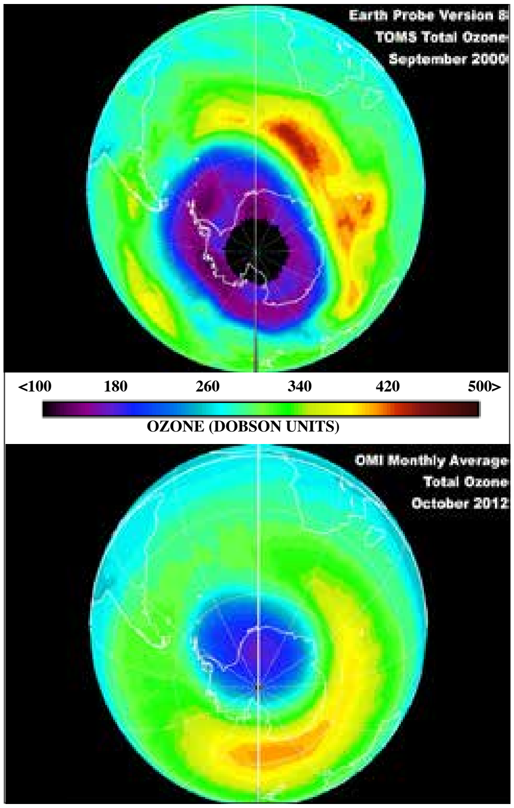
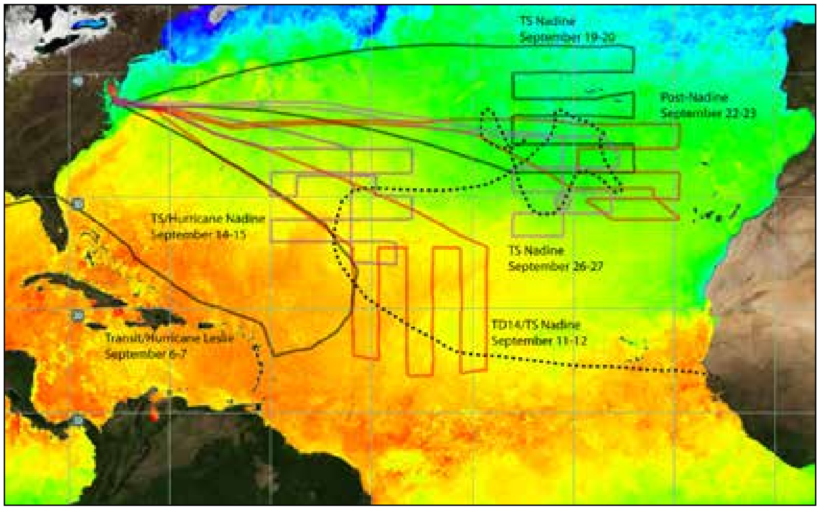
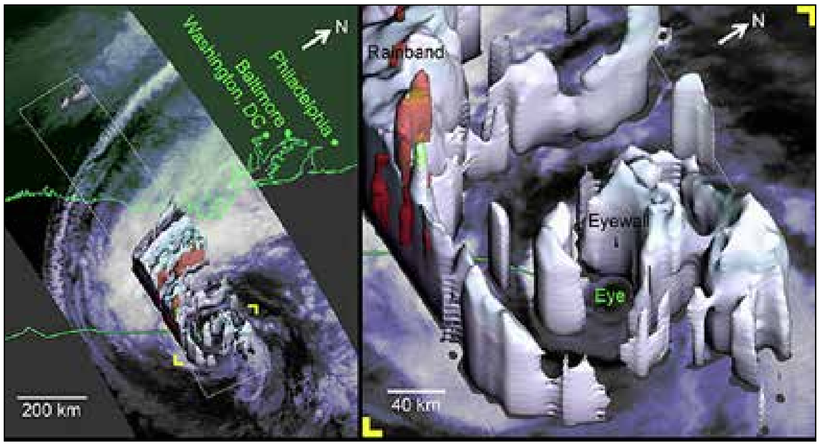
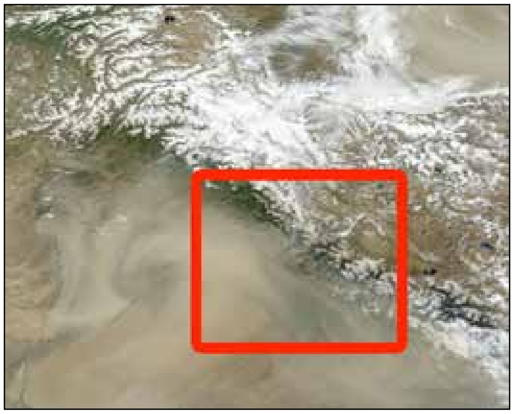
NASA/TM–2013-217510

Atmospheric Research
2012 Technical Highlights









July 2013

Cover Photo Captions

UPPER LEFT

HS3 Flight Tracks

HS3 conducted seven flights of the environmental Global Hawk (GH) aircraft. The first flight was the ferry from Dryden to Wallops on September 6–7, during which time the GH flew along the outflow region of Hurricane Leslie. The next five flights were in Hurricane Nadine, the only storm to occur during the major portion of the deployment, but one that occurred virtually throughout the period. The last two flights, also in the Azores region on September 22–23 and 26–27, investigated Nadine's interaction with an extratropical trough. Nadine re-intensified into a hurricane on September 28, 2012. The last flight consisted of two north-south tracks under the Aqua and NPP satellites.

