hail (Figure 2.23). The relative rarity of severe storms makes them important to observe and measure for precipitation science, satellite applications, and weather decision support.

July 24, 2014: NPOL and DS3 Reassembled for GPS Ops in Newark, MD



NPOL Observes Cherrystone Tornadic Storm

- EF-1 Tornado, 75+ mph in-line winds
- Golf-ball– to tennis-ball–size hail
- Two dead, 36 injured, 100s evacuated

Classic "hook" on a NPOL Mapped Rapidly Evolving Storm Structure

Vertical Slice of Storm

Figure 2.23: NPOL and D3R radars in Newark, Maryland, on July 24, 2014, with the NPOL radar scanning during the event. Lower left: Damage at the RV campground. Lower center: Classic "pendant" echo in radar reflectivity. Lower right: Vertical slices collected in NPOL range-height scanning mode showing the deep storm with its precipitation structure. Note the large echo-void region in the upper Reflectivity plot and the large hail located above that region in the lower Precipitation Type plot. This was where the severe storm's strong updraft was located.

For further information on PRF GPM-site instruments, activities, and operations—including images of real-time NPOL data (when operating)—or access to disdrometer and rain gauge network data, go to http://wallops-prf.gsfc.nasa.gov/. Additionally, GPM Ground Validation network and field campaign data can be accessed (e.g., IPHEx and other campaigns) at the new PRF-developed GPM GV Web site at GPM GV: http://gpm-gv.gsfc.nasa.gov/. Contact: walt.petersen@nasa.gov ***(Walt Petersen, David Wolff)***

2.4.2. Cryospheric Science in 610.W

2.4.2.1. Airborne Topographic Mapper (ATM) and Deployment in Operation IceBridge

The ATM lidar instruments, based at NASA's Wallops Flight Facility (WFF) Code 610.W, have continued to provide climate change scientists with accurate (<10 cm) surface elevation measurements of polar land and sea ice on an annual basis for more than 21 years. In CY 2014, the WFF Airborne Topographic Mapper Lidar project flew 47 missions aboard the NASA P3B aircraft over Arctic land and sea-ice regions, based out of Alaska and Greenland in March thru May. In October and November 2014, the ATM lidars were onboard the NASA DC8 aircraft base from Punta Arenas, Chile, and successfully collected data during 22 Antarctic missions. During CY 2014, the ATMs flew over 197,000 nautical miles during 650 flight hours on 69 NASA IceBridge missions. The data from the 2014 Arctic deployment has been processed and uploaded to the National Snow and Ice Data Center (nsidc.org); the Antarctic campaign data is currently being processed. The ATM lidars have successfully collected data on 533 climate change missions since 1993 (including 290 IceBridge missions since 2009). All ATM lidar elevation data taken since 1993 is available to the public at nsidc.org. Contact william.b.krabill@nasa.gov. ***(William Krabill, Jim Yungel)***

Figure 2.24: ATM Lidar workstation and data collection during IceBridge aboard the NASA DC-8.

2.4.2.2. ICESat-2 Data System

The ICESat-2 Science Investigator-led Processing System (SIPS) and Instrument Support Facility (ISF) teams supported the successful ICESat-2 Mission critical design review in February. During 2014, the SIPS and ISF completed Version 1 software, system development, and testing for the ICESat-2 mission. Contact: Peggy.l.jester@nasa.gov. ***(Peggy Jester)***

2.4.3. Ocean Science in 610.W

2.4.3.1. Ocean Ecology

Climate change will alter the magnitude and timing of ocean-forcing conditions that affect phytoplankton biomass and productivity with consequences to the ocean carbon cycle. A strong motivation exists for developing novel approaches at the base of the food chain to create more precise formulations of biogeochemical models that incorporate ecosystem function and marine productivity. An understanding of phytoplankton taxonomic composition in relation to ocean color chlorophyll *a* allows for a more mechanistic understanding of past and future changes between climate and ecosystem dynamics. Research efforts in Code 610.W—in support of future missions such as PACE, HyspIRI, and GeoCAPE—have focused on the spatial and temporal variability of various phytoplankton functional types (PFTs). These PFTs are critical to improving modeled primary productivity and biologically mediated fluxes of elements between the upper ocean and the ocean interior, and for understanding the feedbacks of climate change. Contact: tiffany.a.moisan@nasa.gov ***(Tiffany Moisan, Kay Rufty)***

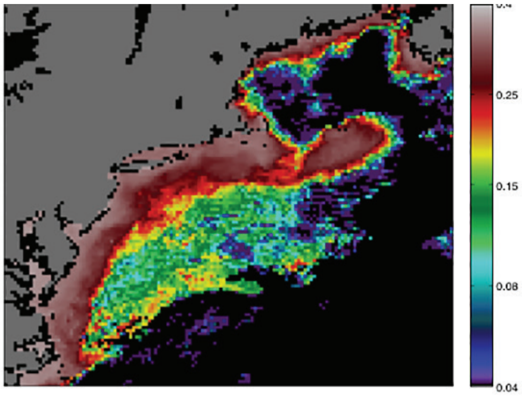


Figure 2.25: This image shows concentrations of diatom biomass (fucoxanthin/chlorophyll a*; shaded) during the summer of 2007 in the North Atlantic.*

2.4.3.2. Airborne Sensors for Hyperspectral Reflectance Imaging of Marine Pigments (AirSHRIMP)

A miniature hyperspectral radiometry instrument was developed for integration into an Unmanned Airborne System (UAS) platform. This year's activities focused on: 1) completing integration for installation into a UAS; 2) preparing to carry out flight tests over the coastal ocean; 3) developing a real-time cross-track scanning capability to support of real-time, vicarious calibration techniques; 4) completing NIST-traceable calibration protocols; and 5) integrating additional radiometers to expand the spectral observing range to include 200 to 2,500 nm. This instrument is being built to collect hyperspectral observations for development of an inverse modeling capability in addition to potentially supporting future plans for ocean color mission activities (e.g. PACE/ACE/GeoCAPE/HyspIRI). Contact: john.r.moisan@nasa.gov ***(John Moisan, Geoff Bland)***

2.4.3.3. Climate Adaptation Science Investigation (CASI) Sea-Level Risk Assessment

During 2014, a Level 1 "Bathtub Model" sea-level-rise risk assessment related to climate change at the Wallops Island facilities was completed; the results are being published as a NASA Technical Memorandum. The NASA launch range at Wallops Flight Facility is located on a barrier island on the Eastern Shore of Virginia that is exposed to the Atlantic Ocean. Facilities on this island support a wide range of launch services, ranging from launching suborbital sounding rockets, to larger International

Space Station (ISS) commercial resupply and scientific satellites, to supporting an unmanned aircraft runway capability. The island provides invaluable environmental services for protecting the coastal regions from storms and provides important habitats for large-scale bird migrations. Future climate change scenarios and observed present sea level rise trends elevate the risk of ocean flooding events. How risk changes for the various WFF assets over time depends on the location of the asset, the long-term sea level rise and storm activity forecasts, observed tidal and storm related sea level variability and the risk of hurricanes and other regional storm events to the Eastern Shore. The results from this CASI risk analysis focus on a first order cost-based risk analysis approach that makes use of presently available observations of sea level variability, coastal elevation data sets, and a WFF building-specific cost/valuation assessment. The resulting methodology can be used in planning for future facility improvements through. The next phase of this analysis will focus on improvement of the accuracy of the risk estimates through incorporation of a facility specific elevation dataset that will be developed through internship support. Contact: john.r.moisan@nasa.gov or CASI PI tiffany.a.moisan@nasa.gov. ***(John Moisan, Tiffany Moisan)***

2.4.3.4. Genetic Programming for Ocean Microbial Ecology and Biodiversity

This Genetic Programming for Ocean Microbial Ecology and Biodiversity is funded by the NASA Science Mission Directorate and The Gordon and Betty Moore Foundation jointly; John R. Moisan is the principal investigator. This past year's accomplishments have resulted in the publication of software package called GPCODE, available through a GitHub distribution (https://github.com/). Presently, the GPCODE can evolve satellite algorithms (single equations), and it has completed testing for solutions to simple box model ecosystems. We are presently working to model the colored, dissolved organic matter for various global regions in an attempt to evolve specific ecosystem models to the ocean. Contact: john.r.moisan@nasa.gov ***(John Moisan)***

2.4.4. Unmanned/Remotely Operated Vehicles

2.4.4.1. ROVER

Training operations were conducted with two Remotely Operated Vehicles for Education and Research (ROVER) at the Chesapeake Bay Environmental Center (CBEC) during April and July. The "X-3" ROVERs are the final result of a 2011–2013 IRAD project for education, with partners at the University of Maryland Eastern Shore (Bland, et al). The CBEC deployment was a first step in incorporating new hardware and practices for the Remote-sensing Earth Science Teacher Program (RSESTeP, Coronado, et al). The ROVER/RSESTeP activities focus on a team approach to science learning using miniature instrumentation and platform technologies. Key Goddard participants included Sallie Smith (606.3), Patrick Coronado (606.3), Ted Miles (569), and Geoff Bland (610.W). Contact: geoffrey.l.bland@nasa.gov. ***(Geoff Bland)***

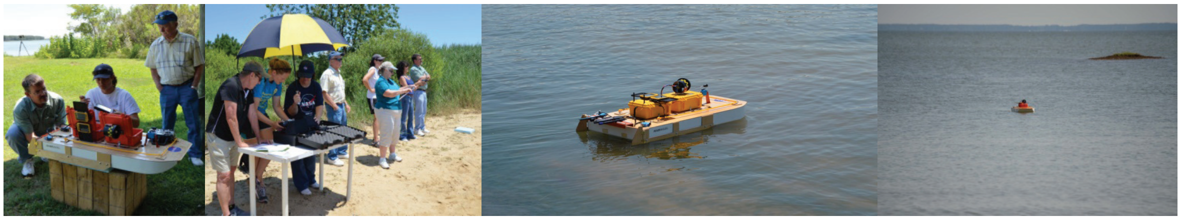


Figure 2.26: Testing the X-3 ROVER in the Chesapeake Bay.

2.4.4.2. Dragon Eye UAS Sulfur Dioxide Sensor Development

A series of sulfur dioxide sensor instrument packages were prepared and integrated in nose cones for the Dragon Eye unmanned aircraft fleet operated by NASA ARC. These instrument systems incorporated electrochemical, temperature, humidity, and pressure sensors; data loggers; and batteries, with a total mass of less than 350 grams, including nose shell. These instrument packages will be flown on multiple aircraft simultaneously to test out formation flying as a method for capturing spatially distributed measurements. The first formation flying research target is the Salton Sea in California, and the experiment is part of a series led by David Pieri (JPL) that is focused on *in situ* observations of volcanic plumes. Previous single aircraft flights were conducted at the Turrialba volcano in Costa Rica in 2013. Ted Miles (569) and Geoff Bland (610.W) created the novel instrument packages. Contact: Geoffrey.l.bland@nasa.gov ***(Geoff Bland, Ted Miles)***

Figure 2.27: Dragon Eye UAS nose cones as designed for sulfur dioxide in situ sampling.

2.5. Wallops Upper Air Program

Upper air observations continued for the longest sustained ozone measurement site in the world at the Wallops Flight Facility. Routine weekly ozone and thermodynamic profile soundings were launched from the site. Several special operations were also conducted in coordination with Aura and SNPP overpasses. Continued measurements were collected from the ground-based Ozone Research Facility (ORF) using the Dobson spectrophotometer and a ground-based UV radiometer (GUV-51C). In collaboration with the NOAA Geodetic Survey, a Trimble NetRS GPS instrument was also used for the Continuously Operating Reference Station (CORS) network “VAWI” site at Wallops. Operational assistance and resupply was completed for the recent return-to-service of the Natal, Brazil, (Barra de Maxaranguape) ozone observing site, in collaboration with the Southern Hemisphere Additional Ozonesondes (SHADOZ) program under the guidance of Dr. A. Thompson, principal investigator (613). Natal resumed its weekly ozonesonde soundings operating under the joint NASA-INPE MOU. The existing support contract was modified to include logistics and processing for the Natal station in addition to the ongoing Wallops site operation. Contact: francis.l.bliven@nasa.gov. ***(Larry Bliven, Tom Northam)***

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. Decadal Survey Missions

3.1.1.1 ACE

The Aerosols, Clouds, and Ecosystems (ACE) mission is a Tier-2 mission recommended by the National Research Council (NRC) *Decadal Survey for Earth Sciences* (2007). Aerosols and clouds are major factors in modulating global climate change. ACE seeks to provide the necessary measurement capabilities to enable robust investigation of aerosols and clouds and their role in climate and global change, especially with regards to characterizing and understanding the physical processes that are occurring. The plan is to fly one or two satellites in sun-synchronous polar orbit to provide high-resolution global measurements of aerosols, clouds, and ocean ecosystems. In particular, the mission will provide major new measurement capabilities to enable dramatic steps forward in understanding the direct radiative role of aerosols in global climate change, the indirect aerosol effects via interactions with clouds and precipitation, and cloud processes. The current nominal plan is for a 2023 launch into low Earth-orbit at an altitude of 400–450 km. The nominal ACE payload includes an advanced polarimeter for aerosol and cloud measurements, a nadir-pointing, 7-channel HSRL ($3\beta+2\alpha+2\delta$), and a dual-frequency (w- and ka-band) Doppler radar with limited scanning capability. Broad-swath radiometers sensing in the infrared, microwave, and sub-millimeter spectral regions are also included in the mission concept.

A comprehensive report, including detailed science traceability matrices, is available for review at: http://acemission.gsfc.nasa.gov/. Significant progress was made in advancing the technical readiness (TRL) of the instrument concepts in 2013 and 2014. Significant progress was also made in developing and maturing the associated science algorithms, especially polarimeter retrievals of aerosol properties and also including initiation of efforts to develop multi-sensor algorithms for clouds that are mission critical to advance the science. The polarimeter definition experiment (PODEX) was successfully conducted over California in January through February 2013. Analysis of data acquired during PODEX is proceeding. These data and their analysis directly support algorithm development and ultimately trade studies to resolve questions about the polarimeter concepts. PODEX was conducted in close coordination with DISCOVER-AQ. DISCOVER-AQ acquired highly valuable *in situ* and remote-sensing validation data and also included HSRL-2, a simulator for the full $3\beta +2\alpha +2\delta$ system envisioned for ACE. Analysis indicates excellent data and target quality, and acquisition of a substantial subset of the desired scene types. The first radar definition experiment (RADEX) was conducted in May through June 2014 in the vicinity of North Carolina and over nearby waters. This experiment leveraged the International Precipitation-Hydrology Experiment (IPHEx) that was largely sponsored by the Ground Validation Program for the Global Precipitation Mission (GPM). For the first time, radar data were concurrently collected at four frequencies (at w-, k_a-, ku-, x-bands) from NASA's high-altitude ER-2, along with lidar and microwave radiometer observations. *In situ* microphysical data were also obtained (UND Citation). The goal of RADEX is to demonstrate the potential and limitations of radar retrievals of cloud microphysical profiles, especially multi-sensor approaches. A second deployment is planned, this time to the Seattle region in November and December 2015 (RADEX-15), again in coordination with GPM GV (OLYMPEX).

A comprehensive report on ACE progress over the past five years is presently in final stages of preparation and will constitute a substantial update and input to the upcoming next NRC *Decadal Survey for Earth Sciences*. For further information, please contact the ACE Science Study Lead, Arlindo da Silva (arlindo.dasilva@nasa.gov), or David Starr (david.starr@nasa.gov).

3.1.1.2 ASCENDS

The Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission, recommended by the NRC's 2007 Earth Science Decadal Survey, is considered the technological next step in measuring CO_2 from space following deployment of passive instruments such as the Japanese Greenhouse gases Observing Satellite (GOSAT, 2009) and the NASA Orbiting Carbon Observatory re-flight (OCO–2, 2014). Using an active laser measurement technique, ASCENDS will extend CO_2 remote-sensing capability to include uninterrupted coverage of high-latitude regions and nighttime observations with sensitivity in the lower atmosphere. The data from this mission will enable investigations of the climate-sensitive southern ocean and permafrost regions, produce insight into the diurnal cycle and plant respirations processes, and provide useful new constraints for global carbon cycle models. NASA currently plans for launch in the FY 2022–2023 timeframe. An ASCENDS mission white paper is in preparation.

The Atmospheric Chemistry and Dynamics Laboratory supports ASCENDS through technology development, analysis of airborne simulator data, instrument definition studies, and carbon cycle modeling and analysis. Lab members are engaged in CO_2 instrument development and participate on technology projects led by the Laser Remote-sensing Laboratory, which target instrument and mission development for ASCENDS. The laboratory plays a key role in radiative transfer modeling, retrieval algorithm development, instrument field deployment, and data analysis on a project to develop a laser spectrometric instrument for ASCENDS. Based on experience and knowledge of carbon cycle science, they actively help to keep the technology development on track to best achieve the science objectives for ASCENDS. They also support the ASCENDS flight project by performing observing system simulations to establish science measurement requirements and to evaluate the impact of various mission technology options. For further information, please contact S. Randolph Kawa (stephan.r.kawa@nasa.gov) or see the NASA ASCENDS Web site: http://decadal.gsfc.nasa.gov/ascends.html.

3.1.1.3 GEO-CAPE

Geostationary Coastal and Air Pollution Events (GEO-CAPE) is one of the missions recommended by the National Research Council's Decadal Survey, with the goal of measuring atmospheric pollution (aerosols and trace gases) and coastal water from a geostationary platform. Scientists in Code 613 and 614 have been involved in GEO-CAPE atmospheric studies for several years, including defining science objectives, measurement requirements, retrieval accuracy, retrieval sensitivity, etc. The Tropospheric Emissions: Monitoring of Pollution (TEMPO), led by principal investigator Kelly Chance of the Harvard Smithsonian Astrophysical Observatory, was selected as an Earth Venture-Instrument (EVi) mission and is expected to launch before 2020. Since its selection, the focus of the GEO-CAPE study has been centered on assessing to what extent the GEO-CAPE atmospheric science objectives can be achieved by TEMPO and how additional measurements and synergistic efforts between TEMPO and other satellite programs can help fulfill the GEO-CAPE objectives.

In FY 2014, Goddard scientists involved in GEO-CAPE's Aerosol Working Group have focused on evaluating the aerosol and related products from MODIS that are retrieved with the MAIAC algorithm over North America, (including the aerosol optical depth (AOD) and cloud mask) and comparing their findings with ground-based measurements and other satellite products. The purpose is to assess the potential use of MAIAC for GEO-CAPE aerosol retrieval from the combination of TEMPO and GOES-R satellite sensors. Other GEO-CAPE studies scientists in Code 614 and GMAO involved in this effort include the global and regional Observing System Simulation Experiment (OSSE) that use global and regional models to generate atmospheric states at high spatial and temporal resolution to test the GEO-CAPE retrieval sensitivities and methodology. The aerosol and OSSE studies in Goddard will continue in FY 2015. For further information, please contact Mian Chin (mian.chin@nasa.gov).

3.1.1.4 Global 3D-Winds

The NRC *Decadal Survey* for Earth Science identified the Global Tropospheric 3D-Winds mission as one of the 15 priority missions recommended for NASA's Earth Science program. The 3D-Winds mission will use Doppler lidar technology to accurately measure (from space) the vertical structure of the global wind field from zero to 20-km altitude in order to fill this important gap in the global observing system. The *Decadal Survey* panel recommended a two-phase approach to achieving an operational global wind measurement capability. First, the panel recommended that NASA develop and demonstrate the Doppler lidar technology and measurement concept, and establish the performance standards for an operational wind mission. The second phase would develop and fly a space-based wind system based on this technology. In FY 2012, we made significant advances in the technological readiness of the direct-detection Doppler lidar approach leading towards space. Highlights of these advances include the October 2013 flights of the TWiLiTE Doppler lidar system, an airborne technology test bed for the space-based system, from NASA's ER-2 research aircraft. These flights yielded the first measured profiles of winds through the entire troposphere. These wind profiles, which extend from the aircraft altitude of 20 km to the surface with a vertical resolution of 250 m, demonstrated the data utility of the Doppler lidar wind system. Also in FY 2013 the TWiLiTE system was reconfigured to fly on the NASA Global Hawk as part of the Hurricane and Severe Storm Sentinel (HS3) Earth Venture Mission.