UPPER MIDDLE-RIGHT

Ozone Hole Reduction

The average area covered by the Antarctic ozone hole in 2012 was the second smallest in the last 20 years, according to data from NASA and National Oceanic and Atmospheric Administration (NOAA) satellites. Scientists attributed the change to warmer temperatures in the Antarctic's lower stratosphere. In this comparison, the September 10, 2000 ozone hole (top) was the largest on record at 11.5 million square miles (29.9 million square kilometers). The average size of the 2012 ozone hole (bottom) was 6.9 million square miles (17.9 million square kilometers).

LOWER LEFT

Looking Into a Hurricane

NASA's Tropical Rainfall Measuring Mission, or TRMM satellite, can measure rainfall rates and cloud heights in tropical cyclones, and was used to look into Hurricane Sandy on October 28, 2012. Owen Kelly of the Goddard's Precipitation Processing System generated this image of Hurricane Sandy using TRMM data.

LOWER RIGHT

Dust on the Himalayas

This Terra/MODIS image shows a major dust outbreak over South Asia on June 9, 2003. The outbreak led to dust-capped snow surfaces that darkened the western Himalayan snow (highlighted in red) as a result of absorbing the aerosol deposits. This could accelerate snowmelt and thereby potentially affecting the cryospheric reservoirs of the Himalayan-Tibetan Plateau. Consequently, this snow albedo reduction may lead to a warmer regional climate with possible impacts on the summer monsoon circulation and rainfall distribution, and therefore, the overall hydrological cycle of southern and eastern Asia.

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

NASA/TM–2013-217510

Atmospheric Research 2011 Technical Highlights

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2013

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:

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- 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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Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Reader:

Welcome to the Atmospheric Research 2012 Atmospheric Research Highlights report. This report, as before, is intended for a broad audience. Our readers include colleagues within NASA, scientists outside 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 2012.

The 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, Earth Sciences Division in the Sciences and Exploration Directorate of NASA's Goddard Space Flight Center. The overall mission of the office is "advancing knowledge and understanding of the Earth's atmosphere." Satellite missions, field campaigns, peer-reviewed publications, and successful proposals are essential to our continuing research.

The following are some noteworthy events that took place during 2012.

Congratulations to Paul Newman and Scott Braun for a successful Hurricane and Severe Storm Sentinel (HS3) campaign that demonstrated a new way gather difficult-to-obtain measurements of wind speeds, precipitation, and cloud structures in and around tropical storms. HS3 used autonomously operated instruments on unmanned aircraft capable of flying for much longer periods of time than manned aircraft, thus allowing for collection of that was previously difficult to obtain. Scientists hope to use that data to gain new insights into how tropical storms form and, more importantly, how storms intensify into major Atlantic hurricanes—information that forecasters need to make better storm predictions, save lives.

Kudos to the PMM science team for advancing the ability of the TRMM satellite to measure rainfall rates and cloud heights in tropical cyclones, and to Owen Kelly, the TRMM Precipitation Processing System Scientist, for creating the spectacular image to look into Hurricane Sandy on Oct. 28, 2012 (shown on cover). The TRMM radar data revealed a Category-1 hurricane comprised of a super-sized rainband that extended to the west and north of the center with vigorous storm cells. The cells eventually merged and with an impending extratropical storm and became invigorated, thus creating the most destructive hurricane to hit the northeastern Atlantic seaboard and the second most costly Atlantic hurricane on record, behind only Hurricane Katrina.

Atmospheric scientists played key roles in numerous field campaigns other than HS3. These include validation and calibration of remote sensing techniques for snowfall in Canada (GPCEx); measurement of water vapor from Raman lidar in western Ontario (AIVICE); observations of aerosol-cloud interactions in Southeast Asia (7-SEAS); GPM ground validation studies in the Mediterranean; and Hydrology in the Mediterranean Experiment (HyMeX).

Atmospheric scientists received many top professional honors and appointments during the year. William Lau has been elected President-Elect for the Atmospheric Sciences Section of AGU for 2013–2014. Joe Munchak received the AMS's Robert Leviton Award for his paper, "A Modular Optimal Estimation Method for Combined Radar-Radiometer Precipitation Profiling" and presented at the 92nd annual meeting of the

AMS in New Orleans, LA. Robert Levy was awarded the International Radiation Commission's Young Scientist Award for outstanding contribution to aerosol retrieval algorithm, data processing, and analysis. Pawan Bhartia received the Y. Kaufman Award from the AGU for unselfish collaboration.

The year was a time to bid farewell to Lorraine Remer who spent 21 years at GSFC working on remote sensing of aerosol and interactions with climate. Lorraine is now a faculty member at the Joint Center for Earth Systems Technology where she continues her research. We also bid farewell to Francis (Frank) J. Schmidlin, John Gerlach, Karen Pope, and Katherine Krokos-Miller after many years of quality service. Frank and John retired after 60 and 45 years, respectively, of Federal service. Frank managed the Wallops Upper Air Research Facility and will continue his work at Wallops in the Emeritus Program. John served as a branch head and lead radar scientist in the Wallops Flight Facility Office of Field Support. Karen Pope retired as a business management officer in Code 603, serving Code 610. Prior to this position she spent many years as a resource analyst for the Atmospheric laboratories. Katherine Krokos-Miller retired as a resource analyst and managed many atmospheric grants and contracts. We thank all of these retired employees for their years of service to NASA.