We also continued to explore new technologies in collaboration with the engineering Directorate by completing an ESTO-funded development program named The Hybrid Wind Lidar Transceiver (HWLT) telescope system. The HWLT utilizes a unique, all-composite structure that greatly reduces the weight, increases the stiffness, and decreases temperature sensitivity of the telescope system. Finally, space-based mission studies, sponsored by NASA Earth Science Technology Office, were carried out in the Goddard Integrated Design Center to explore the possibility of flying a Doppler lidar system on the ISS in the next several years. For further information, please contact Bruce Gentry (bruce.m.gentry@nasa.gov).

Table 3.1: Mission Study Scientists

Name	Mission
David Starr, Dong Wu	ACE Study Lead
Mian Chin, Omar Torres	GEO-Cape
Randy Kawa	ASCENDS
Bruce Gentry	Global 3D-Winds

3.1.2. NASA's Planned Missions

3.1.2.1 DSCOVR

Goddard scientists and engineers are working on the finishing touches for two Earth-viewing instruments on board the Deep Space Climate Observatory (DSCOVR) spacecraft, scheduled for a launch in 2015 to the Lagrange-1 (L1) orbital point between the Earth and the Sun. These instruments are the National Institute of Standards (NIST) Advanced Radiometer (NISTAR) and the Earth Polychromatic Imaging Camera (EPIC). The four-channel radiometer, NISTAR, provides broadband measurements (UV to IR) of the entire sunlit Earth's reflected radiation. The 10-channel EPIC measures spatially resolved radiances that can detect ozone levels, aerosol index, aerosol optical depth, scene reflectivity, cloud height, vegetation, and leaf area indices. Recently, the DSCOVR spacecraft has been undergoing thermal vacuum testing on the PlasMag, EPIC, and NISTAR instruments in preparation for the launch.

Data collection will start earlier than originally scheduled—now 110 days after launch instead of 6 months. The first 20–30 days have been designated for commissioning before routine data operations begin. However, usable data will be obtained almost immediately after injection into L1 orbit and opening the telescope door. The project will use a powered trip to L1 to shorten the time and reduce project costs for a "marching army". This will reduce the amount of fuel available when at L-1, but it will still leave enough for a possible 5 years of operation. The mission still has an official 2-year lifetime to completion. For further information, please contact Alexander Marshak (alexander.marshak@nasa.gov) or Jay Herman (jay.r.herman@nasa.gov).

3.1.2.2 JPSS

The Joint Polar Satellite System (JPSS) is the Nation's next generation polar-orbiting operational environmental satellite system. JPSS is a collaborative program between the National Oceanic and Atmospheric Administration (NOAA) and its acquisition agent, National Aeronautics and Space Administration (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 2014, the JPSS program focused its near-term efforts on supporting the operations of Suomi NPP. The JPSS program provides three of the five instruments, the ground system, and post-launch satellite operations to the NPP mission. Suomi NPP observatory operations were successfully transferred from the JPSS program to the NOAA Office of Satellite and Product Operations in February 2013.

The future JPSS missions, J1 and J2, are currently scheduled for December 2016 and November 2021 launches. The J1 mission will be very similar to NPP, using the same spacecraft and instrument complement. The JPSS Program Critical Design Review was help in April 2014. At the end of 2014, the OMPS and CERES Instruments were shipped and integrated with the J1 spacecraft. The other three instruments were in system-level test with calibration, characterization, and environmental testing to be completed in 2014. For further information, please contact James Gleason (james.gleason@nasa.gov).

3.1.3. NASA's Active Flight Missions

3.1.3.1 Aqua

The Aqua spacecraft, launched on May 4, 2002, carries six Earth-observing instruments: AIRS, AMSU, AMSR-E (operating at reduced capacity), CERES (two copies), HSB (no longer operational), and MODIS. The report of the 2013 Senior Review panel for satellite missions in extended operations (available at http://nasascience.nasa.gov/earth-science/missions/operating/) awarded Aqua very high scores for scientific merit, scientific relevance, and scientific product maturity, and the highest overall score among all missions from the National Interests Panel. In addition to collecting data pertaining to Earth's water in all its phases, as highlighted by the name "Aqua," mission instruments also provide measurements for (among others) radiative energy flux, atmospheric temperature and composition, aerosols, cloud properties, land vegetation, phytoplankton and dissolved organic matter in the oceans, and surface albedo, temperature and emissivity. These measurements help scientists to quantify the state of the Earth system, validate climate models, address key science questions about the planet's environment, and serve the applications community. Aqua Deputy Project Scientist, Lazaros Oreopoulos assists Project Scientist Claire Parkinson in a variety of activities that support the mission and has the lead on budgetary matters and fund disbursement. For further information, please contact Lazaros Oreopoulos (lazaros.oreopoulos@nasa.gov).

3.1.3.2 Aura

The Aura spacecraft, which was launched July 15, 2004, carries four instruments to study the composition of the Earth atmosphere. The Ozone Monitoring Instrument (OMI), the Microwave Limb Sounder (MLS), the High Resolution Dynamics Limb Sounder (HIRDLS), and the Tropospheric Emission Spectrometer (TES) make measurements of ozone and constituents related to ozone in the stratosphere and troposphere, aerosols, and clouds. With these measurements the science team has addressed questions concerning the stratospheric ozone layer, air quality, and climate. Ten years have passed since launch, and two of the instruments continue to make daily measurements. HIRDLS suffered an anomaly and is no longer operational. TES shows signs of aging and presently makes limited measurements intended to validate products that were not standard at launch and to characterize composition in targeted regions.

In 2014, Aura data revealed new aspects of the Earth composition while continuing to build a multiyear, global dataset reveals connections between chemistry and climate. The OMI measurements of nitrogen dioxide, a pollutant produced mainly by combustion of gasoline in vehicles and coal in power plants, show the dramatic decline in US cities over the past decade due to regulation, technological improvement and economic changes. Analysis of MLS data in the tropics and lower stratosphere along with TES observations in the middle latitude mid-troposphere reveal their connections due to changes in the stratospheric circulation as a result of El Niño/La Niña and the quasi-biennial oscillation. TES spectra provide novel information about the seasonal cycle of peroxyacyl nitrate (PAN) from Asian pollution in the free troposphere and its subsequent transport to North America (where it can contribute to ozone pollution). Although HIRDLS is no longer operational, recent analysis of HIRDLS high vertical resolution profiles provided unprecedented information about gravity waves and their contributions to atmospheric circulation at both climate and weather scales. More information on Aura science highlights can be found at http://aura.gsfc.nasa.gov/ or contact Anne Douglass (anne.r.douglass@nasa.gov).

3.1.3.3 GOES

NOAA's Geostationary Operational Environmental Satellites (GOES) are built, launched, and initialized by Goddard's GOES Flight Project Office under an interagency program hosted at Goddard (http://www.goes-r.gov/). The GOES series of satellites carry sensors that continuously monitor the Earth's atmosphere for developing weather events, the magnetosphere for space weather events, and the Sun for energetic outbursts. The project scientist from 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. During 2014, the first flight models of five new and improved instruments were delivered for the next generation of GOES satellites, the first of which is scheduled for launch in March 2016.

The project scientist also operates a GOES ground station that offers real-time, full-resolution, calibrated GOES images to support scientific field experiments and to supply Internet users with high-quality data during severe weather events. The GOES Project Science Web site (http://goes.gsfc.nasa.gov/) offers weather imagery and movies overlaid on a true-color background—an attractive and popular format. For example, in August 2014, the site served 3.7 terabytes to 339 thousand guests from around the world at the average rate of three requests-per-second. For further information, please contact Dennis Chesters (dennis.f.chesters@ nasa.gov).

3.1.3.4 GPM

The Global Precipitation Measurement (GPM) is an international satellite mission that provides next-generation observations of rain and snow, worldwide, every three hours. NASA and the Japan Aerospace Exploration Agency (JAXA) launched the Core Observatory satellite on February 27, 2014, carrying advanced instruments that set a new standard for precipitation measurements from space. Its data is used to unify precipitation measurements made by an international network of satellites provided by partners from the European Community, France, India, Japan, and the United States and to quantify when, where, and how much it rains or snows around the world. The GPM mission will advance our understanding of the water and energy cycles, and extend the use of precipitation data to directly benefit society. In support of pre- and at-launch precipitation retrieval algorithm development, GPM has been conducting a series of field campaigns with international and domestic partners in the past five years. In May–July of 2014, GPM, Duke University, and NOAA jointly conducted the Integrated Precipitation and Hydrology EXperiment (IPHEX) in the southern Appalachian Mountains. Space and ground instruments were used to evaluate the accuracy of flood forecasting models and precipitation measurements from space. International science collaboration in GPM ground validation (GV) plays a vital role in refining remote-sensing algorithms and in assessing the quality and utility of satellite precipitation products in different climate and geographic regimes. Under GPM programmatic leadership, GPM GV partners from approximately 20 countries developed consensus plans for GV instrument calibration, tier infrastructures, and coordinated future GV campaigns.

Significant milestones and activities were met during 2014. GMI Level 1 data was released in June, two months early, to support tropical storm forecasting. All Level 2 precipitation products were released on schedule in September. The science team met in Baltimore in August to review algorithm development, plan for future activities, including a general reprocessing during 2015 that will establish a consistent data record back to the beginning of the TRMM era (1998), and celebrate the life of the late project scientist, Arthur Hou. A vigorous outreach and education effort included consolidating data and documentation links into a coherent set of data access pages, and establishing a Master Teacher program. For further information, please contact Gail Skofronick Jackson (gail.s.jackson@nasa.gov) or visit the GPM homepage at http://gpm.nasa.gov.

3.1.3.5 ISS/JEM-EF (CATS)

The Cloud-Aerosol Transport Lidar (CATS) is a light detection and ranging (LiDAR) remote-sensing instrument designed to provide measurements of the particulate contents within the atmosphere including clouds and aerosols. The CATS instrument can function as both a standard backscatter lidar and a high spectral resolution lidar (HSRL). As an on-orbit demonstration, the HSRL aspect of CATS will provide direct measurement of optical properties (e.g., extinction) without the assumptions normally required for backscatter lidar retrievals. The instrument uses a laser to obtain data on the location, composition, and distribution of atmospheric constituents that impact the climate on a global scale. A better understanding of cloud and aerosol coverage and properties is critical for understanding and modeling of the Earth system and associated climate feedback processes.

CATS was originally designed for operation on high-altitude aircraft to demonstrate the technology for future spaceborne missions, such as the proposed Aerosol-Cloud-Ecosystems (ACE) mission, as well as to provide critical validation capability for future missions. The success of the system has enabled the transition to a spaceborne system. CATS will fly as an attached payload for the Japanese Experiment Module Exposed Facility, or JEM-EF, onboard the International Space Station (ISS). The CATS payload successfully completed all testing and was integrated to the SpaceX launch vehicle on October 8, 2014. The CATS payload is scheduled for launch to the ISS in January 2015.

The CATS mission goals: (1) to provide long-term (six months to three years) operational science from ISS; (2) to provide near–real-time measurements of clouds and aerosols that can be assimilated into aerosol transport models; (3) to provide an on-orbit technical demo for high rep-rate laser, photon-counting detection, and 355-nm laser operation in space; and (4) to provide risk reduction for future Earth Science missions. The cloud and aerosol products of layer boundaries, optical depth, and extinction are similar to the current Cloud Physics Lidar (CPL, http://cpl.gsfc.nasa.gov) data products. For further information, please contact Matt McGill (matthew.j.mcgill@nasa.gov) or http://cats.gsfc.nasa.gov.

3.1.3.6 SORCE

SORCE has been making daily measurements of TSI (Total Solar Irradiance) since March 2003. On July 30, 2013 SORCE went into its safe hold mode, temporarily ceasing 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 5-month gap in SORCE daily solar measurements, new flight software was developed by Orbital Sciences Corporation (OSC) and CU-LASP, and it was installed via uplink radio commands in time for a special campaign in the last week of December 2013 to ensure overlapping measurements between SORCE and TCTE (TSI Calibration Transfer Experiment)/TIMs (Total Irradiance Monitor) launched in November 2013 on the Air Force's Operationally Responsive Space (ORS) Space Test Program Satellite-3. Additional SORCE flight software deployed in late February 2014 enabled a "hybrid" operation mode that has allowed SORCE to resume making daily solar observations until the NOAA Total and Spectral Solar Irradiance Sensor (TSIS) begins operations in 2017 on the International Space Station (ISS). For further information, please contact Robert Cahalan (robert.f.cahalan@nasa.gov).

3.1.3.7 Suomi NPP

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

Suomi NPP is on track to extend and improve upon the Earth system data records established by NASA's Earth Observing System (EOS) fleet of satellites, which have provided critical insights into the dynamics of the entire Earth system: clouds, oceans, vegetation, ice, solid Earth, and atmosphere. Data from the Suomi NPP mission will continue the EOS record of climate-quality observations after EOS Terra, Aqua, and Aura.

Since launch, Suomi NPP's instruments have been in nominal operations. Suomi NPP's Level 1 instrument data and all the higher-level data products have been publicly released and are available from the archive.

In August 2013, CrIS radiance data was added to the ATMS radiance data being ingested into operational numerical weather prediction models used by the National Weather Service. NOAA has been using VIIRS Imagery data from the SNPP direct broadcast data in the Advanced Weather Interactive Processing System (AWIPS) for weather forecasting in Alaska.

The 2010 Science Team has determined that the Suomi NPP instruments and the Level 1 data quality is sufficient and is to create data continuity products. A re-competition of the Suomi NPP Science Team was announced in the Research Opportunities in Space and Earth Sciences (ROSES) – 2013, with selections announced in August 2014. Science Team Members from Earth Science/Atmospheres include N. Christina Hsu, Robert Levy, Steven Platnick, Richard McPeters, P.K. Bhartia, Alexei Lyapustin, and Joel Susskind. The 2013 Science Team members have the mandate to create NASA data products from Suomi NPP mission that continue the data record from the EOS missions. For further information, please contact James Gleason (james.f.gleason@nasa.gov).

3.1.3.8 Terra

Launched on December 18, 1999 as NASA's Earth Observing System flagship observatory, Terra carries a suite of five complementary instruments: (1) ASTER (contributed by the Japanese Ministry of Economy, Trade and Industry with a American science team leader at JPL) 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) CERES (LaRC) 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) 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) MODIS (GSFC) 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) 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 15 years, the Terra mission has been providing the worldwide scientific community with an unprecedented 79 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, MOPITT); volcanic ash monitoring for the FAA (ASTER, MISR, MODIS); weather forecasting through NESDIS (MODIS, MISR, CERES); forest fire monitoring for resource allocation by U.S. Forest Service (ASTER, MODIS, MISR); and carbon management and global crop assessment by USDA and USDA-FAS (MODIS, CERES). After 15 years of continuous operation, the project office has coordinated closely with the science and engineering team to advocate that the EOS science to maintain a strong Terra program. For further information, please contact Si-Chee Tsay (si-chee.tsay-1@nasa.gov).

3.1.3.9 TRMM

The Tropical Rainfall Measuring Mission (TRMM) launched in late 1997 as a joint mission between NASA and JAXA. The first-time use of both active and passive microwave instruments and the processing, low-inclination orbit have made TRMM the world's foremost satellite for the study of precipitation and associated storms and climate processes in the tropics. TRMM instruments include the first and only precipitation radar (PR) in space, the TRMM microwave imager (TMI), a visible and infrared scanner (VIRS), and a lightning-imaging sensor (LIS). Originally, TRMM's goal was to advance our understanding of the mean distribution of tropical rainfall and its relation to the global water and energy cycles. As the TRMM mission has entered into its 18th year, the science objectives have extended beyond just determining the mean precipitation distribution and have evolved toward determining the time and space varying characteristics of tropical rainfall, convective systems, and storms and how these characteristics are related to variations in the global water and energy cycles.

In March 2014, shorts in one of the TRMM batteries led to the permanent disabling of the VIRS instrument. In July 2014, during an orbital boost to maintain flight altitude, sensors detected significant pressure drops in the fuel system indicating that TRMM was essentially out of fuel and would begin the slow descent back to Earth. The current prediction for shutting down the spacecraft and instruments prior to re-entry is April 2015. On October 7, 2014, TRMM PR data distribution was halted as the satellite fell below the operational altitude limit for valid PR data. As the spacecraft approaches its original orbit altitude of 350 km (likely in February 2015), PR data distribution will resume until near the end of the mission. With the launch of GPM in February 2014, TRMM will have almost a year of useful overlap with GPM (for TMI and GMI). The TRMM Web site (http://pmm.nasa.gov/TRMM) provides links to near–real-time precipitation estimates every three hours, with daily and weekly accumulations, as well as flood potential maps. A brief synopsis of many major hurricanes, typhoons, and flood events around the globe with attendant images of accumulated precipitation or precipitation structure can be found at http://trmm.gsfc.nasa.gov/publications_dir/extreme_events.html/. For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

3.2. Project 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 lists project and deputy scientists for current and planned missions. Table 3.3 lists the validation and mission scientists and major participants in field campaigns.

Table 3.2: Atmospheres Project and Deputy Project Scientist

Project Scientists		Deputy Project Scientists	
Name	**Project**	**Name**	**Project**
Charles Jackman	AIM	Lazaros Oreopoulos	Aqua
Anne Douglass	Aura	Bryan Duncan	Aura
Steve Platnick	EOS	Joanna Joiner	Aura
Dennis Chesters	GOES	Alex Marshak	DSCOVR
Gail Skofronick Jackson	GPM	George Huffman	GPM
James Gleason	JPSS/NPP	Christina Hsu	NPP
James Irons	LDCM	Si-Chee Tsay	Terra
Pawan K. Bhartia	OMI		
Robert Cahalan	SORCE and TSIS		
Scott Braun	TRMM		

Table 3.3: Atmospheres Validation, Instrument and Mission Scientists

Validation Scientists		Instrument Scientist	
Name	**Mission**	**Name**	**Campaign**
David Starr	EOS	Kenneth Pickering	DISCOVER-AQ
Ralph Kahn	EOS/MISR	Walter Petersen	GPM GV
Matthew McGill	ISS/JEM-EF/CATS	Scott Braun	HS3
Robert Cahalan, Dong Wu, Jae Lee, Charles Ickoku	TCTE/PFF (U.S.A.F.)	Walter Petersen	iFLoodS
		Judd Welton	MPLNET
		William Krabill	Operation IceBridge
		Walter Petersen	MC3E
		Judd Welton, Si-Chee Tsay	7 SEAS
		David Starr	PODEX
		Walter Petersen	Dragon Eye
		Tom Hanisco	SEAC4RS, SENEX

4. FIELD CAMPAIGNS

Field campaigns use the resources of NASA, other agencies, and other countries to carry out scientific experiments, to validate satellite instruments, or to conduct environmental impact assessments from bases throughout the world. Research aircraft, such as the NASA Global Hawks, ER-2, DC-8, and WB-57F, serve as platforms from which remote-sensing and in situ observations are made. Ground-based systems are also used for soundings, remote sensing, and other radiometric measurements. In 2014, atmospheric research personnel supported activities in the planning, testing, coordination and field operation phases as scientific investigators or as participants. Activities also included analysis and reporting from previous years campaigns and studies and planning for future efforts. Table 4.1 lists the Instrument Scientists and Managers associated with the various instrument systems and field programs.

4.1. CONTRAST

Glenn Wolfe (614), Dan Anderson (graduate student UMD) and Tom Hanisco (614) are participating in the convective transport of reactive species (CONTRAST) campaign in Guam. CONTRAST's research objectives were to quantify how large convective clouds redistribute atmospheric gases in the tropical atmosphere. The study took place in Guam from January 15 to February 28, 2014. The ISAF *in situ* formaldehyde is on the NCAR GV. The campaign goal is to track convective transport with a focus on reactive species including ozone, $NO_{x,}$ VOCs, halogens (bromine and iodine) and formaldehyde. The campaign coincided with the NASA Attrex campaign using the Global Hawk. The NCAR GV focused on the boundary layer to the upper troposphere (500 ft–47,000 ft). The following links provide more detail:

- UCAR Media Relations issued a press release yesterday about our project and the collaboration with NASA and the UK colleagues: http://www2.ucar.edu/atmosnews/news/10889/scientists-examine-pacifics-global-chimney
- Walison Rockwell of EOL EO lead has a very useful public communication page (linked to the main website): https://www.eol.ucar.edu/content/quick-questions-contrast-pis
- The *Baltimore Sun* published "Checking on Earth's 'chimney'": http://www.baltimoresun.com/features/green/blog/bs-hs-pacific-research-flights-20140124,0,6663971.story.

4.2. DISCOVER-AQ

The fourth and final field deployment for the Earth Venture DISCOVER-AQ project proceeded in July at the NCAR Research Aviation Facility at Broomfield, Colorado. The Wallops P-3B and Langley King Air were used to focus on the Front Range region of Colorado, from south of Denver to Ft. Collins. Moisture from the Southwest Monsoon began streaming over Colorado, creating cloudiness that hampers flights and ground operations. NCAR conducted a simultaneous project called the Front Range Air Pollution and Photochemistry Experiment (FRAPPE) with the objectives of examining inflow to and outflow from the Front Range Region, studying the upslope and downslope flow over the mountains, and characterizing various emission sources. Seven days of forecasting and flight planning continued to be a challenge in July as cloud cover had been an issue on most days. The flight on July 22 captured data from the largest ozone event of the season, with observations in the lower boundary layer of slightly over 100 ppbv.

The highest ozone generally is found under a mountains-plains solenoid circulation pattern, which recirculates polluted air over the locations in the foothills west of Denver. Some influence from wild fires in Wyoming, Nevada, and Utah was found, but this did not constitute a large impact, with aerosol optical depths from the dense network of AERONET sites not exceeding 0.4 to 0.5 for a daily average. The flight of July 28 captured the effects of low-level outflow from thunderstorms, rapidly cleaning out the boundary layer pollution. Dr. Anne Thompson (614) is operating a ground site with extensive instrumentation at Platteville, Colorado. This location is strongly impacted by downslope flow from Denver, overnight and in the early morning, as is affected by impacts from extensive oil and gas drilling activity in that region.

Over 200 spiral profiles were performed with the NASA P-3B aircraft during this deployment, with the total over four deployments exceeding 800 spirals. While ozone pollution in the Front Range Region of Colorado was not as pronounced, in general, as in many recent summers, the project could still to sample a wide variety of pollution conditions. Maximum one-hour average ozone levels at the surface ranged from about 60 ppbv to nearly 100 ppbv on flight days. Typically, somewhat larger values were measured on the aircraft in the lowest one km of the atmosphere. Forthcoming analyses will determine how strongly the column amounts of gases and aerosols (as would be measured by satellite) are related to surface pollution conditions in this region. Goddard observational participants included Scott Janz (UV/Vis spectrometer on the King Air aircraft), Jay Herman (UMBC; Pandora UV/Vis spectrometer ground-based network), Anne Thompson (ground-based instrumented trailer and ozonesondes), and Brent Holben (dense AERONET network). This concluded the DISCOVER-AQ observations.

In addition, the Goddard tropospheric ozone lidar (Tom McGee) participated under separate funding. Intensive analysis and modeling will take place in 2015.

4.3. Hurricane and Severe Storm Sentinel EV-1

The Hurricane and Severe Storm Sentinel (HS3) EV-1 mission began science operations for its third and final field deployment at the Wallops Flight Facility on August 26, 2014. Science flights took place from August 26 to September 29. HS3 used NASA's Global Hawk unmanned aircraft to study how hurricanes form and intensify in the Atlantic basin. Air Vehicle 6 (AV-6) carried three instruments that examined the environment around the storms, including the Scanning High-resolution Interferometer Sounder (S-HIS, University of Wisconsin), the Advanced Vertical Atmospheric Profiling System (AVAPS, NCAR/NOAA)—also known as dropsondes, and the Cloud Physics Lidar (CPL, NASA/GSFC). AV-6 conducted science flights over Hurricane Cristobal with a focus on the outflow layer of the storm and its contribution to development of disturbances downstream. Two days later, AV-6 followed Cristobal as it moved rapidly northeastward and underwent extratropical transition (i.e., transitioned from a tropical to a mid-latitude frontal system), providing a first-of-its-kind data set of this late-stage development.

The environmental Global Hawk flew two missions between September 11 and 15 into Hurricane Edouard (September 11–12 and 14–15)—the first when Edouard was a tropical storm and the second when it was a rapidly intensifying hurricane.

HS3's over-storm aircraft, AV-1, had major electrical problems, so a decision was made on September 4 to move two of the instruments, HIWRAP from Goddard and HIRAD from Marshall, to the WB-57. For its third and final field deployment, the environmental Global Hawk flew two missions between September 16 and 19 into Hurricane Edouard (September 16–17 and 18–19), the first when Edouard was near peak intensity as a Category 3 hurricane and the second when Edouard was rapidly weakening in the northeastern Atlantic. In all, HS_3 completed four flights into Edouard over the hurricane's life cycle.

The HS_3 mission completed science flights on September 29. At the request of NOAA, two missions were flown on September 22–23 and 28–29 while performing broad surveys of the Atlantic main development region (MDR) for Atlantic hurricanes. NOAA contributed funds to the HS3 mission to add a fifth week of deployment and several flights. NOAA used the data for model validation and data assimilation experiments. In all, HS3 conducted 10 science flights during 2014, including two over Hurricane Cristobal, one over Tropical Storm Dolly, and four over Hurricane Edouard. WB-57 flights continued until mid or late October. HS3 was led by Scott Braun (612) as principal investigator and Paul Newman (610) as deputy principal investigator.

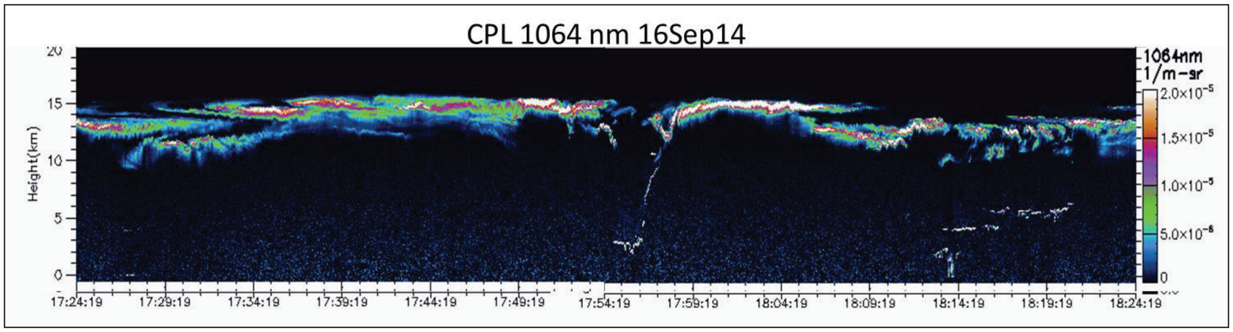


Figure 4.1: Cloud Physics Lidar image from a pass over the eye of Hurricane Edouard on September 16 just after the storm reached Category 3 intensity. The data show the high cloud tops associated with the storm and, near the center between 17:54-17:58 UTC, the rapid lowering and then raising of cloud tops as the Global Hawk passes over the eye.

4.4. The Integrated Precipitation and Hydrology Experiment (GPM Ground Validation)

The Integrated Precipitation and Hydrology Experiment (IPHEx) field effort officially began May 1. IPHEx was a ground validation campaign focused in the southern Appalachian Mountains. The campaign closely followed the launch of the Global Precipitation Measurement Mission (GPM) Core satellite in early 2014. The goal of the campaign was to help validate measurements from the new satellite by comparing them with observations taken from the ground. The southern Appalachians were chosen since they represent an area of relatively complex terrain, where precipitation regimes are difficult to observe and model. The campaign was a joint venture between NASA, NOAA, and Duke University. The High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), ER-2 X-band Radar (EXRAD), and Cloud Radar System (CRS) Goddard radars were installed on the ER-2 for the aircraft component of IPHEx. This provided the widest range of frequencies ever flown (9.6 to 94 GHz) for precipitation and cloud studies. The NPOL and D3R radars were also delivered to the IPHEx field location. Wallops staff also provided 24 Parsivel, 6 Joss-Waldvogel and 5 two-dimensional video (2DVD) disdrometers, and more than 50 rain gauges.

From May 26 to June 10, Dr. Joe Munchak (612/ESSIC) participated in the experiment in Asheville, North Carolina, as the mission scientist coordinating the observation of precipitation from the NASA ER2 (with X-, Ku-, Ka-, and W-band radars, and 10–183 GHz radiometers) and University of North Dakota Citation aircraft (*in situ* microphysics) and ground radars over heavily instrumented watersheds in western North Carolina.

The IPHEx field campaign completed its six-week intensive observation phase in North Carolina on June 15, 2014. During the last week of operations, IPHEx airborne and ground-based radar instrumentation sampled strong to severe convection coincident with a GPM overpass and a long-lasting mountain precipitation event that caused strong river flow in the Pigeon watershed. A total of 113 flight hours were flown by the NASA ER-2 and 78 hours by the UND Citation. Numerous flights were conducted in collaboration with the ACE/Radar Experiment as part of a concerted effort to combine mission science studying the cloud to precipitation continuum.

The principal investigator was G. Heymsfield (612) and the lead engineers were Matthew McLinden (555) and Lihua Li (555) and Paul Racette (567).

4.5. MPLNET

MPLNET is a federated network of Micro Pulse Lidar (MPL) systems designed to measure aerosol and cloud vertical structure continuously, day and night, over long time periods, required for climate change studies and for ground validation of models and satellite sensors in the NASA Earth Observing System (EOS). Most MPLNET sites are co-located with sites in the NASA Aerosol Robotic Network (AERONET) (Holben et al., 1998) to provide both column and vertically resolved aerosol and cloud data. MPLNET data and additional information on the project are available at http://mplnet.gsfc.nasa.gov.

Dr. Judd Welton is PI of the network and coordinates lidar deployments and research in support of NASA's science objectives. During the year, he travelled to meet with the following MPLNET partners to plan additional monitoring sites.

- Taiwan: Planned a replacement of the long-term lidar site at National Central University. Discuss joint plans for air quality research in the region around Taipei.
- Silpakorn University, Thailand: Discussed plans for a new permanent MPLNET site in the country and visited a potential site at the Royal Rainmaking Department's ground station in Om Koi.
- Chiang Mai, Thailand: Oversaw installation of an MPLNET site in the mountains of Northern Eastern Thailand at Doi Angkhang in support of the 7-SEAS Spring 2014 Field Campaign, aimed at researching the properties and transport patterns of smoke aerosols emitted across Northern Indochina.
- Vietnam Academy of Science and Technology: Developed plans to relocate the existing site from Hanoi to the mountains of North Western Vietnam.
- Vietnam: Discussed potential sites at meteorological stations in Yen Bai, Son La, and Moc Chau, Vietnam.
- The Indonesian Meteorology, Climatology, and Geophysics (BMKG): Discussed ongoing collaborations and plans to install permanent lidar stations at BMKG sites in Kalimantan and Sumatra that formerly hosted MPLNET for field campaign in 2012.
- Kuala Lumpur, Malaysia: Travelled September 7–10, 2014 to meet with 7-SEAS colleagues from the Malaysian Meteorology Department (MMD), the Universiti Kebangsaan Malaysia (UKM), and the University of Notthingham Malaysia Campus (UNMC). Meetings with MMD and UKM were held to finalize plans to put permanent AERONET and MPLNET instruments at the MMD site in Kuching, Sarawak Malaysia (on Borneo). The Kuching site hosted the NASA networks for a 2012 field campaign, and the site is ideally suited to support 7-SEAS and potential YMC objectives.

MPLNET results have contributed to studies of dust, biomass, marine, and continental aerosol properties, the effects of soot on cloud formation, aerosol transport processes, and polar clouds and snow. MPLNET data has been used to validate and help interpret results from NASA satellite sensors such as GLAS, MISR, and TOMS. MPLNET also serves as a ground calibration network for space-based lidars.

Table 4.1: Instrument Scientists/ Managers

Name	Instrument Systems	2014 Campaigns
Bill Cook	MABEL	Proteus Test Flights
Gerry Heymsfield	EXRAD	ER-2 Test Flights
Jay Herman	Pandora UVNIS	DISCOVER-AQ
Scott Janz	ACAM	DISCOVER-AQ
Matt McGill	UAV-CPL	HS3, SEAC4RS
Walt Petersen	NPOL	GPM/IFloodS
Walt Petersen	D3R Radar	GPM/IFloodS
Walt Petersen	*In situ* SO_2	Dragon Eye
Si-Chee Tsay	SMARTLabs	7-SEAS
Judd Welton	MPLNET	7-SEAS
Tom Hanisco	ISAF	SENEX, SEAC4RS
Anne Thompson	O_3 Sondes	SEAC4RS
William Krabill	ATM	Operation IceBridge
Vanderlei Martins	PACS	PODEX

5. AWARDS AND SPECIAL RECOGNITION

5.1. Goddard and NASA Awards and Special Recognition

Table 5.1: List of Honor Awards Received in CY 2014

Honor Award	Recipient	Citation
Distinguished Service Medal	James Irons	*For his leadership and guidance on the Landsat program and Landsat 8 mission.*
The Earth Observatory Team	Kevin Ward	*For informing and inspiring the public, worldwide, about NASA Earth science through the publication of the widely used and widely acclaimed Earth Observatory website*

Table 5.2: List of Robert H. Goddard Awards Received in CY 2014

Robert H. Goddard Award	Recipient	Citation
Exceptional Achievement Science	George Huffman	*For scientific leadership in multi-satellite global precipitation retrieval algorithm development and rain product dissemination*
Exceptional Achievement in Leadership	Judd Welton	*For scientific leadership and implementation of the Micro Pulse Lidar Network and resultant impacts on global aerosol science*
Exceptional Achievement Secretarial	Sandra Banks	*For exceptional secretarial and logistical support to the GSFC Code 610.W GPM Ground Validation mission.*
Exceptional Achievement Science	Sergey Marchenko	*For outstanding and unexpected contributions to the understanding of solar variability and visible wavelength remote sensing including nitrogen dioxide retrievals.*
Precipitation Processing Systems Team	Eric Stocker	*For outstanding data processing development to support the Global Precipitation Measurement (GPM) mission.*
GPM Ground Validation Team	Walter Petersen	*For creative development and use of validation data for Global Precipitation Measurement (GPM) from surface-based sensors and four highly successful field campaigns.*
GPM Algorithm Team	Robert Meneghini	*For outstanding precipitation retrieval algorithm development to support the Global Precipitation Measurement (GPM) mission.*
GPM Outreach Team	Dalia Kirschbaum	*For outstanding education and public outreach activities to support the Global Precipitation Measurement (GPM) mission.*

5.2. External Awards and Special Recognition

External Awards	Recipient	Citation
IRAD Innovators of the Year	Matt McGill and his team	*The Goddard Office of the Chief Technologist bestows the award annually on those who achieve significant results that benefit NASA and others in the communities we serve. The committee chose Matt and his team, including Andrew Kupchok, Stan Scott, and John Yorks because of their success advancing technologically advanced instruments vital to climate-change studies and pursuing new platforms from which to fly their innovative concepts*

External Awards	Recipient	Citation
James Kerley Award	Geoff Bland	*Aerodynamically Stabilized Instrument Platform" (AeroPod). This device is designed to provide a stable, lightweight structure to fly remote sensing and in-situ instrumentation from a kite or tethered blimp/balloon. Past winners from 610 included Geary Schwemmer (1998), Matt McGill (2000), and Norden Huang (2003)*

The following people were recognized for notable achievements by national, international or professional organizations.

Gail Skofronick Jackson (612) was elevated to an Institute of Electrical and Electronic Engineers (IEEE) Fellow, effective January 1, 2015, for contributions to microwave remote-sensing of snow.

George Huffman and Ralph Kahn (613) received the American Geophysical Union (AGU) 2013 Editor's Citation for Excellence in Refereeing" for outstanding service to the authors and readers of the Journal of Geophysical Research-Atmospheres.

W.-K Tao (612) received the award for Most Cited Article Award from the Terrestrial, Atmospheric and Oceanic Sciences Journal of the Chinese Geoscience Union.

John Sullivan (614) for the best poster at the 18th Joint Conference on the Applications of Air Pollution Meteorology in Atlanta Georgia, February 2–6, 2014, titled "Initial Results Obtained from a Differential Absorption Lidar (DIAL) to Measure Tropospheric Ozone".

John Yorks (612) successfully defended his PhD dissertation, entitled "An Investigation of Cirrus Cloud Properties Using Airborne Lidar" at University of Maryland College Park on April 3, 2014. The dissertation described a new HSRL technique to directly retrieve cloud and aerosol optical properties using the Airborne Cloud-Aerosol Transport System (ACATS).

5.3. AGU Honors Program: Union Fellows

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

The following current and former Goddard atmospheric scientists have received this distinguished honor.

Recipient	Year
David Atlas	1972
Joanne Simpson	1994
Mark R. Schoeberl	1995
Richard S. Stolarski	1996
David A. Randall	2002
Anne M. Thompson	2003
Marvin A. Geller	2004
Gerald R. North	2004
Eugenia Kalnay	2005
Michael D. King	2006

Recipient	Year
William K.-M. Lau	2007
Anne R. Douglass	2007
Paul Newman	2010
Warren Wiscombe	2013
David Atlas	1972
Joanne Simpson	1994
Mark R. Schoeberl	1995
Richard S. Stolarski	1996
David A. Randall	2002
Anne M. Thompson	2003

Recipient	Year
Marvin A. Geller	2004
Gerald R. North	2004
Eugenia Kalnay	2005
Michael D. King	2006
William K.-M. Lau	2007
Anne R. Douglass	2007
Paul Newman	2010
Warren Wiscombe	2013

5.4. American Geophysical Union (AGU) Yoram J. Kaufman Unselfish Cooperation in Research Awards

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

Recipient	Year
Ralph Kahn	2009
Pawan Bhartia	2012

5.5. AMS Fellows

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

Recipient
Robert F. Adler
Dave Atlas
Robert M. Atlas
Wayman E. Baker
John R. Bates
Antonio J. Busalacchi
Robert F. Calahan
Anne R. Douglass
Franco Einaudi
Donald F. Heath
Arthur Hou

Recipient
Eugenia Kalnay
Jack A. Kaye
Michael D. King
Steven E. Koch
Christian Kummerow
William K. Lau
Paul A. Newman
Gerald R. North
David A. Randall
Richard R. Rood
Mark R. Schoeberl

Recipient
Siegfried D. Schubert
J. Marshall Shepherd
Jagadish Shukia
Johanne Simpson (Honorary Member)
Eric A. Smith
Wei-kuo Tao
Anne M. Thompson
Louis W. Uccellini
Thomas T. Wilheit
Warren Wiscombe

6. EDUCATION AND OUTREACH

6.1. Introduction

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

The laboratories supported a range of programs intended to inspire and develop a future generation of Earth Scientists. Among these programs are: The Practical Uses of Math and Science (PUMAS, https://pumas.gsfc.nasa.gov/), The Summer Institute in Earth Sciences (SIES) and Graduate Student Summer Program (GSSP) managed by GEST (http://gest.umbc.edu/student_opp/students.html), Graduate student advising, teaching university courses, the NASA Postdoctoral Program (NPP, http://nasa.orau.org/postdoc/description/index.htm).

6.2. Other University and K–12 Interactions

Wei-Kuo Tao (612) was invited by The Department of Atmospheric Sciences at Texas A&M University to present a talk entitled, "Goddard Multi-Scale Modeling Systems with Unified Physics." He was also invited to have a meeting with department graduate students about his career at NASA.

Dr. Mircea Grecu (**612/GESTAR**) participated in the Thunder Hill Elementary (Howard County, Maryland) STEM DAY on February 20th. He gave presentations on the water cycle and precipitation measurements to first-grade students and talked about the GPM launch.

Robert Levy (613) discussed the water cycle as it relates to the recent GPM launch to a fourth-grade class at Oakview Elementary School in Silver Spring. He also conducted an experiment that showed how aerosols contribute to cloud making on March 18.