I am pleased to welcome research scientists George Huffman, David Wolf, and Glen Jaross. George will work on pre-launch algorithm and product development for GPM, and the transition of his TRMM Multi-satellite Precipitation Analysis to GPM. David will focus research efforts on field measurements, instrument development, and data analysis supporting the NASA Precipitation Science Program. Glen will be responsible for the Suomi NPP OMPS Limb instrument performance and Level One data quality and will be supporting the JPSS Program as the OMPS-Nadir instrument scientist. We also welcome Tracy Baker in her new position as business management officer in Code 603 as a replacement for Karen Pope. Nicole Raphael is the new resource analyst who will support the research grants and procurements previously managed by Tracy. The scientific and administrative expertise of all these new employees will help us continue to advance our science programs.

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.

William K.-M. Lau,

Deputy Director for Atmospheres

Earth Sciences Division, Code 610

June 2013

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1. INTRODUCTION

Atmospheric research in the Earth Sciences Division (Code 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, observation requirements for remote-sensing platforms, technology and retrieval algorithm development; leading to 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 18-year record of peer-reviewed publications and proposals among the various Laboratories.

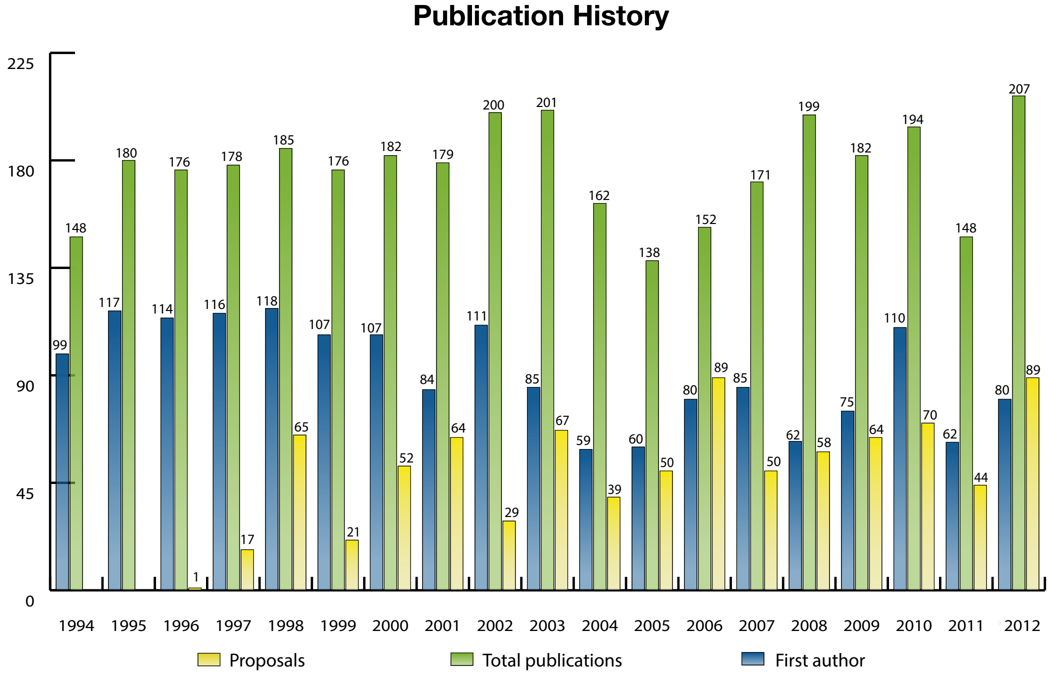

Figure 1.1: *Number of proposals and referred publications by Atmospheric Sciences members over the years. The green bars are the total number of publications and the blue bars the number of publications where a Laboratory member is first author. Proposals submitted are shown in yellow*

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 newly created 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 2012. 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/.