NASA's second annual ReelScience Communications Contest, a student video contest, led by **Ginger Butcher (Sigma Space)** and **Tassia Owen (Sigma Space)** had 22 wonderful submissions in three categories—How Ice Impacts Climate and Climate Impacts Ice (IceSat-2), Forest Fires and Air Quality (Terra), and the Water Planet (Aqua)—of which nine videos were selected as finalists. Creators of last year's winning video, "Hurricanes," was recently featured at the Raleigh's Science Museum in Raleigh, North Carolina. http://reelscience.gsfc.nasa.gov/REELscienceWinners2012.html

On April 15th **Valentina Aquila (614)** held a class for about 35 students at Johns Hopkins University as part of Darryn Waugh course "Science and Policy of Climate Change". The class was based on the article by Pacala and Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science*, 305, 2014. The students had to develop their own policy portfolio for the next 50 years with the goal of stabilizing of CO_2 emissions.

Dave Short (612/SSAI) gave a presentation at DuVal High School in Lanham, Maryland, to Dr. Glazner's Honors Chemistry Class on Thursday, May 29th. The subject was "How Chemistry, Condensation, and

Collisions produce Clouds and Rain." About 25 students also participated in a Monte Carlo experiment designed to generate a skewed probability distribution, similar to those observed for raindrops and rainfall rate.

Charles Ichoku (613) and Toshihisa Matsui (612/ESSIC) are advising Trisha Gabbert (a masters student in Atmospheric and Environmental Sciences at the South Dakota School of Mines and Technology). Trisha is visiting June 2–6 to learn model simulations using NU-WRF for application to the study of biomass-burning impacts on the water cycle dynamics in northern sub-Saharan Africa. She is researching biomass-burning emissions in the Northern Sub-Saharan African region. The project utilizes a first-ever, gridded, smoke-aerosol emissions coefficient (Ce) product developed by NASA's Fire Energetics and Emissions Research (FEER) team. The goal is to process satellite measured fire radiative power and use FEER's Ce product to generate smoke aerosol emissions for NASA's Unified Weather Research and Forecasting (NU-WRF) model, that represents smoke dynamics and impacts in the African Sahel and surrounding areas. Trisha was first introduced to smoke emissions research during a summer internship at Goddard Space Flight Center during her undergraduate studies. She is very excited to continue learning about the interactions of fire emissions on our climate, weather, and air quality. She is a recent winner of a scholarship from the International Association of Wildland Fire.

On April 25th **Valentina Aquila (614)** held a class on climate change at George Mason University as part of their Environmental Engineering course. About 35 students were present. The class was composed of two parts. During the first part she introduced some results of the latest IPCC, and some basic notions on the climate change, such as the greenhouse effect. During the second part, she lead a discussion on the article by Pacala and Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," Science, 305, 2014, where the students had to develop their own policy portfolio for the next 50 years with the goal of reaching the stabilization of CO_2 emissions.

On July 18 and 25 **Valentina Aquila (614)** and Rolando Olivas (Johns Hopkins University) gave two short presentations to two groups of about 30 high schoolers at University of Maryland. The presentations were part of Jump Start, a program sponsored by the Howard Hughes Medical Institute to enhance the training of high school students in biomedical science. Their presentations focused on how to use climate data in public health. Aquila spoke about a Hopkins study that related malaria occurrence in Peru with climate variables, and Olivas discussed air quality from satellite observations.

Anne Thompson (614), Rennie Selkirk (USRA) and Prof Gary Morris (Valparaiso University) led a group of Penn State and Valparaiso students in ozonesonde training at the Penn State Meteorology Department, 15–July 17, in University Park, Pennsylvania. During the SEAC4RS campaign, ozonesondes will collect data from the surface to 30+ km for satellite and aircraft instrumentation verification as well as input to DC-8 flight-planning and models. The purpose of the workshop was to prepare participants for launching sondes in the Southern American Consortium for Intensive Ozonesonde Network Study (SEACIONS), a component of SEAC4RS for which Thompson is PI. The SEACIONS network consists of multiple universities (e.g., Florida State, Saint Louis, University of Alabama–Huntsville, New Mexico Tech, etc.) as well as NOAA/GMD in Boulder, Colorado. The Goddard group will also launch water vapor sondes to compare to ER-2 instruments during landings at Ellington Field, Texas. SEACIONS launches will operate daily, mostly during the A-Train overpass.

Kristen Weaver presented on the GPM mission and education resources to 28 teachers from around the country and trained them in GLOBE precipitation and cloud protocols as part of a NASA Teacher Learning Academy focused on GPM, SMAP, and HS3. Teachers also visited Wallops Flight Facility and Goddard Space Flight Center where they listened to a presentation from GPM Applications Scientist **Dr. Dalia Kirschbaum.**

Dorian Janney (612/Adnet), Kristen Weaver (612/USRA) and Lou Mayo (690.1/Adnet) presented an Education and Public Outreach Colloquium talk on September 10, entitled "From the Laboratory to the Classroom: Inspiring the Next Generation Through STEM Education," which gave tips and suggestions to scientists and engineers who might like to become involved in outreach opportunities.

Dorian Janney (612) led a Distance Learning Network webinar on September 25, entitled, "GPM: Studying Precipitation From Above Earth." She described the GPM mission and showed many of the mission's education resources. This was open to teachers at any grade level and 33 teachers participated.

Brian Campbell (610.W) presented Earth Science Satellite mission information to 50 children at the Goddard Child Development Center on Tuesday, September 30.

Dorian Janney and **Kristen Weaver (612)** met with GPM's three curriculum developers to collaborate on lessons plans for elementary and middle school students. They shared the Earth Science Week Kit, the GLOBE poster and related activities, and the Earth Science Week Interactive Map, which was the featured product last year. They also shared other NASA-unique resources that teachers could incorporate into their lesson plans.

On September 24 and 25, **Dorian Janney (612/ADNET)** and **Kristen Weaver (612/USRA)** presented three webinars to a total of about 80 K–12 educators on the topics of freshwater availability around the world, accessing and using NASA data with students, and a general overview of the GPM mission and how it measures precipitation.

Brian Campbell (610.W) presented an Earth Science Satellite online talk and activity to Blackberry Creek Elementary School in Elburn, Illinois on September 29.

David Wolff (610.W) and **Rhonie Wolff (610.W)** attended STEM night at Pocomoke Middle School on October 7. They presented a summary of GPM Ground Validation activities and demonstrated how rain gauges work to dozens of interested students and parents.

On October 11th, **Dorian Janney (612/ADNET)** held a webinar for the 25 GPM master teachers from around the world as well as two Earth to Sky-GPM participants from national parks in the United States. The webinar focused on measuring precipitation. **Chris Kidd (612/UMD-ESSIC)** gave the keynote talk and explained how and why NASA measures global precipitation. Hilarie Davis (Texas A&M University) presented on the importance of collecting metrics for this project and elaborated on the results of the GPM pre-assessment given in schools around the world.

Dorian Janney (612/ADNET) ran a workshop on October 14 at the GSFC Educator Resource Center, which taught elementary school teachers from Prince George's County about Earth's water and the new NASA "Earth Wheel" resource.

On November 5 and 6, **Dorian Janney (612/ADNET)** and **Kristen Weaver (612/USRA)** presented information about the GPM mission and education resources in two webinars held in collaboration with Wallops Flight Facility and the SMAP mission. Each webinar had over 25 educators in attendance.

Amber Emory (Code 612) gave a talk to four groups of high school students (totaling 350 participants) at Binghamton High School on November 24. She presented information on the 2014 launch of GPM, discussed various field campaigns that she participated in while working at Goddard, and provided guidance to students interested in pursuing careers in the STEM fields. Her visit was highlighted by several local news stations, including WBNG. http://www.wbng.com/news/video/Binghamton-High-School-welcomes-back-special-guest-283741861.html

During the weeks of November 10th and 17th, **Kristen Weaver (612/USRA)** spent several days visiting Glenallan Elementary School in Silver Spring, Maryland. She presented about GPM to approximately 100 fourth graders in their STEM Academy to kick-off a unit that included an investigation using the GPM Landslides Activity.

On December 5th, **Dorian Janney (612)** supported an event at Woodley Hills Elementary School in Fairfax County, Virginia, in support of Goddard's Office of Education. Janney presented on GPM to 386 third- through sixth-grade students (a largely minority audience) and about 25 staff members.

Stephanie Schollaert Uz (614/GST, ESSIC/UMD) gave four air quality presentations to fifth-grade students at McKinley Elementary School in Arlington, Virginia, on December 4. This show was identical to the Science on a Sphere show given to a similar group at the Maryland Science Center last spring; however, this time the animated satellite imagery was displayed on a flat screen, as part of an ongoing study to determine whether spherical displays have any advantage over non-spherical displays. The group of 88 students filled out surveys following the show. Just as the earlier show, the group took a pre-show survey the week before the presentation and then were given another survey two months later to test retention. These surveys will be compared to the Science on a Sphere group to determine whether there are any differences in what they gain from a presentation on a sphere versus a flat screen, what they remember, and whether they are inspired to learn more from other sources after seeing the show. Fifth grade is considered the average education level of the general public at museums, according to the Maryland Science Center, so insights gained from this study will be used to guide future programming for distribution to Science on a Sphere museums around the world.

6.3. Lectures and Seminars

One aspect of public outreach includes the seminars and lectures held each year and announced to all our colleagues in the area. Most of the lecturers are from outside NASA, and this series gives them a chance to visit with our scientists and discuss their latest ideas from experts. The following lectures were presented in 2014 among the various laboratories.

Table 6.1: Atmospheric Sciences Distinguished Lecture Series

Date	Speaker	Title
January 16	Robert G. Fovell University of California, Los Angeles, CA	*Influence of Cloud-Radiative Forcing on Tropical Cyclone Storm Structure*
March 20	Tiruvalam N. Krishnamurti Florida State University Tallahassee, FL	*A Pathway Connecting the Monsoonal Heating to the Rapid Arctic Ice Melt*
April 17	Philip J. Rasch Pacific Northwest National Laboratory Richland, Washington	*Problems and Prospects for Improved Representation of Aerosol Impacts in Climate Models*
April 23	David P. Edwards NCAR Earth Systems Laboratory Boulder, CO	*The Atmospheric Composition Geostationary Satellite Constellation for Air Quality and Climate Science*
May 15	Menglin Susan Jin San Jose State University, San Jose, CA	*Mechanisms for Snow Cover Variations over the Sierra Nevada: From Satellite Observing to Modeling*

Date	Speaker	Title
May 15	Rong Fu University of Texas at Austin, Austin TX	*Relationship Between Aerosol and Convective Dynamic Structure Through Convective Life Cycle Deduced from Satellite Observations*
June 19	Shuyi Chen Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL	*Coupled Atmosphere-Wave-Ocean Modeling for Better Understanding Tropical Cyclone Prediction and Predictability*
July 17	William Randel National Center for Atmospheric Research, Boulder, CO	*Tropical Tropopause Dynamics Observed from a Decade Of GPS Radio Occultation Data*
August 19	Hui Su NASA JPL	*Hadley Circulation, Cloud Feedback and Climate Sensitivity*
October 16	Anthony D. Del Genio NASA GISS	*The Madden(ing)-Julian Oscillation: Signs of Progress?*

Table 6.2: Mesoscale Atmospheric Processes

Date	Speaker	Title
July 18	S.A. Rutledge Colorado State University	*Convection over the Central Indian Ocean: Observations from DYNAMO and TRMM*
August 8	Shoichi Shige Kyoto University, Japan	*Shallow Orographic Heavy Rainfall in the Asian Monsoon Region Observed by TRMM PR*
October 6	Zhiquan Liu National Center for Atmospheric Research	*Aerosol Data Assimilation for Regional Air Quality and Weather Forecasts*
October 15	Philippe Chambon CNRM/GAME, Météo-France and CNRS, Toulouse, France	*Data Assimilation Experiments of the Megha-Tropiques/SAPHIR Observations into the Météo-France Global Model*
December 3	In-Sik Kang School of Earth Environment Sciences, Seoul National University, Seoul Korea	*A GCM with Explicit Cloud Microphysics for Simulation of Extreme Precipitation Frequency*

Table 6.3: Climate and Radiation

Date	Speaker	Title
January 15	Sally McFarlane U.S. Department of Energy	*An Overview of DOE's Atmospheric System Research Program*
January 29	Jie Gong, USRA-GESTAR, Climate & Radiatio n Laboratory	*Persistent Impact of Atmospheric Transient Perturbations: From Stratospheric Gravity Waves to Upper-Tropospheric Clouds*
February 19	Michael Studinger NASA GSFC	*NASA's Operation IceBridge: Using instrumented aircraft to bridge the observational gap between ICESat and ICESat 2 laser altimeter measurements*

Date	Speaker	Title
March 5	Eugene Clothiaus Penn State University	*Coherent Scattering from Cloud Drops and Ice Crystals: One Perspective on Its Ramifications for Climate, Cloud Property Remote-Sensing and Evaluation of Cloud Microphysical Models*
March 19	Guojun Gu UMD-ESSIC	*Understanding Long-Term Precipitation Changes during the Satellite Era (1979–2012)*
April 2	Linette N. Boisvert IMD-ESSIC	*Moisture Flux Estimates Derived from EOS Aqua Data in the Arctic*
April 16	Sergey Marchenko SSAI and Atmospheric Chemistry and Dynamics Laboratory	*Solar Spectral Irradiance Changes During the On-going Cycle 24*
May 7	Fuzhong Weng NOAA Center for Satellite Applications and Research	*Building High-Quality Climate Data Records from NOAA Operational Weather Satellites*
May 21	Andrew M. Sayer GESTAR-USRA and Climate and Radiation Laboratory	*Satellite Remote Sensing of Aerosol Optical Depth: The "Deep Blue" algorithms*
June 4	Chris Kidd UMD-ESSIC and Mesoscale Atmospheric Processes Laboratory	*The Anatomy of Satellite Precipitation Retrievals: Things we know, would like to know, and would rather not know*
June 24	Santiago Gassó GESTAR/Morgan State University, Climate & Radiation Laboratory	*The Known Unknowns: Marine Biogenic Aerosols and High Latitude Dust*
August 18	Kazuma Aoki, Graduate School of Science and Engineering for Science University of Toyama, Japan	*Validation of Satellite and Model Aerosol Optical Properties using SKYNET Sky Radiometer Measurements*
August 20	Christine Chiu University of Reading	*3D Cloud Observations: Synergy between scanning radars and shortwave radiation measurements*
September 3	Yaping Zhou GESTAR/Morgan State University, Climate & Radiation Laboratory	*Satellite Observed Recent Trends in Global Mean and Extreme Precipitations*
September 17	Seoung-Soo Lee UMD-ESSIC	*Effect of Aerosol on Instability and Convective Clouds*
October 1	Jianping Mao ESSIC and Atmospheric Chemistry & Dynamics Laboratory	*Can We Measure Atmospheric* CO_2 *from Space in one-part-per-million: Challenges and Perspectives of Space Missions*
October 15	Charles Ichoku NASA GSFC	*Wildfire Emissions: A Major Frontier in Earth Systems Research, and How We are Tackling it from Satellite*

Date	Speaker	Title
November 6	Alexei L. Lyapustin NASA GSFC	*Remote-Sensing Based on Time Series Analysis: Algorithm MAIAC*
November 19	Donifan Barahona NASA GSFC	*Representation of the Aerosol Indirect Effect in the NASA Goddard Earth Observing System Model, Version 5 (GEOS-5)*
December 3	Mariya M. Petrenko ORAU, NASA Postdoctoral Fellow	*The use of satellite AOD snapshots to constrain biomass burning emissions in the GOCART model, and introduction to AEROCOM biomass burning experiment*

6.3.1. Maniac Talks

Maniac talks are monthly talk series to promote scientific interaction between young and experienced scientists in order to learn, improve, and revise the knowledge of basic science and fundamental scientific methods for research. The talk format is informal and encourages healthy discussion. For further information, please contact the meeting organizer, Charles K. Gatebe (Charles.k.gatebe@nasa.gov)

Table 6.4: Maniac Talk Series

Date	Speaker	Title
January 24	William Lau NASA GSFC	*My Story: A tale of three continents*
February 14	Peter Hildebrand NASA GSFC	*From Studies of Solubility and Divers Breathing Helium, to DOGS, then NCAR and NASA*
March 6	Henning Leidecker NASA GSFC	*How I Came to NASA to Fix Spacecraft…*
April	Anne Thompson NASA GSFC	*A Career in Many Ozone Layers*
May 28	James Gavin NASA GSFC	*From Brownian Motion to Mars, by Way of Hockey on the Rocks*
June 25	Aprille Joy Ericsson NASA GSFC	*A Rocket Scientist Grows Up in Brooklyn, NY*
July 23	Jack Kaye NASA HQ	*An Unlikely but Rewarding Journey—From Quantum Chemistry to Earth Science Research Program Leadership*
August 27	P.K. Bhartia NASA GSFC	*Maxwell Demon, Black Swan and a Rom in Scientific Hinterlands*
September 24	Brian Dennis NASA GSFC	*From Picking Potatoes to Measuring the Biggest Bangs in the Solar System—Always a Farm Boy!*
October 22	James Irons NASA GSFC	*Balancing Precariously on Giants' Shoulders: Landsat and Project Science*
November 19	John Mather NASA GSFC	*Creating the Future: Building JWST, what it may find, and what comes next?*

Table 6.5: Atmospheric Chemistry and Dynamics

Date	Speaker	Title
January 9	Peter Colarco NASA GSFC	*Large Contribution of Natural Aerosols to Uncertainty in Indirect Forcing*
January 16	Bill Heaps NASA GSFC	*Optical Instrumentation to Address NASA Missions*
January 23	Charles Jackman NASA GSFC	*Two-dimensional Modeling, Solar Proton Events, and Geoengineering*
February 20	Tom Hanisco and Glenn Wolfe NASA GSFC	*Photochemistry, Fluxes, and Transport of Formaldehyde*
February 24	Mian Chin NASA GSFC	*A global model analysis of multi-decadal aerosol variations from 1980 to 2009*
February 26	Akihiko Kuze	*Fluorescence Measurement from ISS*
February 27	Valentina Aquila USRA	*The Mystery of Recent Stratospheric Temperature Trends*
March 5	Andrew Roberts LARC Affiliate	*Update on the WB-57 Platform*
March 13	Xiaohua Pan ORAU	*What is Wrong with These Multi- Models In Simulating Aerosols Over South Asia?*
March 20	Scott Janz, NASA GSFC and Matt Kowalewski, USRA	*Recent UV/VIS Calibration Lab Activities Inter-Annual Variability and Trends*
April 1	John Worden NASA JPL	*Tropospheric Ozone, Composition, and Climate from the Aura Tropospheric Emission Spectrometer*
April 3	Sunny Choi SSAI	*Global free tropospheric* NO_2 *Abundances Derived using a Cloud Slicing Technique Applied to Satellite Observations from the Aura Ozone Monitoring Instrument (OMI)*
April 10	Joanna Joiner NASA GSFC	*New Measurements and Applications of Terrestrial Chlorophyll Fluorescence with GOME-2*
May 1	Folkert Boersma KNMI/TUD	*Global Soil NOx Emission Estimates from OMI* NO_2 *Retrievals*
May 5	Jung-Eun Lee Brown University	*Forest Productivity and Water Stress in Amazonia: Observations from GOSAT chlorophyll fluorescence*
May 29	Nikolai Balashov Penn State	*Ozone Variability and Trends over the South African Highveld and What Does It*
June 2	Pepijn Veefkind GSFC Science Collaborator	*The First Decade of OMI-TROPOMI Data*
June 5	Simon Carr and Jennifer Telling, MTU	*New Insights Into Volcanic Eruptions and Degassing from NASA's A-Train Satellite Constellation*
June 12	John Sullivan ORAU	*Initial Results from the GSFC TROPospheric OZone Differential Absorption Lidar (GSFC TROPOZ DIAL)*

Date	Speaker	Title
June 19	Randy Kawa NASA GSFC	*Development of Instrumentation for Direct Validation of Regional Carbon Flux Estimates*
July 17	Nick Krotkov NASA GSFC	*Remote Sensing of Atmospheric Pollution and Volcanic Clouds*
August 14	Ed Nowottnick USRA	*Use of the CALIOP Vertical Feature Mask for Evaluating Global Aerosol Models*
August 21	Glen Wolfe UMBC	*Maximum Efficiency in the Hydroxyl-Radical-Based Self-Cleansing of the Troposphere*
August 27	Pawan K. Bhatia NASA GSFC	*Maxwell Demon, Black Swan, and a Romp in Scientific Hinterlands*
September 11	Luke Oman NASA GSFC	*GEOSCCM: It's not always Cherries Jubilee*
September 25	Sarah Strode USRA	*Trends and Variability in Ozone and Carbon Monoxide*
October 9	Ken Pickering NASA GSFC	*DISCOVER-AQ Update (and more)*
October 16	James Wang SSAI	*Observational Evidence for Interhemispheric Hydroxyl-Radical Parity*
October 23	Ray Desjardins	*Highlights from Thirty Years of Aircraft-Based Flux Measurements*
October 30	Lorenzo Polvani Columbia University	*Recent Temperature Trends and Ozone Extremes in the Arctic And Their Potential Effects on Surface Climate*
November 6	Clara Orbe ORAU	*Transport from the Northern Hemisphere Midlatitude Surface: A Transit Time Distribution Approach*
November 13	Omar Torres, NASA GSFC and Hiren Jethva, USRA	*Advances in Aerosol Remote Sensing in 10 years of OMI Observations*
December 4	Bob Hudson UMD	*Movement of the Sub-Tropical and Polar Upper-Tropospheric Fronts Obtained from Total Ozone Images: Method and climate implications*

6.4. AeroCenter Seminars

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

In 2014, the AeroCenter held 19 seminars with typically 30 to 40 physical attendees, and 5 to 10 WebEx attendees most from outside GSFC. Initiated by Lorrain Remer and Yoram Kaufman, the AeroCenter has played a prime role for more than 10 years, exchanging up-to-date aerosol science across NASA laboratories and other institutions since 2001. In 2014, NASA presented a webinar series on the newly released

MODIS Collection 6 atmosphere products. Each webinar lasted approximately 45 minutes followed by a question and answer period. The webinars gave an overview and explanation of each of the products for a general audience and presented a segment on the differences between Collection 6 and Collection 5.1 for experienced users. For further information, please contact Valentina Aquila (valentina.aquila@nasa.gov).

6.5. Public Outreach

GPM's Science on a Sphere movie called "WaterFalls" premiered on Saturday, January 25, at The Wild Center in New York and at the Space Foundation in Colorado on Wednesday, January 29. On Friday January 31, the movie was released to all locations with Science on a Sphere movie theater.

Glenn Wolfe (614) was mentioned in a *Baltimore Sun* article for his work on the CONTRAST mission (http://www.baltimoresun.com/features/green/blog/bs-hs-pacific-research-flights-20140124,0,6663971.story). Wolfe was measuring formaldehyde onboard the NSF G-V in the tropical western Pacific. One major goal is to understand convective re-distribution of ozone-depleting substances. This is a joint mission with NASA's ATTREX mission and a British project, Coordinated Airborne Studies in the Tropics (CAST).

A Space Act Agreement was signed on January 6 between NASA and a commercial toy company, littleBits Electronics™. Under a GSFC IRAD FY 2013 award, **Bryan Duncan (614)** and **Ginger Butcher (Sigma Space)** worked with littleBits to develop a set of active-learning investigations about energy, the electromagnetic spectrum, and fundamentals of NASA remote-sensing science instruments. The resulting littleBits Space Kit contains unique electronic components designed and built by littleBits with activities developed by NASA with help from optics engineers Matt Bolcar (Code 551) and David Aronstein (Code 551). A press release is pending approval from the Office of Communications at NASA HQ.

GPM participated in NASA's Earth Day exhibit at Union Station on April 21–22. EPO staff and scientists hosted a GPM table and display. **Ginger Butcher (Sigma Space)** and **Stephanie Uz (Sigma Space)** presented an engaging activity demonstrating how instruments onboard the Aura satellite measure gases and particles in the atmosphere to visitors, including NASA Administrator Charlie Bolden. Later in the week, Mike Taylor and Tassia Owen (both Sigma Space) joined Ginger Butcher to conduct the activity at the U.S. Science and Engineering Festival. Visitors assembled their own energy-sensing circuit using littleBits' electronic components and used it to take measurements of light shining through milky water that simulates scattering by gases and particles in the atmosphere. This activity, titled Measuring the Atmosphere, is one of the NASA activities created in collaboration with littleBits under a 2013 IRAD award and Space Act Agreement. For more info, visit: http://www.nasa.gov/content/goddard/nasa-partners-with-littlebits-electronics-on-stem-activities/#.U15hnl7Zdg0

Dr. Dalia Kirschbaum gave a HyperWall presentation and gave a live interview with the Weather Channel regarding GPM on April 22.

The Applied Remote SEnsing Training (ARSET) Program (within NASA's Applied Sciences Program) conducted a five-week webinar, The Fundamentals of Remote Sensing for Air Quality Applications for the Indian Sub-continent Region, from March 19 to April 16, 2014. The webinar was primarily designed for the air quality agencies in the region. There were about 100 participants from 13 countries representing several governments, non-profit, and private agencies. Air quality monitoring agencies such as Central Pollution Control Board (CPCB), state pollution boards, along with several research institutes such as the India Institute of Tropical Meteorology (IITM) and the India Institute of Science (IISc). The Energy and Resource Institute (TERI), and The International Centre for Integrated Mountain Development (ICIMOD) were among the participants.

There was also participation from faculty and students from several academic institutes in the region. The webinar was organized **by Pawan Gupta** and conducted by Pawan Gupta **and Jacquie Witte (Code 614), and Richard Kleidman (Code 613).** The webinar included an overview of the ARSET program, basics of satellite remote sensing, and an introduction to NASA air quality products and online tools for data access.

Ginger Butcher (Sigma Space) and Matt Bolcar (551) participated in a Google+ Hangout hosted by littleBits on June 9. They answered questions from the littleBits community about how NASA instruments sense electromagnetic energy and how components are tested before they are launched into orbit. Ginger demonstrated her "Measuring the Atmosphere" activity that illustrates how satellites can sense gases and aerosols in the atmosphere. The archived Hangout can be viewed at https://www.youtube.com/watch?v=UkxDvv0r--o

Geoff Bland (610.W) attended a ribbon cutting ceremony for the Chester River Watershed Observatory in Chestertown, Maryland. This event was the kick-off for an extensive instrumentation and analysis project lead by the Washington College Center for the Environment and Society. Bland exhibited the Remotely Operated Vehicle for Environmental Research (ROVER-X3) as prepared by Ted Miles (569). This instrumented platform system was developed under an education IRAD with the University of Maryland, Eastern Shore, and there has been significant interest in utilizing this system by other institutions.

The NASA Global Hawk used in the Hurricane Severe Storm Sentinel (HS_3) and used in the EV-1 mission and the Goddard High-Altitude Imaging Wind and Airborne Profiler (HIWRAP) were briefly shown on NBC Nightly News during a hurricane clip. (http://www.nbcnews.com/nightly-news/hurricane-season-officially-begins-today-n119896)

A new Science On a Sphere story on Air Quality has been created by the Aura E/PO team, including project scientist **Bryan Duncan as well as Ginger Butcher and Stephanie Schollaert Uz (Sigma Space).** On April 24, the show was presented to 72 fifth-grade students and 26 adults at the Maryland Science Center in Baltimore. There was enthusiastic audience participation with many great questions and comments about air quality. To test what people had gained from seeing a Science On a Sphere show, everyone completed a survey at the end of the show. Additionally, the students completed surveys a few days prior to their trip to MSC to better test what they knew ahead of time. They will also complete surveys in June to test what students remembered from the show. In addition to using the surveys to improve the show prior to publication, the scientists also seek to understand what people gain from Science On a Sphere shows and what they remember.

On September 13, **Dorian Janney (612/Adnet) and Kristen Weaver (612/USRA)** held the first monthly webinar with the 2014–15 cohort of GPM Master Teachers. As part of the virtual meeting, George Huffman (612) gave an overview of the GPM mission to the 25 educators from across the country, as well as Nigeria and Switzerland. Participants were introduced to each other and informed about several upcoming activities related to Earth Science Week in October and a fall GLOBE Student Precipitation Field Campaign

During September 18–19, **David T. Bolvin (612/SSAI), S. Joseph Munchak (612/ESSIC), Jacob B. Reed (612/TELOPHASE),** and **Kristen L. Weaver (612/USRA)** with assistance from **George J. Huffman (612),** staffed a table showcasing GPM and the use of precipitation data by SERVIR at the USAID Frontiers in Development forum, held in the Reagan Building in Washington, DC. This major international symposium on extreme poverty included an Innovation Marketplace exhibit that showcased USAID partners across a wide spectrum of international development issues. SERVIR, a NASA initiative that provides end-users with environmental data, invited GPM to participate because its data will soon succeed the TRMM products, which are key to SERVIR. A steady stream of knowledgeable users from across governmental, non-governmental, and academic institutions visited the table.

Ginger Butcher (Sigma Space) presented a retrospective of Aura education and public outreach efforts over the past 10 years at Aura's tenth anniversary science team meeting. Highlights included Aura's partnership with American Chemistry Society on the publication of five special issues of their *ChemMatters* publication, the 2006 Smithsonian "Change is in the Air" exhibit at the Natural History Museum, numerous outreach publications including booklets, posters, and lenticulars, and development and demonstration of outstanding hands-on activities such as the "Engineer a Satellite" activity using Legos and the "Measuring the Atmosphere" activity using littleBits electronic components. And finally, in 2014, a new exhibit at GSFC's Visitor's Center highlights Aura's contributions to monitoring stratospheric ozone and tropospheric pollutants through an indoor display and outdoor ozone bio-indicator garden.

On September 24, **Kristen Weaver (612)** conducted a Distance Learning Network webinar called "Earth By the Numbers, Accessing NASA Earth Science Data." The webinar was primarily for high school teachers, and she had 18 participants. Weaver focused on showing participants "MyNASAData" and other easily available Earth science data sets. She shared ways they might incorporate using this data into their lessons.

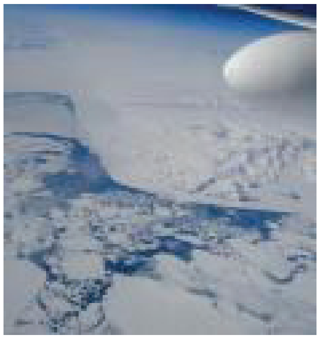
NASA's Applied Remote-sensing Training Program (ARSET) conducted a two and half day on September 29–October 1 training on Remote-sensing Data Usage for Air Quality Assessment at the Environmental Protection Agency's office in the Research Triangle, North Carolina.

7. ATMOSPHERIC SCIENCE IN THE NEWS

The following pages contain news articles and press releases that describe some of the Laboratory's activities during 2014.

New NASA Laser Technology Reveals How Ice Measures Up

Published: Wednesday, January 29, 2014 - 08:12 in Astronomy & Space



NASA/Tim Williams

NASA/Kelly Brunt

New results from NASA's MABEL campaign demonstrated that a photon-counting technique will allow researchers to track the melt or growth of Earth's frozen regions. When a high-altitude aircraft flew over the icy Arctic Ocean and the snow-covered terrain of Greenland in April 2012, it was the first polar test of a new laser-based technology to measure the height of Earth from space.

NASA's Multiple Altimeter Beam Experimental Lidar flew over Southwest Greenland's glaciers and sea ice to test a new method of measuring the height of Earth from space.

Aboard that aircraft flew the Multiple Altimeter Beam Experimental Lidar, or MABEL, which is an airborne test bed instrument for NASA's ICESat-2 satellite mission slated to launch in 2017. Both MABEL and ICESat-2's ATLAS instrument are photon counters -- they send out pulses of green laser light and time how long it takes individual light photons to bounce off Earth's surface and return. That time, along with ATLAS' exact position from an onboard GPS, will be plugged into computer programs to tell researchers the elevation of Earth's surface—measuring change to as little as the width of a pencil.

This kind of photon-counting technology is novel for satellites; from 2003 to 2009, ICESat-1's instrument looked at the intensity of a returned laser signal, which included many photons. So getting individual photon data from MABEL helps scientists prepare for the vast amounts of elevation data they'll get from ICESat-2.

"Using the individual photons to measure surface elevation is a really new thing," said Ron Kwok, a senior research scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "It's never been done from orbiting satellites, and it hasn't really been done much with airborne instruments, either."

ICESat-2 is tasked with measuring elevation across Earth's entire surface, including vegetation and oceans, but with a focus on change in the frozen areas of the planet, where scientists have observed dramatic impacts from climate change. There, two types of ice—ice sheets and sea ice—reflect light photons in different patterns. Ice sheets and glaciers are found on land, like Greenland and Antarctica, and are formed as frozen snow and rain accumulates. Sea ice, on the other hand, is frozen seawater, found floating in the Arctic Ocean and offshore of Antarctica.

MABEL's 2012 Greenland campaign was designed to observe a range of interesting icy features, said Bill Cook, MABEL's lead scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. With the photon counts from different surfaces, other scientists could start analyzing the data to determine which methods of analyzing the data allow them to best measure the elevation of Earth's surface.

"We wanted to get a wide variety of target types, so that the science team would have a lot of data to develop algorithms," Cook said. "This was our first real dedicated science mission."

The flights over the ocean near Greenland, for example, allowed researchers to demonstrate that they can measure the height difference between open water and sea ice, which is key to determining the ice thickness. MABEL can detect enough of the laser light photons that bounce off Earth surface and return to the instrument, and programs can then make necessary elevation calculations, Cook said.

"Part of what we're doing with MABEL is to demonstrate ICESat-2's instrument is going to have the right sensitivity to do the measurements," Cook said. "You can do this photon counting if you have enough photons."

In an article recently published in the *Journal of Atmospheric and Oceanic Technology*, Kwok and his colleagues showed how to calculate elevation from MABEL data, and do so over different types of ice -- from open water, to thin, glassy ice, to the snow-covered ice.

"We were pretty happy with the precision," Kwok said. "The flat areas are flat to centimeter level, and the rough areas are rough." And the density of photons detection could also tell researchers what type of ice the instrument was flying over.

The contours of the icy surface are also important when monitoring ice sheets and glaciers covering land. The original ICESat-1 mission employed a single laser, which made it more difficult to measure whether the ice sheet had gained or lost elevation. With a single beam, when the instrument flew over a spot a second time, researchers couldn't tell if the snowpack had melted or if the laser was slightly off and pointed down a hill. Because of this, scientists needed 10 passes over an area to determine whether the ice sheet was changing, said Kelly Brunt, a research scientist at NASA Goddard.

"ICESat-1 was fantastic, but it was a single beam instrument," Brunt said. "We're more interested in repeating tracks to monitor change -- that's hard to do."

ICESat-2 addresses this problem by splitting the laser into six beams. These are arranged in three pairs, and the beams within a pair are spaced 295 feet (90 meters), or just less than a football field apart. By comparing the height of one site to the height of its neighbor, scientists can determine the terrain's general slope.

Brunt and her colleagues used MABEL data from the 2012 Greenland campaign to try to detect slopes as shallow as 4 percent incline; their results will be published in the May 2014 issue of the journal *Geoscience and Remote Sensing Letters*. They counted only a portion of the photons, in order to simulate the weaker laser beams that ICESat-2 will carry. With computer programs to determine the slope, the researchers verified it against results from earlier missions.

"The precision is great," Brunt said. "We're very confident that with ICESat-2's beam pair, we can see slope."

And there are still more things for MABEL to measure. The instrument team is planning a 2014 summer campaign to fly over glaciers and ice sheets in warmer weather. "We want to see what the effects of the melt is," Cook said. "How do glaciers look if they're warmer, rather than colder?"

Source: NASA/Goddard Space Flight Center

N. African dust stimulates monsoons

By AFP | AFP – Sun, Mar 16, 2014

AFP/AFP/File - Rain clouds loom over the Brahmaputra river in Guwahati, India on August 27, 2013

Desert dust from North Africa and the Arabian peninsula stimulates monsoon rains over India, said a study Sunday suggesting that desertification from global warming may boost these seasonal downpours.

Analysis of satellite data showed that dusty conditions in North Africa and West Asia were followed within days by stronger monsoon rains in the subcontinent, according to research published in the journal Nature Geoscience.

“Dust in the air absorbs sunlight west of India, warming the air and strengthening the winds carrying moisture eastward,” the US-based Pacific Northwest National Laboratory said in a press release.

“This results in more monsoon rainfall about a week later in India.”

Indians have long known that heavy dust brought by strong winds occurs frequently just before monsoon rains, but no scientific link has previously been drawn.

“The study... shows that natural airborne particles can influence rainfall in unexpected ways, with changes in one location rapidly affecting weather thousands of miles away,” said the statement.

Commenting on the findings, William Lau of NASA’s Earth Science Division said the reported effect could become more pronounced with climate change.

“The expected expansion of desert and arid regions under global warming could enhance dust transport from the deserts of the Middle East and North Africa to the Asian monsoon regions, further enhancing monsoon rainfall,” he said.

The researchers stressed that dust was not the only phenomenon to affect monsoons.

Others factors include temperature differences between land and ocean, changes in land use, global warming and local effects of pollution heating or cooling air and affecting clouds.

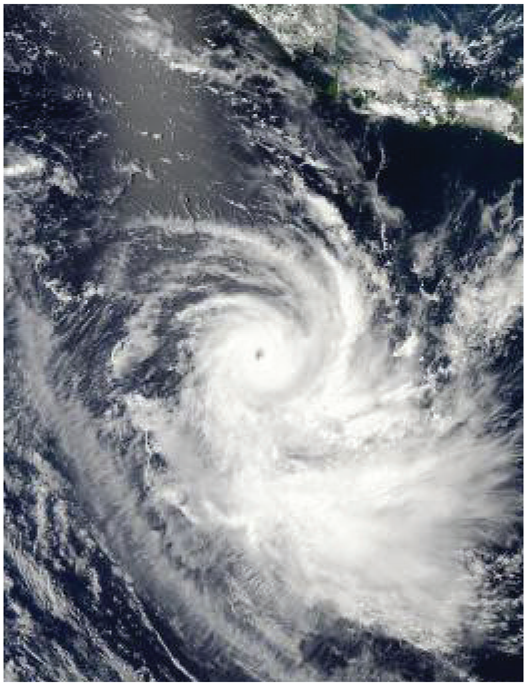
“The strength of monsoons has been declining for the last 50 years,” said study co-author Phil Rasch.

“The dust effect is unlikely to explain the systematic decline, but it may contribute.”

PHYS ORG

NASA spots Tropical Cyclone Gillian's eye closing

24 March 2014, by Rob Gutro
This visible image of Tropical Cyclone Gillian was captured at 06:45 UTC on March 23 by NASA's Aqua satellite.



Credit: NASA Goddard Rapid Response Team

Tropical Cyclone Gillian's eye was starting to "close" or become cloud-filled when NASA's Aqua satellite passed over the Southern Indian Ocean on March 23.

On March 23, Gillian's maximum sustained winds peaked near 140 knots/161.1 mph/259.3 kph making it a Category 5 hurricane on the Saffir- Simpson Scale. Fortunately, Gillian pulled away from Indonesia, so all of the regional warnings were canceled on March 23.

At 06:45 UTC on March 23, NASA's Aqua satellite flew overhead and the Moderate Resolution. By 09:00 UTC/5 a.m. EDT on March 24, Gillian's strength had waned as maximum sustained winds dropped to 120 knots/138.1 mph/222.2 kph. At that time it was centered near 17.2 south latitude and 103.5 east longitude, about 672 nautical miles/773.3 miles/1,245 km west-northwest of Learmonth, Australia. Gillian was moving toward the south at 10 knots/11.5 mph/ 18.5 kph and generating seas around 40 feet high.

JTWC noted that upper-level northwesterly wind shear has been increasing and is now strong, blowing as high as 30 knots/35.5 mph/55.5 kph. The wind shear is weakening the tropical cyclone. In addition, there is a mid-level trough (elongated area of low pressure) approaching Gillian, and that's creating the sinking or subsidence of air, so that thunderstorms (that make up a tropical cyclone) are unable to develop.

JTWC expects Gillian to continue weakening while tracking south for another couple of days before turning to the west.