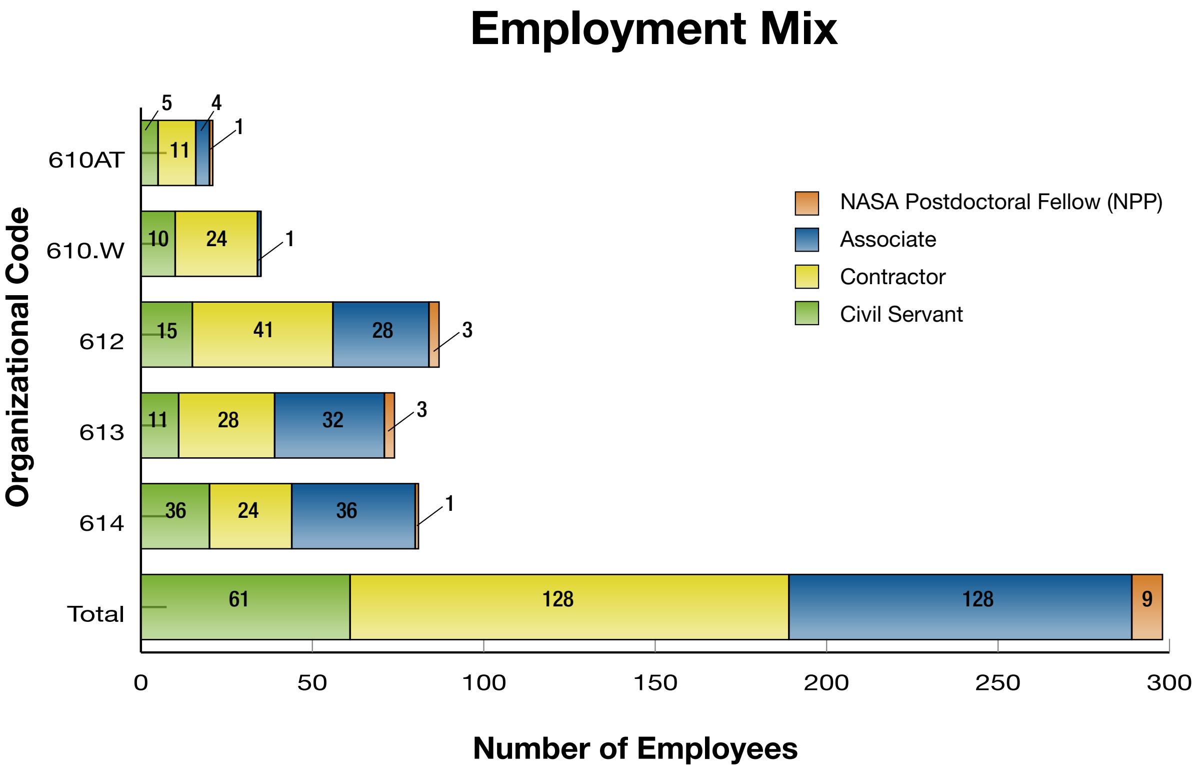

Figure 1.2: Employment composition of the members of Atmospheric Sciences.

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 (1960's–1970's) emphasized ozone monitoring, Earth radiation, and weather forecasting. Planetary atmosphere research with the Explorer, Pioneer Venus Orbiter, and Galileo missions was carried out until around 2000. In the recent years, EOS missions have provided an abundance of data and information to advance knowledge and understanding of atmospheric and climate processes. Basic and crosscutting research is carried out through observation, modeling, and analysis. Observation data is provided through satellite missions as well as in-situ and remote-sensing data from field campaigns. Scientists also focus their efforts on satellite mission planning and instrument development. For example, feasibility studies and improvements in remote-sensing measurement design 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). The following sections summarize some of the scientific highlights for the year 2012 with the contributors named at the end of each summary. Additional highlights and other information may be found at the website: http://atmospheres.gsfc.nasa.gov.

2.1. Mesoscale Atmospheric 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, and on the structure and evolution of meteorological phenomena—ranging from synoptic scale down to micro-scales—with a strong focus on the initiation, development, and effects of cloud and precipitation. A major emphasis is placed on understanding energy exchange and conversion mechanisms, especially cloud microphysical development and latent heat release associated with atmospheric motions. The research is inherently focused on defining the atmospheric component of the global hydrologic cycle, especially precipitation, and its interaction with other components of the Earth system. The Laboratory also 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=2012.

Does Dry Environmental Air Kill Intensifying Hurricanes?

A study was conducted to assess the impact of dry environmental air on hurricane intensification. There is frequent debate within the hurricane research and operational communities about the impact of dry air, with some treating it as a major suppressor of hurricane formation and intensification and others holding that it is very difficult for the dry air to get into the circulation in such a way as to impact intensity. This issue is very difficult to address with approaches other than idealized modeling. A computer model was used to simulate a hurricane under ideal conditions. Then different configurations of dry air were added at middle levels to assess impacts on storm intensity and structure. The results showed that in environments with weak mean flow, the dry air can slow intensification but doesn't prevent it. ***(Scott Braun, Jason Sippel and David Nolan***)

Dense Gauge Network Confirms Improvement in TRMM Radar Rainfall Intensity Estimates

Studying changes in water cycle, global circulation, and water resources depends upon our ability to measure precipitation from space. Precipitation forecasting accuracy and many hydrological applications depend on the accuracy of precipitation estimates. The evaluation of rainfall rate estimates from low-orbital satellites observations, like TRMM and GPM, requires in-situ measurements. Direct comparisons with in-situ measurements (e.g., rain gauges) have been limited to rainfall accumulations. Such comparisons are associated with large uncertainties due to satellite temporal sampling errors. Comparisons of instantaneous rain rate fields (snapshots) from satellite and gauge observations have been avoided, as they are associated with large uncertainties due to volume sampling discrepancies. For the first time, instantaneous rainfall rate fields (snapshots) from TRMM Radar (PR) are compared with those of a dense gauge network (of 1-min accumulations). Very good agreement between the PR and the interpolated gauge rain rate fields were observed with high-correlation and low-bias values (<10%), especially for the near-nadir cases (CC>0.9). Future science flights such as GPM will require accurate reference products for validation, and therefore, will benefit from this effort, which is the first study comparing and assessing snapshots of high-resolution satellite precipitation intensity estimates with in-situ measurements. ***(Eyal Amitai)***

A New, TRMM-based Analysis of African Rainfall Seasonality

Evaluating the effects of climate change on rainfall regimes requires a spatially accurate representation of their seasonal climatology to track changes not only in total annual rainfall but also in the seasonal character of rainfall regimes, which is of crucial importance to rain-fed agriculture and pasture development in the semiarid and sub-humid zones such as Africa. A study was carried out in Africa that represented the first continental-scale analysis of rainfall seasonality using space-based datasets. From the TRMM Multi-satellite Precipitation Analysis (TMPA), a spatially explicit, high-resolution climatology was created in which the temporal sequence of humid, arid, and dry months determined the seasonality regime. Eight different seasonality classes were derived from mean monthly rainfall and land surface temperature with 0.25° resolution from the TMPA and MODIS observation periods. Seasonal rainfall regimes were more than 60% of the continent, non-seasonal arid regimes were approximately 30%, and non-seasonal wet regimes were less than 5%. This demonstrated how the TMPA could be used to perform continental-scale mapping of seasonal climatology using gridded, space-based data products. Such analysis can form the basis for evaluating the implications of climate change on rainfall seasonality regimes and on vegetation phenology within those regimes. ***(Karen Mohr and Stefanie Herrman)***

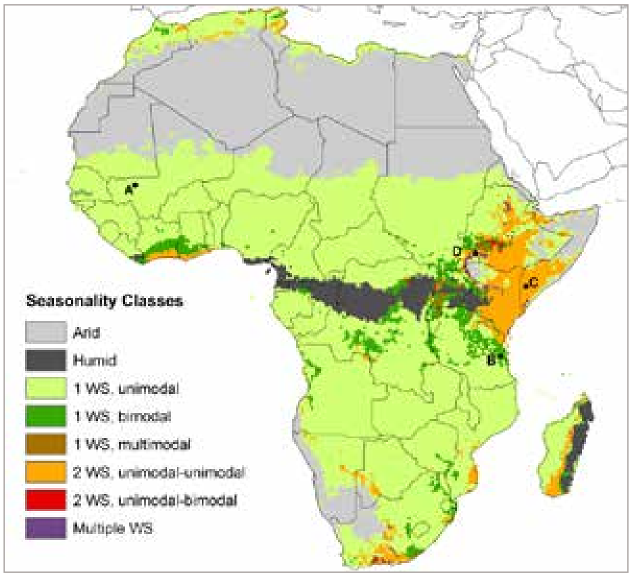

Figure 2.1: Seasonality map based on the TMPA*, indicating non-seasonal as well as single (1 WS), dual (2 WS), and multiple wet season (WS) regimes and their modalities.*

New Dual Frequency Radar for GPM Algorithm Development and Future Validation

The High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) is a dual-frequency (Ka- and Ku-band) radar that was recently converted to operate on the high-altitude ER-2. HIWRAP-ER-2 is a Doppler radar that measures radar backscatter at frequencies similar to the planned GPM Dual-frequency Precipitation Radar (DPR). It participated in the MC3E field experiment in the southern Great Plains along other airborne radiometers, ground-based polarimetric radars, and an in-situ aircraft. The experiment demonstrated the first high-altitude, dual-wavelength measurements and first Ka-band measurements over deep convective storms. Hail storms were observed that had significantly larger attenuation and Mie scattering effects than expected. Spaceborne radar profiling algorithms will therefore be highly challenging in these large convective systems. HIWRAP flying on the ER-2 provides a unique capability to study GPM radar profiling algorithms. These measurements, along with those from microwave radiometers onboard the ER-2, will be extremely useful for GPM algorithm development. ***(Gerald Heymsfield)***

Let It Snow: GPM Cold-season Precipitation Experiment

During the GPM pre-launch period physically based snowfall retrieval algorithms are in an active phase of development. Further refinement and testing of these emerging algorithms requires the collection of targeted ground-validation datasets in snowing environments. In order to develop snow algorithms, the GPM Cold-season Precipitation Experiment (GCPEx) field campaign was held January 17–February 29, 2012 with Environment Canada and other partners 70 km NW of Toronto. Data collected during this field campaign exceeded all expectations, with measurements of heavy (>2 in/hr), moderate (1–2 in/hr), and light falling snow rates, along with mixed phase and rain cases. These heavy- through light-snow cases are ideal for testing the thresholds of detection for falling snow rates using GPM-like sensors. The volumes of snow measured will be combined to provide a fundamental description of snowfall physics at the ground and through the atmospheric column, and to create an associated database of scenes for evaluating and developing satellite snowfall retrieval algorithms. ***(Gail Skofronick Jackson, Walter Petersen and Dave Hudak)***

Validation of Cirrus Cloud Properties Derived from CALIPSO

The CALIPSO data products have a large range of applications to significant climate system studies, such as developing global cloud statistics, initializing global cloud models, and investigating cloud-aerosol interactions and radiative effects. Therefore, validation of the CALIPSO data products is crucial in quantifying uncertainties and detecting biases in the retrievals and should, in turn, strengthen the results of previous and future studies using CALIPSO data. A series of 10 flights were conducted in the summer of 2006 using the airborne Cloud Physics Lidar (CPL) operating on the high-altitude ER-2 aircraft. The CPL provided collocated data to compare and validate the CALIPSO measurements of Cirrus cloud optical properties (e.g., optical depth, extinction). Results indicated that for cirrus clouds the lidar ratio (ratio of extinction to backscatter) and the retrieved extinction compare favorably between the two instruments, thereby validating the CALIPSO retrievals. In general, retrievals of optical depth agree to within ~7%, which is spectacular for lidar intercomparisons. The validation of the CALIPSO data products is crucial in quantifying uncertainties and detecting biases in the retrievals and should, in turn, strengthen the results of previous and future studies using CALIPSO data. ***(Matthew McGill, Dennis Hlavka, John Yorks, Mark Vaughan, Sharon Rodier, Ralph Kuehn, and Stuart Young)***