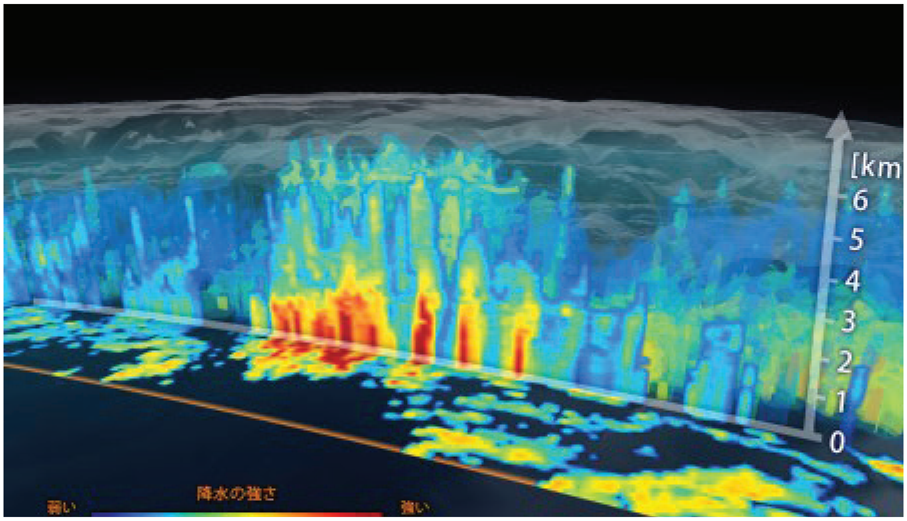
Provided by NASA's Goddard Space Flight Center

APA citation: NASA spots Tropical Cyclone Gillian's eye closing (2014, March 24) retrieved 11 February 2015 from http'Uphys org/news/2014-03-nasa-tropjcal-cyclone-gjl!jan-eye html

PHYS.ORG

First images available from NASA-JAXA global rain and snowfall satellite

26 March 2014, by Steve Cole



3D view inside an extra-tropical cyclone observed off the coast of Japan, March 10, 2014, by GPM's Dual- frequency Precipitation Radar. The vertical cross-section approx. 4.4 mi (7 km) high show rain rates: red areas indicate heavy rainfall while yellow and blue indicate less intense rainfall. Image Credit: JAXA/NASA

NASA and the Japan Aerospace Exploration Agency (JAXA) have released the first images captured by their newest Earth-observing satellite, the Global Precipitation Measurement (GPM) Core Observatory, which launched into space Feb. 27.

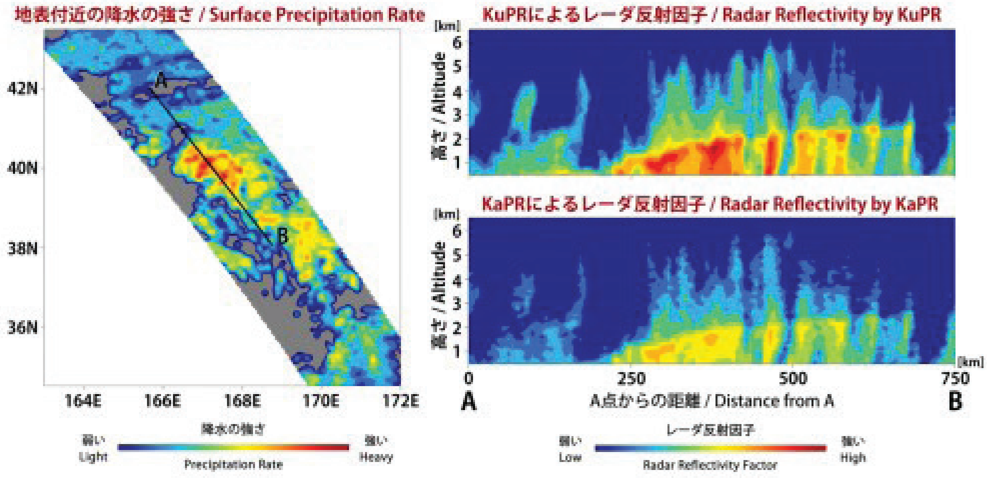
The images show precipitation falling inside a March 10 cyclone over the northwest Pacific Ocean, approximately 1,000 miles east of Japan. The data were collected by the GPM Core Observatory's two instruments: JAXA's Dual- frequency Precipitation Radar (DPR), which imaged a three-dimensional cross-section of the storm; and, NASA's GPM Microwave Imager (GMI), which observed precipitation across a broad swath.

"It was really exciting to see this high-quality GPM data for the first time," said GPM project scientist Gail Skofronick-Jackson at NASA's Goddard Spaceflight Center in Greenbelt, Md. "I knew we had entered a new era in measuring precipitation from space. We now can measure global precipitation of all types, from light drizzle to heavy downpours to falling snow."

The satellite's capabilities are apparent in the first images of the cyclone. Cyclones such as the one imaged—an extra-tropical cyclone—occur when masses of warm air collide with masses of cold air north or south of the tropics. These storm systems can produce rain, snow, ice, high winds, and other severe weather. In these first images, the warm front ahead of the cyclone shows a broad area of precipitation—in this case, rain—with a narrower band of precipitation associated with the cold front trailing to the southwest. Snow is seen falling in the northern reaches of the storm.

The GMI instrument has 13 channels that measure natural energy radiated by Earth's surface and also by precipitation itself. Liquid raindrops and ice particles affect the microwave energy differently, so each channel is sensitive to a different precipitation type. With the addition of four new channels, the GPM Core Observatory is the first spacecraft designed to detect light rain and snowfall from space.

In addition to seeing all types of rain, GMI's technological advancements allow the instrument to identify rain structures as small as about 3 to 9 miles (5 to 15 kilometers) across. This higher resolution is a significant improvement over the capability of an earlier instrument flown on the Tropical Rainfall Measurement Mission in 1997. “You can clearly see them in the GMI data because the resolution is that much better,” said Skofronick- Jackson.



The Dual-frequency Precipitation Radar observes rainfall and snowfall that occurs within clouds in three dimensions, across the surface of Earth and upward into the atmosphere. An extra-tropical cyclone was observed over the northwest Pacific Ocean off the coast of Japan on March 10, 2014. Image Credit: JAXA/NASA

The DPR instrument adds another dimension to the observations that puts the data into high relief. The radar sends signals that bounce off the raindrops and snowflakes to reveal the 3D structure of the entire storm. Like GMI, its two frequencies are sensitive to different rain and snow particle sizes. One frequency senses heavy and moderate rain. A new, second radar frequency is sensitive to lighter rainfall and snowfall.

“Both return independent measurements of the size of raindrops or snowflakes and how they are distributed within the weather system,” said DPR scientist Bob Meneghini at Goddard. “DPR allows scientists to see at what height different types of

rain and snow or a mixture occur—details that show what is happening inside sometimes complicated storm systems.”

The DPR data, combined with data from GMI, also contribute to more accurate rain estimates. Scientists use the data from both instruments to calculate the rain rate, which is how much rain or snow falls to Earth. Rain rate is one of the Core Observatory’s essential measurements for understanding where water is on Earth and where it’s going.

“All this new information comes together to help us better understand how fresh water moves through Earth’s system and contributes to things like floods and droughts,” said Skofronick-Jackson.

GMI was built by Ball Aerospace & Technologies, Corp., in Boulder, Colo., under contract to NASA. DPR was developed by JAXA with the National Institute of Information and Communication Technology.

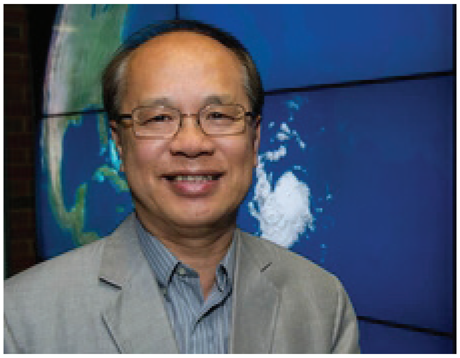
These first GPM Core Observatory images were captured during the first few weeks after launch, when mission controllers at the NASA Goddard Mission Operations Center put the spacecraft and its science instruments through their paces to ensure they were healthy and functioning as expected. The engineering team calibrates the sensors, and Goddard’s team at the Precipitation Processing System verifies the accuracy of the data. More information: pps.gsfc.nasa.gov/

Provided by NASA

APA citation: First images available from NASA-JAXA global rain and snowfall satellite (2014, March 26) retrieved 11 February 2015 from http://phys.org/news/2014-03-images-nasa-jaxa-global-snowfall-satellite.html

Dr. William Lau - Advancing the Understanding of Earth Systems

June 17, 2014
Dr. William Lau



NASA/W. Hrybyk

Name: William Lau

Title: Deputy Director for Atmospheres

Formal Job Classification: Earth Scientist

Organization: Code 610, Earth Science, Science Division

Part One of Dr. Lau's interview

A man of three continents, climate scientist William Lau sees Earth as one.

What do you do and what is most interesting about your role here at Goddard? How do you help support Goddard's mission?

I am an atmospheric scientist by training. I look at how Earth works as a system from a space perspective. I study clouds, precipitation, winds and climate change. In the Earth Science Division, I oversee a lot of activities including launching satellite missions, analysis of data from satellite and ground based observations, field campaigns and computer modeling. The Earth Science Division is also involved in computer simulations of extreme weather and climate events, and building detectors to be installed on satellites.

Do you also perform research?

Yes, my own research involves the atmosphere. I study rainfall, clouds and aerosols and their impact on Earth's water cycle. The water cycle determines the amount of fresh water available to maintain life on Earth. Extreme variation in the water cycle—such as that caused by severe floods and prolonged droughts—can result in major hardships by disrupting the food chain and causing famine and diseases. I examine patterns of change in global rainfall, clouds and winds to understand what is happening. Most people in my position don't do research anymore, but I'm proud that I continue to be active in research.

What makes a good leader?

A good leader in Earth science first needs to have a firm grounding and basic knowledge of the sciences. He or she needs to have a vision and possess excellent leadership and interpersonal skills so he or she can work with a diverse team to carry out the vision. A good leader also anticipates problems ahead of time and makes the right decisions.

What is your vision?

My vision is to advance the understanding of Earth system science: how different parts of Earth's climate system connect with each other and how they respond to climate change.

What is the most important issue facing the Earth climate system?

The big debate going on in the climate change community is how Earth is responding to both natural and anthropogenic changes. There is a general consensus that humans are doing something to change our climate, but we aren't sure about the extent of changes that can be attributed to human activities in different parts of the climate system. Climate change can happen without anthropogenic forcing.

When we see major extreme weather events like the recent snow storms and extreme cold of this past winter over the central and eastern U.S., we cannot necessarily attribute them to climate change. We have to conduct very thorough data analyses and model simulations in order to answer this question. The answer is likely to be different depending on each phenomenon.

Why is your story one of three continents?

I was born in Macau, then a Portuguese colony but now a part of China. I lived there for the first ten years of my life. I had an official Portuguese birth certificate, though I never considered myself Portuguese because my parents were Chinese. They escaped from the communist regime in mainland China as refugees in Macau, the closest city connected to but outside of China at that time. When I was ten, my family moved to Hong Kong, still a British colony at that time. I left Hong Kong after graduating from Hong Kong University at the age of 22 and enrolled at the University of Washington, Seattle, as a graduate student in physics.

Mine is a story of three continents. I was born in Asia and was raised culturally as Chinese. As a kid, I went to a Portuguese Jesuit school. From high school to college, I was educated under a British colonial system in Hong Kong. In graduate school, I came into the American educational system and have worked for the rest of life in the U.S. I've been the beneficiary of a lot of cross-cultural education.

What was the impact of having a cross-cultural education?

I appreciate people from different cultures. I value my Chinese traditions, but I also value the culture and educational systems of Europe and America. I see the strengths and weaknesses in these different systems.

My cross-cultural experiences shape my work ethic in terms of how I see things and how I interact with people. I'm comfortable with diversity. My basic instinct is to work hard and get results. My Chinese culture tells me to value education and to respect institution and authority, but my U.S. training tells me to be assertive and to value individual freedom. I applied these principles to the best of my judgment under different situations.

Part Two of Dr. Lau's interview

Why did you become an atmospheric scientist?

When I was in high school in Hong Kong, I was very much inspired after hearing a lecture from the first two Chinese-American Nobel Prize winners in physics, Drs. Yang Chen-Ning, and Lee Tsung-Dao. I remember standing in line waiting to listen to their public lecture on "Parity Conservation of Elementary Particles." I didn't understand a thing, but I was fascinated. I thought winning a Nobel Prize was very cool.

I was interested in how things work; that's the realm of physics. I am theoretically-oriented; I like to think a lot about how things work.

I got my undergraduate degree in physics and mathematics at Hong Kong University and majored in physics in my first year of graduate school at the University of Washington. In Hong Kong, I was at the top of my class in physics and mathematics. But when I came to Seattle, I quickly found out that I was out of my depth in theoretical physics. I realized that I was never going to win a Nobel Prize. Most importantly, the job market for theoretical physics was really bad. The University of Washington's physics program required, on average, about seven years to get a Ph.D. That was too much for me. I began looking for another field in my second year of graduate school.

By accident, someone told me that the university was starting a top-notch department of atmospheric science. I didn't know what atmospheric science was and certainly was not aware that the everyday weather can be described quantitatively by the laws of physics. In any case, the subject of intrigued me. In my second year, I switched from hard-core physics to the relatively new area of atmospheric sciences. It was pure serendipity that I entered the field of atmospheric sciences. I've never looked back. I love climate science, which is the discipline I specialize in within atmospheric science.

What did you learn from changing your goals?

You should always have a goal, but you may need to reestablish your goal depending on changing circumstances. If something doesn't fit, change your goal to something that fits you better and that you enjoy more. The Nobel Prize in physics inspired me, but that goal was unreachable. I'm much happier as a climate scientist. My work is not only intellectually challenging, but also is directly relevant to society.

Why did you specialize in the subdiscipline of climate science and what changes have you seen in the field?

The field has a global reach. Everyone is interested in how climate change may affect his or her life. Rainfall affects everybody. It's an instant conversation starter. Our work involves the use of sophisticated tools, computers and satellites, but the end results are usually explainable to an average person.

When I started over 30 years ago, the atmospheric science field was divided into isolated subfields, such as atmospheric dynamics, radiation, cloud physics and atmospheric chemistry. Scientists within the different subfields of atmospheric science seldom talked to each other.

Nowadays, Earth scientists talk about Earth system science and how everything is connected in Earth's system. As a climate scientist, you don't just study one subject, say clouds, you need to study how clouds are related to the rest of Earth. Clouds are generated and driven by atmospheric motions. Cloud droplets are formed from microscopic suspended particles in the atmosphere called aerosols. Both clouds and aerosols can affect the amount of sunlight reaching Earth, which drives atmospheric winds. Winds transport water vapor in the atmosphere and drive ocean currents and sea surface temperatures, which, in turn, modulate Earth's climate. Vegetation on land depends on sunlight and rainfall to grow. Changing vegetation due to deforestation and agricultural land use can change evaporation and alter rainfall pattern, which can upset the ecosystem balance.

Everything exists on Earth for a reason. It's all connected. Earth is one system.

What is most intriguing about climate science?

Earth's responses to climate forcing are very nonlinear. This means that the magnitude of the response is not necessarily proportional to the forcing imposed. Through feedback processes, small initial perturbations can be amplified to a great extent and evolve into something totally unrecognizable from the initial conditions and unexpected from the forcing.

We actually have a name for such a phenomenon: the "butterfly effect," first coined by the famous atmospheric scientist Edward Lorenz. He also discovered chaos theory, a branch of mathematics that deals with sensitivity on initial conditions in nonlinear systems. He once said that the flutter of a butterfly wing in the Amazon may be responsible for the formation of a hurricane over the Atlantic Ocean several weeks later. Something very small initially could react within a connected environment leading to a big change that no one thought was possible. It's the interconnectivity that's so fascinating. That's what makes Earth science so interesting and challenging.

Turns out, atmospheric science is just as complex as any branch of physics. It's just more down to Earth.

What makes Goddard unique?

Goddard is a great place to work. We have a unique teaming of scientists and engineers who do big things. A Goddard scientist can get involved in the end-to-end process of conceiving and formulating scientific ideas or hypotheses, designing and building instruments in the lab to make the necessary measurements, working with engineers to build the hardware needed to launch the instrument into space and finally analyzing the resultant data to test the original hypotheses. There is no other place that integrates science and technology in the way that is being done at Goddard.

Is there something surprising about your hobbies outside of work that people do not generally know?

I played competitive table tennis, or ping pong, in college. I am also a pretty good badminton and tennis player. I stopped playing now, because I developed some neck and back problems. I taught my kids to play ping pong, but they were not interested. They were born in the U.S. and prefer to play baseball, softball and golf.

Ping Pong is a big part of the Chinese culture. Chinese are among the best in the world in ping pong. At a high level, ping pong requires very fast reaction and a lot of stamina. It's very vigorous sport. We wear special shoes to make us move faster. It's not the sort of ping pong played by the side of a swimming pool. We can return and attack a ball that was sent ten feet beyond the edge of the table. Can you imagine that?

Since I cannot play fast sports, I took up Tai Chi recently and practice it during my spare time. The slower pace suits me. I am now an assistant instructor for a local Tai Chi group.

I'm also member of a choir, which is another slower-paced hobby. We're a group of Chinese-Americans, mostly retired, all of whom (except me) have had good musical training. We sing all kinds of music: Chinese, Italian, American, classical and pop. The choir didn't require formal training, but I am learning a lot about vocal science and music. We perform locally and sometimes the group even performs overseas.

Who, living or dead, would you like to meet and what would be the first thing you would ask them?

I would like to meet my paternal grandfather, whom I never met. I have documents showing that he was an officer and government official of the Qing Dynasty (1644-1911), the last dynasty in China. Under his command, his battalion squelched an uprising in southern China. He received a certificate of commendation from the emperor for his bravery, inscribed in classical Chinese and in Manchurian. The certificate is a museum piece that is hanging in my brother's living room. I'd love to personally meet my paternal grandfather and ask him what he did during the Qing dynasty.

My maternal grandfather is also someone I'd like to meet. I never met him either. According to my mother, her father worked for Dr. Sun Yat-San, the founding father of modern China, the equivalent of George Washington. Dr. Sun led the revolution that overthrew the Qing Dynasty in 1911. Both of my parents were from the village where Dr. Sun was born.

As the leader of the revolution, Dr. Sun was wanted by the Chinese government. He fled to Hawaii, where he formed the China Reform Society. In the late1800s to early1900s, many villagers in southern China, including my maternal grandfather went to Hawaii to work and later settled there. Later, he joined the Society and helped overthrow the Qing Dynasty. My mother told me that her father used to carry Dr. Sun's briefcase. When the dynasty was overthrown, my maternal grandfather returned to China. I'd like to ask him what he did to help Dr. Sun overthrow the Qing Dynasty.

By the way, it took China more than 50 years after the revolution to find a workable system of government. That system is still evolving today.

As a descendant of revolutionaries on both your mother's and father's side, are you a rebel?

Well, in some senses, I am. My rebellious spirit is ingrained in my inquisitive nature.

Science is not about authority. You have to be very curious and challenge authority. An important quality of being a good scientist is that you cannot be a conformist. Science is not done by consensus. You must always be aware that the consensus could be wrong. Scientists have to back up their findings and statements with solid evidences.

Elizabeth M. Jarrell

NASA's Goddard Space Flight Center

(e) Science News

New NASA images highlight US air quality improvement

Published: Thursday, June 26, 2014 - 13:59

Images from NASA Goddard's Scientific Visualization Studio/T. Schindler

Anyone living in a major U.S. city for the past decade may have noticed a change in the air. The change is apparent in new NASA satellite images unveiled this week that demonstrate the reduction of air pollution across the country. After ten years in orbit, the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite has been in orbit sufficiently long to show that people in major U.S. cities are breathing less nitrogen dioxide -- a yellow-brown gas that can cause respiratory problems.

Nitrogen dioxide is one of the six common pollutants regulated by the U.S. Environmental Protection Agency (EPA) to protect human health. Alone it can impact the respiratory system, but it also contributes to the formation of other pollutants including ground-level ozone and particulates, which also carry adverse health effects. The gas is produced primarily during the combustion of gasoline in vehicle engines and coal in power plants. It's also a good proxy for the presence of air pollution in general.