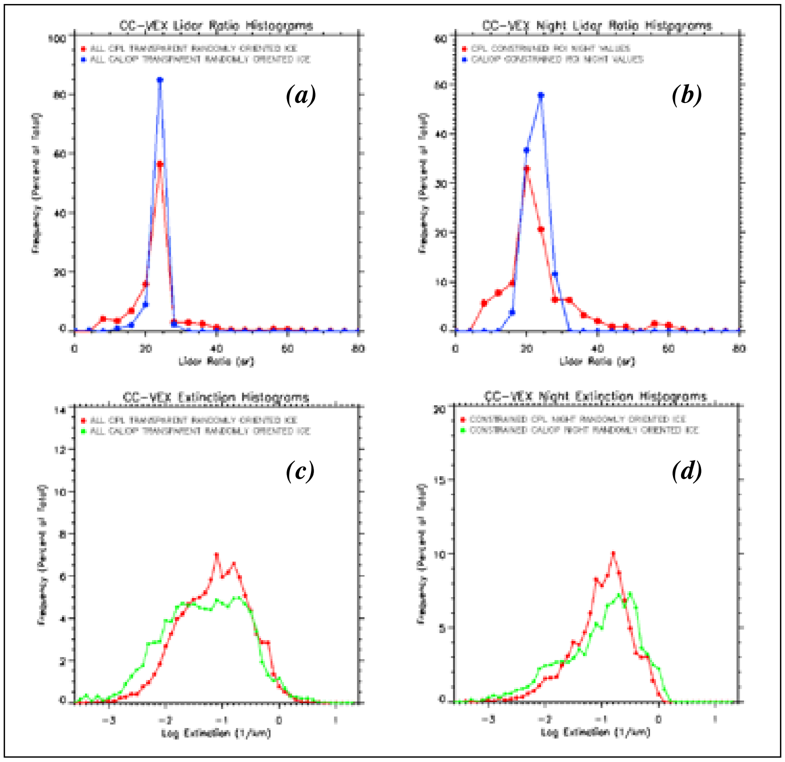

Figure 2.2: These figures show the frequency distributions of lidar ratio from CPL *(red) and* CALIPSO *(blue) from periods of coincident measurement (restricted to cases of cirrus with randomly-oriented ice conditions only). Figure (a) shows the composite distribution of all data and (b) shows the nighttime-only distribution. Figures (c) and (d) show the corresponding extinction distributions for* CPL *(red) and* CALIOP *(green) for the same composite and nighttime-only distributions, respectively. There is some difference evident from day to night, although exact reasons for the difference are not apparent.*

First Snow and Ice ICESat2-like Data from MABEL

The Multiple Altimeter Beam Experimental Lidar (MABEL) instrument completed an extremely successful deployment to Iceland, acquiring data from most target types of interest to the ICESat-2 mission currently in development by NASA. MABEL used a multi-beam photon counting technique to measure elevation and surface brightness over sea ice, snowfields, glaciers, bare soil, water, clouds, and a few select vegetation targets during transit. MABEL flew aboard NASA's ER-2 aircraft in 15 flights, collecting over 100 hours of high-quality science data during April 2012. The MABEL data contain both laser photons and solar-reflected photons at wavelengths that allow them to pass through the spectrally narrow etalon filter. Understanding and properly modeling the solar background measured by the altimeter is critical to developing robust algorithms for elevation retrieval. The density of solar photons is indicative of the underlying reflectivity of the surface and the solar zenith angle. Hence, MABEL provides information on background reflectivity and target type in addition to elevation. This Iceland/Greenland campaign was the first concentrated MABEL deployment designed to produce data for algorithm development for ICESat-2/ATLAS, and acquire the first MABEL snow and ice data. ***(William B. Cook)***

The Airborne Cloud–Aerosol Transport System

Cloud and aerosol properties have a significant influence on the Earth's climate system. Obtaining an accurate assessment of cloud and aerosol properties and their influences on the atmospheric radiation budget remain a major challenge in understanding and predicting the climate system. The Airborne

Cloud-Aerosol Transport System (ACATS) is a lidar system that is both a Doppler lidar and a high spectral resolution lidar (HSRL). The ACATS lidar fundamentally measures the particulate backscatter (bottom), Rayleigh backscatter, and Doppler shift as a function of altitude at 532-nm wavelength. Wind speed and direction is determined from the Doppler shift, while the separation of the particulate and Rayleigh backscatter (HSRL) allows the ACATS instruments to directly retrieve profiles of extinction. ACATS test flights on the NASA ER-2 aircraft occurred in February 2012. ACATS should contribute to future space-based missions by advancing component technologies and by producing an airborne instrument directly applicable to prototyping and validation for NASA's Cloud-Aerosol Transport System (CATS), Aerosol-Cloud-Ecosystem (ACE) and 3-D Winds missions. For example, the current algorithm development for ACATS data products will be used for algorithm development of the International Space Stations (ISS) CATS instrument. ***(John E. Yorks and Matthew J. McGill)***

Simulating Extreme Rainfall using the NASA Unified Weather Research and Forecasting Model

Typhoon Morakot hit Taiwan on the night of August 7, 2009 as a Category 1 storm and caused up to 3000 mm of rain, leading to the worst flooding there in 50 years, as well as devastating mudslides, which resulted in nearly 700 casualties. Simulations were conducted of Morakot with the NASA Unified Weather Research and Forecasting Model (NU-WRF) at high resolution (2-km inner grid spacing) to understand the development of this extreme weather event. The results indicated that the high-resolution NU-WRF is capable of simulating the tremendous rainfall (the maximum rainfall exceeded 2800 mm over a 72-h integration) observed in this case as well as the elongated rainfall pattern in the southwest-northeast direction and the heavily concentrated north-south line over southern Taiwan that was also observed. This work improved understanding of how tropical cyclones interact with the larger-scale circulation and coastal terrain to produce extreme rainfall and landslide events. This work will also provide context for the analysis of data from the 2012–2014 Hurricane and Severe Storm Sentinel (HS_3) Earth Venture-1 campaign and for future research on extreme rainfall events using future data products from the Global Precipitation Mission (GPM) set to launch in 2014. ***(Wei-Kuo Tao, Roger Shi, and Stephen Lang)***

Raman Water Vapor Lidar Cal/Val Mission within NDACC

Water vapor is the strongest greenhouse gas in the atmosphere and the most variable state parameter. It governs numerous atmospheric processes and is anticipated to increase in concentration in the atmospheric due to climate change. Water vapor in the upper troposphere and lower stratosphere (UT/LS) is particularly effective in modulating the atmospheric radiation budget. Predicting the consequences of changes in water vapor amount are of great importance to society so work is needed in monitoring these changes. The ALVICE (Atmospheric Laboratory for Validation, Interagency Collaboration, and Education) mobile laboratory has a unique suite of instrumentation for field measurements of water vapor, temperature, aerosols, and clouds. The complement of measurement systems provides information for intercomparisons and validation of other atmospheric profiles such as the Raman lidar at the University of Western Ontario. ALVICE was deployed to the University of Western Ontario field station in London, Ontario, for a field campaign, Network for the Detection of Atmospheric Composition Chance (NDACC) Cal/Val, which focused on Raman lidar measurements of UT/LS water vapor. The deployment period was May 16 to June 13, 2012 with 11 measurement nights. Comparisons of the measurements indicate modifications are needed in the UWO system. ***(David Whiteman, Demetrius Venable, and Robert Sica)***

Comparing High-resolution Precipitation Products over NW Europe

The accurate retrieval of precipitation from satellites is critical for a range of applications. Although retrievals in the Tropics are generally good, the estimation of precipitation in the extra-tropical regions is more challenging; this is primarily due to the different meteorological regimes, which are dominated by light, shallow precipitation systems. This study analyzed seven years of global, 3-hourly, 0.25° data from six satellite products, the ECMWF operational forecast model, and surface gauges. Over the tropics, the precipitation products agree well, except for the surface gauges. In the extra-tropical region above 35°N there are increasing discrepancies between the retrievals, with significant underestimation by the satellite techniques. Neglecting surface radar artifacts, the ECMWF operational forecast model provides a better representation of precipitation across all seasons. This work identifies some of the shortcomings in the current global precipitation retrieval schemes. A better knowledge of the regional performance of precipitation retrieval schemes will better target further development work. Satellite techniques are currently being refined to better identify and quantify light, mixed-phase precipitation over the extra-tropical regions. The forthcoming Global Precipitation Mission (GPM) will help to address these shortcomings through improved active (radar) and passive (imaging) sensors more capable of detecting and retrieving precipitation over such regions. ***(Chris Kidd, Peter Bauer, Joe Turk, George Huffman, Robert Joyce, Kuolin Hsu, and Daniel Braithwaite)***

Assimilating Simulated HIWRAP Doppler Velocity Data into Hurricane Forecasts

This study utilizes ensemble Kalman filter (EnKF) simulated-data experiments to analyze the potential impact of assimilating radial velocity observations with the High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP). HIWRAP is a new Doppler radar mounted on the NASA Global Hawk unmanned airborne system that flies above hurricanes and has the benefit of a 25- to 30-hr flight duration, which also permits accurate mesoscale analyses for tropical cyclones that are very far from land. Study results indicate that a Weather Research and Forecasting WRF-EnKF system is capable of accurately analyzing a hurricane using radial velocity data from HIWRAP. This is an important result, which also shows that tropical cyclone intensity change can be analyzed, thus leading to a better understanding of tropical cyclones. Data from the 2012–2014 Global Hawk Hurricane and Severe Storm Sentinel (HS_3) Earth Venture-1 campaign will offer the first opportunity to study real-time hurricane intensity change. In the future, such analyses could lead to considerable improvements in real-time tropical cyclone forecasts. Future work will also assess assimilation of multiple types of observations taken from the Global Hawks, and the resulting analyses have the potential to give significantly more insight into hurricanes than any single set of observations. ***(Jason Sippel and Scott Braun)***