Air pollution has decreased even though population and the number of cars on the roads have increased. The shift is the result of regulations, technology improvements and economic changes, scientists say.

In fact, about 142 million people still lived in areas in the United States with unhealthy levels of air pollution, according to the EPA. Also, high levels of air pollution remain an issue in many other parts of the world, according to the global view from satellites

"While our air quality has certainly improved over the last few decades, there is still work to do -- ozone and particulate matter are still problems," said Bryan Duncan, an atmospheric scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Decision makers and regulatory agencies like EPA have long relied on data from ground sites to inform air quality science and forecasts. NASA, while not directly involved with regulation or making forecasts, provides a consistent, global, space-based view -- not possible from any other source -- of when and where air pollution occurs.

Another ongoing effort by NASA to study air quality is Discover-AQ, a multi-year airborne mission flying this summer in Denver to learn more about how the wide range of air pollutants viewed from satellites relates to what's happening close to the ground where people live and breathe. The mission flew previously in 2011 over Baltimore, Maryland and Washington, D.C.; in 2013 over the San Joaquin Valley, California; and in 2013 over Houston, Texas.

"You can't control what you don't measure," said Russ Dickerson of the University of Maryland, College Park, and member of the NASA Air Quality Applied Sciences Team -- created in 2011 by the NASA Applied Sciences Program to serve the needs of U.S. air quality management through the use of Earth Science satellite data, suborbital, and models. "NASA measurements of air quality have value to the people with the authority to control emissions and develop policy."

The new NASA images also take a close up look at the Ohio River Valley, Northeast Corridor, and some populous U.S. cities. They show how nitrogen dioxide concentrations during spring and summer months, averaged from 2005-2007, compare to the average from 2009-2011.

Measurements of nitrogen dioxide from OMI depict the concentration of the gas throughout a column of air in the troposphere, Earth's lowest atmospheric layer. The images are color-coded: Blue and green denote lower concentrations and orange and red denote higher concentrations, ranging from 1x1015 to 5x1015 molecules per square centimeter, respectively.

Images were composed by NASA's Scientific Visualization Studio based on data and input provided by atmospheric scientists Yasuko Yoshida, Lok Lamsal, and Bryan Duncan, all of NASA's Goddard Space Flight Center in Greenbelt, Maryland.

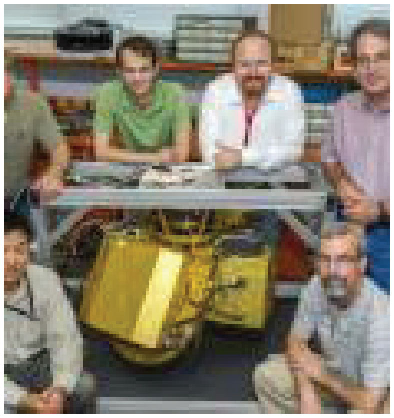
Source: NASA

(e) Science News

Three radars are better than one: Field campaign demonstrates two new instruments

Published: Thursday, August 14, 2014 - 13:54

Image Credit: NASA Goddard/Bill Hrybyk



Putting three radars on a plane to measure rainfall may seem like overkill. But for the Integrated Precipitation and Hydrology Experiment field campaign in North Carolina recently, more definitely was better. The three instruments, developed by the High Altitude Radar group at NASA's Goddard Space Flight Center in Greenbelt, Maryland, flew as part of the Global Precipitation Measurement (GPM) mission's six-week ground-validation program that took place May 1 through June 15 in the southern Appalachians, specifically to measure rain in difficult-to-forecast mountain regions. In addition to validating measurements, the campaign tested data-processing algorithms made by the GPM Core Observatory, launched in February.

The campaign represented a first for NASA. Never before has the agency flown more than two radar systems, tuned to different frequencies, to measure rainfall in the field. In addition, two of the instruments were making their maiden flight to demonstrate technological improvements that may pave the way for future high-performance airborne or space-borne precipitation radars for studying storms.

Future precipitation missions and, more particularly, the Aerosol Clouds Ecology, or ACE, mission, which the National Research Council recommended in its Earth Science Decadal Survey, have made the development of new radar systems to observe clouds and light precipitation a priority.

Why Radar and Why Three?

The decision to fly three different systems was far from overkill, according to campaign scientists.

Rainfall comes in more than 31 flavors, from tiny cloud droplets and misty drizzle, to fat raindrops and two-inch hailstones, and, of course, everything in between. Different radar frequencies pick up different precipitation types, generally based on size and whether the particles are ice or liquid. Radars flying with multiple frequencies can study more precipitation types and identify where they occur inside clouds, giving scientists a more complete picture of the inner workings of a rainstorm.

In particular, lower-microwave frequencies can detect heavy rain all the way to the ground. But tiny cloud particles require a higher-microwave frequency signal to detect them. Because that signal sometimes gets attenuated before it makes it all the way through the cloud and back to the radar, precipitation radars traditionally require a large, high-powered antenna.

What's Old is New Again

Enter the Cloud Radar System, a 20-year-old radar that has been completely rebuilt from the inside out, said Gerry Heymsfield of Goddard's High Altitude Radar group, which revamped the instrument. "The old one was a good radar," Heymsfield said, "but the big difference in the new one is we're using a solid-state transmitter." The new transmitter, which sends the radar pulse, requires less power, occupies less space, and returns more reliable results -- advances that make a radar system more suitable for aircraft and satellites.

The Cloud Radar System also sports a new antenna for receiving the data-laden return signals, or backscatter, of the radar pulse. Partners at Northrup Grumman designed the new antenna, led by Goddard Principal Investigator Paul Racette, and the result is a scaled down, proof-of-concept of what may one day fly in space, Heymsfield said.

The Cloud Radar System design grew out of a similar approach the High Altitude Radar group used to build the two other radars that measured rainfall during the campaign: the High-altitude Wind and Rain Profiler (HIWRAP), and the ER-2 X-Band Radar (EXRAD).

Satellite Simulator

During the field campaign in North Carolina, all three radars flew at an altitude of 65,000 feet on NASA's ER-2 aircraft, managed by Armstrong Flight Research Center in Edwards, California. Beneath the ER-2, a second plane, managed by the University of North Carolina, flew through clouds to collect data on the details of the precipitation and cloud particles. On the surface, NASA's GPM team worked with NOAA's Hydrometeorological Test Bed and Duke University to capture precipitation as it hit the ground, using ground-based radar that scanned the air between the surface and the rainclouds and a network of rain gauges throughout the mountains and valleys.

During the six-week field campaign, HIWRAP -- one of several instruments also used on NASA's Hurricane and Severe Storm Sentinel mission flying later this summer and fall -- stood in for the GPM satellite. Its two radar frequencies, 35 gigahertz for light rain and 13.5 gigahertz for heavy rain, are nearly identical to the GPM Core Observatory's Dual-frequency Precipitation Radar. Scientists collected the data, which they now will process with computer algorithms specifically designed to convert radar-retrieval data into rain estimates. They then will compare those estimates with the ground data to determine whether they need to fine-tune the algorithms, Heymsfield said.

EXRAD, like the retooled Cloud Radar System, made its flight debut during the campaign. It complemented HIWRAP by gathering data in the 10-gigahertz frequency band ideal for measuring big raindrops and hail in thunderstorms. Unlike the other radars that just point down, EXRAD also has a scanning capability to capture rainfall over a wider field of view below.

Unique Capability

Multiple radars with multiple frequencies looking at the same storm provided the science team with a unique capability, Heymsfield said. As the ER-2 flew overhead, the radars and other instruments captured how the range of cloud droplets, raindrops, and ice pellets moved and changed relative to one another over time. Those observations get at the heart of how storm systems behave, which in turn will lead to better models used for weather and flood forecasting, Heymsfield said.

"When you look at different clouds with different frequencies, it tells a lot about the cloud particles that are in there," said Heymsfield. "Having four frequencies on the ER-2 allowed us to measure a much broader range of cloud and precipitation that will help both GPM and future cloud and precipitation missions."

Source: NASA/Goddard Space Flight Center

(e) Science News

NASA simulation portrays ozone intrusions from aloft

Published: Saturday, April 12, 2014 - 15:38

Outdoor enthusiasts in Colorado's Front Range are occasionally rewarded with remarkable visibility brought about by dry, clear air and wind. But it's what people in the mountainous U.S. West can't see in conditions like this -- ozone plunging down to the ground from high in the stratosphere, the second layer of the atmosphere -- that has attracted the interest of NASA scientists, university scientists and air quality managers. Invisible Intruder

Ozone in the stratosphere, located on average 10 to 48 kilometers (6 to 30 miles) above the ground, typically stays in the stratosphere.

Not on days like April 6, 2012.

On that day, a fast-moving area of low pressure moved northeast across states in the Western U.S., clipping western and northern Colorado. Ozone-rich stratospheric air descended, folding into tropospheric air near the ground. Winds took hold of the air mass and pushed it in all directions, bringing stratospheric ozone to the ground in Colorado and along the Northern Front Range. The event, called a stratospheric ozone intrusion, raised ground-level ozone concentrations in some areas to potentially unhealthy levels. Watch the intrusion unfold in a new NASA simulation of the event.

Ozone high in the atmosphere, in the stratosphere, forms naturally when sunlight mingles with oxygen molecules to form the well-known "layer" that protects life on Earth from the sun's harmful ultraviolet rays. That's in contrast to ozone near the ground, in the troposphere, which forms from complex reactions involving chemicals emitted from industrial processes, vehicle exhaust, and other byproducts of fossil fuel combustion. Ozone at ground level can damage lung tissue and pose an immediate threat to sensitive groups such as people with asthma.

For this reason, the Clean Air Act requires the U.S. Environmental Protection Agency to set a threshold for ground-level ozone, as outlined in the National Ambient Air Quality Standards. States that exceed this threshold can be fined, although the EPA can grant exceptions for natural events or those proven to be beyond reasonable control.

That's why ozone intrusions are on the minds of air quality managers like Patrick Reddy, lead forecast meteorologist at Colorado's Department of Public Health and Environment in Denver, Colo. Reddy co-leads the EPA Stratospheric Intrusion Work Group, tasked to identify ozone intrusion events and collect input for improved analysis.

The state of Colorado flagged the concentrations associated with the April 6 event as possibly exceeding the EPA's allowable threshold. Now it's up to Reddy and colleagues to determine if the intrusion on April 6 is a viable candidate for the preparation of documentation to be classified as an exceptional event.

"We need to use the best science that we can to demonstrate conclusively that 'but for' this intrusion there would not have been an exceedence," Reddy said. Resolution Requirements

Reddy says it's fairly obvious when a stratospheric ozone intrusion has occurred, based on signatures in satellite data, air quality monitoring stations and meteorological data. For example, low water vapor, wind and high ozone at remote locations are often characteristic of stratospheric air.

Evidence of the intrusions, however, doesn't show up in the models currently used by air quality managers. Many of those models assume ozone moves from the stratosphere to the troposphere at a constant, average rate. This fails to capture the episodic intrusion events.

Meiyun Lin, an atmospheric scientist at Princeton University and NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey, set out to better quantify the impact of stratospheric ozone intrusions. Lin and colleagues used satellite and meteorological observations alongside a global chemistry-climate model to simulate intrusions in high-resolution.

Like the pixels in a photograph, the resolution of a model refers to the size of three-dimensional boxes of atmosphere. Models simulate the chemistry and atmospheric processes inside each box. For perspective, a model with 200-kilometer (124-mile) resolution is typical of today's high-end climate models, and 25-kilometer (16-mile) resolution is typical of high-end weather forecasts. "We absolutely need to use a model with a grid size at least as small as, or smaller than, 50-by-50 kilometers (31-by-31 miles) to look at where and when the stratospheric air reaches the surface," Lin said.

Lin's analysis, based on a GFDL model with 50-kilometer (31-mile) resolution, suggests that the impact on ground level ozone in the U.S. West from springtime intrusion events is two to three times greater than previously estimated. The study was published October 2012 in Journal of Geophysical Research.

Steven Pawson and Eric Nielsen, atmospheric scientists at NASA's Goddard Space Flight Center in Greenbelt, Md., are also in pursuit of improved model simulations of stratospheric ozone intrusions. The team set out to see if the Goddard Earth Observing System Model, Version 5 (GEOS-5) Chemistry-Climate Model could replicate stratospheric intrusions at 25-kilometer (16-mile) resolution.

They show that indeed, the model could replicate small-scale features, including finger-like filaments, within the apron of ozone-rich stratospheric air that descended over Colorado on April 6, 2012. "High-resolution modeling is giving us the capability to examine these events comprehensively for the first time," Nielsen said.

High-resolution models are possible due to computing power now capable of simulating the chemistry and movement of gasses and pollutants around the atmosphere and calculating their interactions. The addition of chemistry to these models, however, is not without a computational cost. For example, a weather forecast that takes about one hour of computational time would take five hours to run at the same resolution with the chemistry included.

"For a long time people thought excluding stratospheric chemistry was a reasonable approximation to make," said Lesley Ott, an atmospheric scientist at NASA Goddard. "But recent work has shown that you really need to consider what the stratosphere is doing. It's not just something you can totally ignore, despite the fact that it's more computationally intensive."

Atmospheric measurements from the ground and from aircraft suggest the higher resolution models are on track. In June and July 2011, NASA aircraft flew at low altitude over the Baltimore- Washington area as part of DISCOVER-AQ, a NASA airborne campaign to study urban air quality. Comparing data from the aircraft with the model output, Ott says the models performed well.

Tying it Together

Scientists already know that intrusions reaching surface air are more frequent in spring and early summer, when chemistry and weather conditions are more favorable for such events. Also, intrusions are more likely to affect mountainous regions in the U.S. West simply because land at elevation is closer to the stratosphere.

The next step is to find out how the frequency of intrusions changes from year to year and what controls its variability. "This is really the first time that our models are giving us the chance to try to answer those questions," Ott said.

Reddy, too, looks forward to seeing if the models can streamline reporting and forecasting efforts. "The nice thing about the new model products is that they could help us potentially do a better job forecasting these events and documenting what happened for those events that we want to submit to the EPA," he said.

The models could also help Reddy as his agency works to refine and expand its services. Models that could more accurately focus the timing and scale of intrusion effects would enhance the state's ability to issue advisories that better target affected populations.

Does that mean that spring skiers will have an additional forecast to consider before heading to the slopes?

"In the West, don't be surprised if on a clean-looking, windy day in spring there's an ozone health advisory," Reddy said.

As for Bryan Duncan, an atmospheric scientist at NASA Goddard, "It wouldn't stop me from enjoying the powder conditions."

Source: NASA/Goddard Space Flight Center

NATURE GEOSCIENCE | VOL 7 | APRIL 2014 | www.nature.com/naturegeoscience

Desert dust and monsoon rain

William Lau

The climate regimes of monsoon regions and deserts are connected. Satellite data and numerical experiments reveal that an increase in dust aerosol loading over the Arabian Sea and West Asia can lead to enhanced summer monsoon rainfall over central India on timescales of days to weeks.

For centuries, inhabitants of the Indian subcontinent have known that heavy dust events brought on by strong winds occur frequently in the pre-monsoon season, before the onset of heavy rain. Yet scientists have never seriously considered the possibility that natural dust can affect monsoon rainfall. Up to now, most studies of the impacts of aerosols on Indian monsoon rainfall have focused on anthropogenic aerosols in the context of climate change.

However, a few recent studies have shown that aerosols from anthropogenic and natural sources over the Indian subcontinent may affect the transition from break to active monsoon phases[1,2] on short timescales of days to weeks. As they report in Nature Geoscience, Vinoj and colleagues[3] now show that desert dust aerosols over the Arabian Sea and West Asia can strengthen the summer monsoon over the Indian subcontinent in a matter of days.

Prevailing low-level winds carry dust particles from the deserts of West Asia, the Middle East and North Africa across the Arabian Sea to the Indian subcontinent each year, before the onset of the summer monsoon[4] (Fig. 1). As the monsoon develops, these low-level winds strengthen and transport more dust from the desert regions. As a result, dust levels over the Arabian Sea, northwestern India, the Indo- Gangetic Plain and the Himalaya foothills peak during the late boreal spring and early summer months. As the monsoon season progresses, atmospheric dust loading diminishes over India because of wash-out by heavy rainfall and weakening winds.

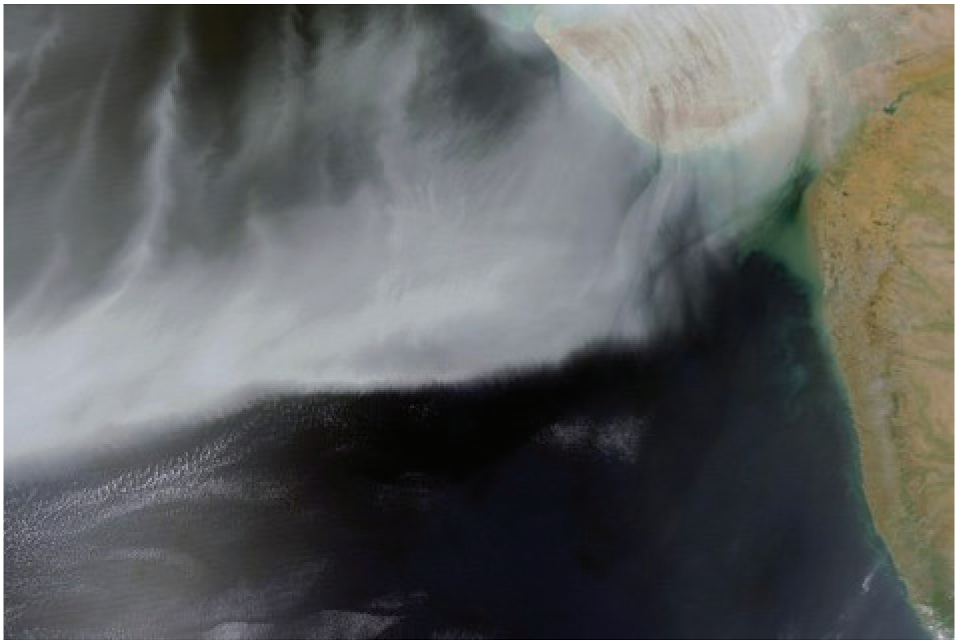


Figure 1 | Desert dust over the Arabian Sea. A giant dust plume stretched across the Arabian Sea from the coast of Oman to India on 20 March 2012. This extensive plume followed days of dust-storm activity over the Arabian Peninsula and southwestern Asia. Vinoj and colleagues[3] show that desert dust over West Asia and the Arabian Sea enhances summer monsoon rainfall in central India within a few days.

Airborne dust particles can cool the underlying surface by reducing the total amount of sunlight reaching the surface through scattering and absorbing incoming solar radiation. The solar radiation absorbed by dust will heat the ambient atmosphere. Increasing concentrations of aerosols (composed primarily of desert dust and sea salt) over the Arabian Sea during the pre-monsoon and early monsoon season (May–June) have been estimated to warm the atmosphere by 10 to 15 W m^{-2}, far exceeding the warming attributed to greenhouse gases[5].

Vinoj and colleagues[3] show that warming of the atmosphere by dust aerosols over the Arabian Sea can induce atmospheric feedback processes, resulting in enhanced summer monsoon rainfall over central India. Using satellite data, they document a positive correlation between dust aerosol levels over the Arabian Sea and the amount of rainfall over central India during the monsoon season. A similar correlation pattern is reproduced in their numerical simulations with an atmospheric global climate model. According to these simulations, dust aerosols can warm the atmosphere over West Asia and the Arabian Sea by as much as 36 W m^{-2} on short timescales. This aerosol-induced warming strengthens the southwesterly monsoon winds, thereby increasing moisture convergence north and east of the region of maximum dust loading over the Arabian Sea, eventually leading to increased rainfall over central India.

To focus on the short-term effects of aerosols on monsoon rainfall, Vinoj et al.[3] ignore the cooling effect of dust aerosols on sea surface temperature in their model simulations. However, over longer timescales, this cooling effect may reduce the north–south temperature gradient, suppressing monsoon rainfall over the Indian subcontinent[6]. Additional model simulations including both dust effects and interactive sea surface temperatures need to be carried out to investigate how monsoon rainfall will respond to dust forcing over longer timescales.

The stimulation of Indian summer monsoon rainfall by desert dust, as proposed by Vinoj et al.[3], could increase with regional population growth and climate change. Emissions of black carbon aerosols — highly absorptive particles released from industrial activities, residential cooking and heating — have risen with population growth in India in recent decades[7]. If emissions continue to rise, dust particles transported across India will become increasingly coated in black carbon aerosols8. The resultant rise in dust-induced warming could further strengthen aerosol– monsoon interactions. Furthermore, the expected expansion of desert and arid regions under global warming[9] could enhance dust transport from the deserts of the Middle East and North Africa to the Asian monsoon regions, further enhancing monsoon rainfall.

Vinoj and colleagues[3] identify a mechanism by which atmospheric warming over the Arabian Sea by desert dust strengthens monsoon rains over central India on short timescales. Their findings add to a growing body of evidence10–12 that aerosols, both natural and anthropogenic, constitute a key component of the monsoon–climate system.

William Lau is at the Earth Science Division of the NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA.

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NOAA/NASA satellite sees holiday lights brighten cities

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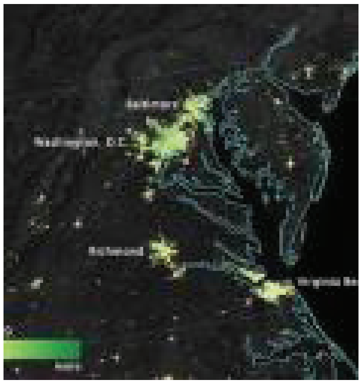


NASA's Earth Observatory/Jesse Allen

Even from space, holidays shine bright. With a new look at daily data from the NOAA/NASA Suomi National Polar-orbiting Partnership (Suomi NPP) satellite, a NASA scientist and colleagues have identified how patterns in nighttime light intensity change during major holiday seasons -- Christmas and New Year's in the United States and the holy month of Ramadan in the Middle East.

Around many major U.S. cities, nighttime lights shine 20 to 50 percent brighter during Christmas and New Year's when compared to light output during the rest of the year, as seen in the satellite data. In some Middle Eastern cities, nighttime lights shine more than 50 percent brighter during Ramadan, compared to the rest of the year.

Suomi NPP, a joint NASA/National Oceanic and Atmospheric Administration (NOAA) mission, carries an instrument called the Visible Infrared Imaging Radiometer Suite (VIIRS). VIIRS can observe the dark side of the planet -- and detect the glow of lights in cities and towns worldwide. In 2012, NOAA scientists released "Earth at Night" maps, created from VIIRS data. These well-known images are composites -- based on monthly long-term averages of data collected on nights with no clouds or moonlight.

The new analysis of holiday lights uses an advanced algorithm, developed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, that filters out moonlight, clouds and airborne particles in order to isolate city lights on a daily basis. The data from this algorithm provide high-quality satellite information on light output across the globe, allowing scientists to track when -- and how brightly -- people illuminate the night.

Christmas and New Year's in the United States

In the United States, the lights started getting brighter on "Black Friday," the day after Thanksgiving, and continued through New Year's Day, said Miguel Román, a research physical scientist at NASA Goddard and member of the Suomi NPP Land Discipline Team, who co-led this research. He and his colleagues examined the light output in 2012 and 2013 in 70 U.S. cities, as a first step in determining patterns in urban energy use -- a key factor in greenhouse gas emissions.

In most suburbs and outskirts of major cities, light intensity increased by 30 to 50 percent. Lights in the central urban areas did not increase as much as in the suburbs, but still brightened by 20 to 30 percent.

"It's a near ubiquitous signal. Despite being ethnically and religiously diverse, we found that the U.S. experiences a holiday increase that is present across most urban communities," Román said. "These lighting patterns are tracking a national shared tradition."

Because snow reflects so much light, the researchers could only analyze snow-free cities. They focused on the U.S. West Coast from San Francisco and Los Angeles, and cities south of a rough imaginary line from St. Louis to Washington, D.C. The team also examined lighting patterns across 30 major towns in Puerto Rico, known for its vibrant nocturnal celebrations and for having one of the longest Christmas holiday periods.

It's official -- our holiday lights are so bright we can see them from space. Thanks to the VIIRS instrument on the Suomi NPP satellite, a joint mission between NASA and NOAA, scientists are presenting a new way of studying satellite data that can illustrate patterns in holiday lights.

"Overall, we see less light increases in the dense urban centers, compared to the suburbs and small towns where you have more yard space and single-family homes," said Eleanor Stokes, a NASA Jenkins Graduate Fellow and Ph.D. candidate at Yale University's School of Forestry and Environmental Studies, New Haven, Connecticut, who co-led the study with Román.

These new results, illustrating holidays in lights, were presented at the American Geophysical Union's Fall Meeting in San Francisco.

Ramadan in the Middle East

The idea to look at holiday light-use patterns stemmed from one of the first analyses of the new daily lights algorithm, Román said. Colleagues from NASA Goddard and Yale were looking data of Cairo in 2012 and noticed a large discrepancy.

"'Either you have something going on with your data that's wrong, or there's a real signal there that you have to look into,'" Román recalls them saying. When the team investigated the satellite record, they found that the large increase in light output in Egypt's capital corresponded with the holy month of Ramadan. During Ramadan, Muslims fast during the day, pushing meals and many social gatherings, markets, commerce and more to nighttime hours.

To confirm that the nighttime signal was not merely an instrument artifact, they examined three consecutive years worth of data from 2012 through the fall of 2014. They found that the peaks in light use closely tracked the Islamic calendar, as Ramadan shifted earlier in the summer.

But not all Middle Eastern cities responded the same as Cairo. Light use in Saudi Arabian cities, such as Riyadh and Jeddah, increased by about 60 to 100 percent through the month of Ramadan. Light use in Turkish cities, however, increased far less. Some regions in Syria, Iraq and Lebanon did not have an increase in light output, or even demonstrated a moderate decrease, possibly due to unstable electrical grids or conflict in the region.

"Even within majority Muslim populations, there are a lot of variations," Stokes said. "What we've seen is that these lighting patterns track cultural variation within the Middle East."

With the high resolution provided by VIIRS, that variation even appears at the neighborhood level. Román and Stokes used data from Cairo to divide the city's neighborhoods into different socioeconomic groups, based on available records of voting patterns, access to public sanitation, and literacy rates. Some of the poorest and most devout areas observed Ramadan without significant increases in light use throughout the month, choosing -- whether for cultural or financial reasons -- to leave their lights off at night. But during the Eid al-Fitr celebration that marks of the end of Ramadan, light use soared across all study groups, as all the neighborhoods appeared to join in the festivities. This is telling researchers that energy is providing services that enable social and cultural activities, Stokes said, and thus energy decision-making patterns are reflecting social and cultural identities.

"Whether you're rich or poor, or religious or not, everybody in Egypt is celebrating the Eid, or the end of Ramadan," Román said. This demonstrates that the drivers of demand for energy services aren't just controlled by individual factors, like price; they are also influenced by the beliefs, statuses, and routines of a city's inhabitants, he added.

Understanding Energy Decisions

"Having a daily global dynamic dataset of nighttime lights is a new way for researchers to understand the broad societal forces impacting energy decisions," Stokes said. And with the Intergovernmental Panel on Climate Change noting that greenhouse gas reductions are going to come from energy efficiency and conservation, scientists and policy makers will need to better understand the driving forces behind energy use.

"More than 70 percent of greenhouse gas emissions come from urban areas," Román said. "If we're going to reduce these emissions, then we'll have to do more than just use energy-efficient cars and appliances. We also need to understand how dominant social phenomena, the changing demographics of urban centers, and socio-cultural settings affect energy-use decisions."

The VIIRS data also provide a new way of looking at how people use cities, from an energy perspective, Román said. Earth-observing satellites like the Landsat series have mapped the footprints and the built infrastructure within urban boundaries for decades -- but the presence of buildings doesn't reveal whether people are actually using them. The new daily dynamic data is a step in that direction, he said.

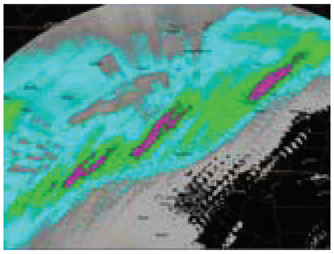
"What's really difficult to do is to try and track people's activity patterns and to understand how this shapes the demand for energy services," Román said. "We can now see pieces of these patterns from space -- when, where and how often we turn on the lights."

Source: NASA/Goddard Space Flight Center

New satellite aids Asheville-area rainfall study

Sabian Warren, swarren@citizen-times.com 7:46 p.m. EDT May 12, 2014
ASHEVILLE

A new phase of an intensive federal study of Western North Carolina rainfall is underway to help scientists learn more about the mountains' sometimes unpredictable precipitation patterns.



(Photo: Special to the Citizen-Times)

In an effort that started May 1 and lasts through June 15, scientists are using a network of ground monitoring stations, special aircraft and a state-of-the-art NASA weather satellite that was launched in February to fine-tune measurements of rain.

"This is the newest generation up there in space," UNC Asheville professor Doug Miller, who's taking part in the project, said of the satellite. "It's able to see things in finer scale and also to differentiate the kind of rain that's falling."

The project is a joint effort of the National Oceanic and Atmospheric Administration and NASA in collaboration with universities across the state, with the aim of improving forecasters' ability to predict potentially dangerous flooding from thunderstorms or tropical systems, lessons that could be applied across the country.

The overall project kicked off last June and is expected to last 18 months. The six-week effort underway now has a specific focus of using the ground stations and aircraft to help verify what the satellite is seeing, Miller said. A ground station on a remote peak in the Smokies, for example, could determine in real time the intensity of rain at that site, allowing scientists to calibrate the satellite to accurately determine rainfall in similar situations in the future in other parts of the world without the need for ground measurements.

The idea for the study stemmed from 2004 tropical storms that battered the Southeast, including the mountains. In WNC, the storms claimed a dozen lives and left millions of dollars in damage in their wake.

Miller and eight of his students are participating by launching weather balloons during storms to measure temperature, moisture and wind speed.

North Carolina was chosen for the project because of abundant year-round rainfall and varied topography that ranges from high mountains to coastal plain, said Miller, who chairs UNCA's atmospheric sciences department. And the state, because of its relative proximity to the moisture-rich Gulf of Mexico and Atlantic Ocean, could get heavy precipitation at any time of the year from tropical systems, thunderstorms and winter storms.

Mountain precipitation is difficult to measure, even from satellites. The shape of the rugged slopes interacts with and produces a wide variety of rainfall, through poorly understood processes specific to mountains.

On the ground, rain gauges have to be set up and maintained in remote areas only accessible by foot or on horseback. Ridges block weather radars from seeing very far into the mountains.

"We don't have a whole lot of information in the mountains," Miller said. "If you have a lot of rain falling in a particular watershed, you can get a lot of problems in a hurry."

An important part of the project is learning where rainwater goes after it hits the ground — underground and into streams and rivers where it supplies freshwater to the region, or becomes a natural hazard.

"What we're trying to do is study and learn about the precipitation from the summit to sea, how it evolves as it moves from the mountains to the plains," NASA scientist Walt Petersen said. "Then we use that information to improve satellite observations of precipitation and how those observations can best be used in applications like hydrologic models."

The idea for the study stemmed from 2004 tropical storms that battered the Southeast, including the mountains. In WNC, the storms claimed a dozen lives and left millions of dollars in damage in their wake.

Big 2004 storms

Rainfall in inches from the remnants of hurricanes Frances and Ivan in September of 2004, which claimed a dozen lives in Western North Carolina and left millions of dollars in damages. The storms were the impetus for the current NOAA and NASA rainfall study in WNC. Rainfall totals are listed first for Frances, then Ivan.

Location	*Rainfall Total: Frances*	*Rainfall Total: Ivan*
ASHEVILLE	2.86	3.66
Lake Toxaway	14.82	6.24
Spruce Pine	6.02	2.84
Marshall	3.56	4.68
Canton/Cruso	7.79	17.00
Highlands	10.39	7.20

ACRONYMS

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

3D	Three Dimensional
7-SEAS	Seven SouthEast Asian Studies
ACE	Aerosols, Clouds, and Ecology
ACRIM	Active Cavity Radiometer Irradiance Monitor
AEROKATS	Advancing Earth Research Observation Kites And Tether Systems
AERONET	Aerosol Robotic Network
AETD	Applied Engineering and Technology Directorate
AIRS	Atmospheric InfraRed Sounder
ALVICE	Atmospheric Lindar for Validation, Interagency Collaboration and Education
AMA	Academy of Model Aeronautics
AMS	American Meteorlogical Society
AMSR-E	Advanced Microwave Scanning Radiometer–Earth Observing System
AMSU	Advanced Microwave Sounding Unit
AOD	Aerosol Optical Depth
AOT	Aerosol Optical Thickness
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARM	Atmospheric Radiation Measurement
ASCENDS	Active Sensing of CO2 Emissions over Nights, Days, and Seasons
ASIF	Air Sea Interaction Facility
ASR	Atmospheric System Research
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATM	Airborne Topographic Mapper
ATMS	Advanced Technology Microwave Sounder
BC	Black Carbon
BESS	Beaufort and East Siberian Sea
BEST	Beginning Engineering Science and Technology
BMKG	Meteorological Climatological and Geophysical Agency
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAR	Cloud Absorption Radiometer
CCM	Chemistry-climate model
CCMVal	Chemistry Climate Model Evaluation
CCNY	City College of New York
CERES	Cloud and Earth Radiant Energy System

ACRONYMS

CF	Central Facility
CINDY	Cooperative Indian Ocean experiment on intraseasonal variability
CIRC	Continual Intercomparison of Radiation Codes
CLEO	Conference on Lasers and Electro-Optics
CO	Carbon Monoxide
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
CPL	Cloud Physics Lidar
CrIS	Cross-track Infrared Sounder
CRM	Cloud-resolving Models
CRS	Cloud Radar System
DB-SAR	Digital Beam-forming SAR
DISC	Data and Information Services Center
DISCOVER-AQ	Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality
DOD	Department of Defense
DOE	Department of Energy
DPR	Dual-frequency Precipitation Radar
DSCOVR	Deep Space Climate Observatory
DYNAMO	Dynamics of the Madden-Julian Oscillation
EC	Environment Canada
ECO-3D	Exploring the Third Dimension of Forest Carbon
ENSO	El Niño Southern Oscillation
EOF	Empirical Orthogonal Function
EOS	Earth Observing System
EPIC	Earth Polychromatic Imaging Camera
ESA	European Space Agency
ESSIC	Earth System Science Interdisciplinary Center
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FV	Finite Volume
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
GES	Goddard Earth Sciences

GEST	Goddard Earth Sciences and Technology Center
GESTAR	Goddard Earth Sciences Technology Center and Research
G-IV	Gulfstream IV
GLOPAC	Global Hawk Pacific Missions
GMAO	Goddard Modeling and Analysis Office
GMI	GPM Microwave Imager
GMI	Global Modeling Initiative
GOES	Geostationary Operational Environmental Satellites
GOES-R	Geostationary Operational Environmental Satellite – R Series
GOSAT	Greenhouse gases Observing Satellite
GPCEX	GPM Cold Season Precipitation Experiment
GPM	Global Precipitation Measurement
GRIP	Genesis and Rapid Intensification Processes
GSFC	Goddard Space Flight Center
GUV	Global UltraViolet
GV	Ground Validation
HAMSR	High Altitude Monolithic Microwave Integrated Circuit Sounding Radiometer
HBSSS	Hydrospheric and Biospheric Sciences Support Services
HIRDLS	High Resolution Dynamics Limb Sounder
HIWRAP	High-Altitude Imaging Wind and Rain Airborne Profiler
HOPE	Hyperspectral Ocean Phytoplankton Exploration
HS3	Hurricane and Severe Storm Sentinel
HSB	Humidity Sounder for Brazil
I3RC	Intercomparison of 3D Radiation Codes
IAMAS	International Association of Meteorology and Atmospheric Sciences
IASI	Infrared Atmospheric Sounding Interferometer
ICAP	International Cooperative for Aerosol Prediction
ICCARS	Investigating Climate Change and Remote Sensing
ICESat	Ice, Cloud, and land Elevation Satellite
IIP	Instrument Incubator Program
INPE	National Institute for Space Research (Brazil)
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IRAD	Internal Research and Development
IRC	International Radiation Commission
ITCZ	Intertropical Convergence Zone
IUGG	International Union of Geodesy and Geophysics

ACRONYMS

JAXA	Japanese Aerospace Exploration Agency
JCET	Joint Center for Earth Systems Technology
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JWST	James Webb Space Telescope
LaRC	Langley Research Center
LASP	Laboratory for Atmospheric and Space Physics
LDCM	Landsat Data Continuity Mission
LDSD	Low Density Sonic Decelerator program
LIS	Lightning Imaging Sensor
LIS	Land Information System
LPVEx	Light Precipitation Validation Experiment
LRRP	The Laser Risk Reduction Program
MABEL	Multiple Altimeter Beam Experimental Lidar
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MC3E	Mid-latitude Continental Convective Clouds Experiment
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
MODIS	Moderate Resolution Imaging Spectroradiometer
MoE	Ministry of Environment
MOHAVE	Measurement of Humidity in the Atmosphere and Validation Experiment
MOPITT	Measurement of Pollution in the Troposphere
MPLNET	Micro Pulse Lidar Network
MSU	Morgan State University
NCAR	National Center for Atmospheric Research
NCTAF	National Commission on Teaching and America’s Future
NEO	NASA Earth Observations
NIST	National Institute of Standards
NISTAR	Advanced Radiometer
NLDAS-2	North American Land Data Assimilation System
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar Orbiting Environmental Satellite System
NPOL	Naval Physical and Oceanographic Laboratory
NPP	National Polar-orbiting Partnership

NRC	National Research Council
NRL	Naval Research Laboratory
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSTA	National Science Teachers Association
OASIS	Ocean Ambient Sound Instrument System
OCO-2	Orbiting Carbon Observatory
ODSs	Ozone Depleting Substances
OEI	Ozone ENSO Index
OLI	Operational Land Imager
OMI	Ozone Monitoring Instrument
OMPS	Ozone Monitoring and Profiling Suite
OMPS	Ozone Mapping and Profiler Suite
PACE	Pre-Aerosols, Clouds, and Ecology
PI	Principal Investigator
PR	Precipitation Radar
PSCs	Polar Stratospheric Clouds
PUMAS	Practical Uses of Math and Science
PVI	Perpendicular Vegetation Index
RESA	Regional Education Service Agency
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
SAF	Satellite Application Facility
SAIC	Science Applications International Corporation
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
S-HIS	Scanning High-Resolution Interferometer Sounder
SIM	Spectral Irradiance Monitor
SIMPL	Swath Imaging Multi-polarization Photon-counting Lidar
SMART	Surface-sensing Measurements for Atmospheric Radiative Transfer
SORCE	Solar Radiation and Climate Experiment
SPARRO	Self-Piloted Aircraft Rescuing Remotely Over Wilderness

ACRONYMS

SPE	Solar Proton Event
SSA	Single Scattering Albedo
SSAI	Science Systems Applications, Inc.
SSI	Solar Spectral Irradiance
SST	Sea Surface Temperature
STEM	Science, Technology, Engineering, and Mathematics
SWOT	Surface Water Ocean Topography
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
TOGA	Tropical Ocean Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measurement Mission
TROPOMI	Troposhere Ozone Monitoring Instrument
TSI	Total Solar Irradiance
TSIS	Total Spectral Solar Irradiance Sensor
TWiLiTE	Tropospheric Wind Lidar Technology Experiment
UARS	Upper Atmosphere Research Satellite
UAVs	Unmanned Aerial Vehicles
UMBC	University of Maryland, Baltimore County
UMSA	Universidad Mayor San Andres
USGS	United States Geological Survey
USRA	Universities Space Research Associates
UTLS	Upper Troposphere and Lower Stratosphere
UV	Ultraviolet
VIIRS	Visible Infrared Imaging Radiometer Suite
VIRS	Visible and Infrared Scanner
WAVES	Water Vapor Validation Experiments Satellite and sondes
WFF	Wallops Flight Facility

APPENDIX 1. REFEREED ARTICLES

In 2014, Atmospheric Research published 158 peer-reviewed publications listed below.

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APPENDIX 1: REFEREED ARTICLES

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APPENDIX 1: REFEREED ARTICLES

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