New MPLNET PBL Algorithm Reveals Previously Undetected Diurnal Variability

There have been a limited number of long-term, continuous observations of the planetary boundary layer (PBL) height recorded in climatological literature despite its importance in air quality monitoring, weather forecasting, and climate modeling. The NASA MPLNET provides a valuable dataset for improving our understanding of the PBL with multiple continuously running lidar sites located around the globe. An improved boundary layer height algorithm has been developed for the MPLNET, which reveals seasonal and diurnal trends undetected by the previous method of PBL height retrieval. It is now possible to perform comparisons and validation of atmospheric climate models (e.g. GEOS-5). The new MPLNET PBL height algorithm shows more diurnal variation than the previous PBL height algorithm. The best agreement between MPLNET (new) and GEOS-5 occurs during the fall and the worst agreement occurs in the winter. Both MPLNET and GEOS-5 indicate the maximum PBL heights occur during the spring and summer seasons. The correlation coefficient of monthly maximum daytime PBL heights for MPLNET and GEOS-5 increases from 0.51 to 0.72 using the new algorithm. Similar mixing layer height climatologies will be developed at other MPLNET sites around the globe and used to evaluate PBL retrievals from atmospheric models and CALIPSO. The information gained can provide validation and improvement of atmospheric general circulation models and satellite retrievals of the PBL height. ***(Jasper Lewis, Ellsworth Welton, and Andrea Molod)***

Correcting Non-Uniform Beam Filling Effects for Spaceborne Weather Radars

Non-uniform beam filling (NUBF) occurs when gradients in the radar reflectivity are present within the field of view (FOV) of the instrument. For example, in the case of the TRMM radar, the FOV is 5 km while convective cells can be as small as 1 km. This situation can lead to significant errors in the estimation of rain parameters. For off-nadir incidence angles, Takahashi et al. (2006) showed that multiple estimates of path-integrated attenuation (PIA) can be made within the radar beam. Our work shows how these PIA estimates can be used to obtain attenuation-corrected radar reflectivities over the high-resolution columns within the beam. The method will be applied to data from the TRMM Precipitation Radar to assess its feasibility and accuracy. If successful, the method will be considered for application to the GPM dual-frequency Precipitation Radar. Effects of non-uniform beam filling can be a significant source of error in spaceborne weather radar retrievals of precipitation. This method might mitigate these errors and lead to retrievals that are more accurate. ***(Robert Meneghini and Liang Liao)***

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 I and in the material updated regularly on the Code 613 Laboratory Web site: http://atmospheres.gsfc.nasa.gov/climate/.

Key satellite observational efforts in the Laboratory include MODIS and MISR algorithm development and data analysis, SORCE solar irradiance (both total and spectral) data analysis and modeling, and TRMM and ISCCP data analysis. Leadership and participation in science and validation field campaigns provide key measurements as well as publications and presentations. Laboratory scientists serve in key leadership positions on international programs, panels, and committees; serve as project scientists on NASA missions and PI's on research studies and experiments; and make strides in many areas of science leadership, education, and outreach. Some of the Laboratory research highlights for the year 2012 are described below. These cover the following 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 fertilization of parts of the world's oceans and tropical rainforests; and, 4) Knowledge of aerosol loading is important to determine the potential yield from the green solar energy sources.

Highlights of Laboratory research activities carried out during the year are summarized below. An electronic version of the full highlight may be found on the Climate and Radiation Laboratory Web site, http://atmospheres.gsfc.nasa.gov/climate/science/index.php?year=2012.

The Darkening and Reduced Albedo of the Himalayan Snowpack by Desert Dust Deposition

The Himalayas are among the largest ice-covered regions of the Earth's surface, excluding the poles, and their glaciers are a source of major rivers in Asia that serve a large population base downstream. Recent studies have shown that climate warming accelerated snowmelt over the elevated Himalayas as well as perturbations to the Asian summer monsoon rainfall, is due partly to enhanced absorption of solar radiation by natural and anthropogenic aerosols.

Prior to the onset of the summer monsoon, mineral dust lifts from Southwest Asian deserts and from as far as the Arabian Peninsula, is transported over South Asia on a seasonal basis. Mixed with anthropogenic pollution, mineral dust forms a widespread vertically extended brown haze lapping against the southern slopes of the Himalayas. Episodic dust plumes are also advected over the Himalayas, leading to dust-capped snow surfaces (see front cover). A study of multispectral MODIS spaceborne measurements of reflectivity over the Himalayan snow cover showed a reduction of snow albedo induced by dust deposition. Consequently, snow albedo reduction may lead to a warmer regional climate with possible impacts on the summer monsoon circulation and rainfall distribution, and therefore the overall hydrological cycle of southern and eastern Asia. ***(Ritesh Gautam, N. Christina Hsu, William K. Lau, and Teppei J. Yasunari)***

Mount Etna Plume Height and Eruption Style from MISR

The strength of volcanic eruptions is related to the fraction of volcanic ash in the plume, compared to water and sulfate particles. The elevation of the plume above the surface is also an indication of strength, as well as a key factor in predicting how long the particles will reside in the atmosphere, how far they will travel, and the magnitude of their environmental impact. Data from the NASA Earth Observing System's Multi-angle Imaging SpectroRadiometer (MISR) can monitor both of these quantities worldwide. The two-dimensional maps of height produced from MISR observations compared well in the tests, and provided much more extensive plume height information than is available from any other source. MISR has acquired more than 12 years of global observations, which are now being mined for volcanic plume eruptive style as well as injection height, greatly expanding our knowledge of global volcano environmental impacts. Continuing work includes a detailed study of particle property variations along the plumes for Iceland's Eyjafjalljökull 2010 eruptions, using the MISR research aerosol-retrieval algorithm to provide additional particle type detail beyond the standard algorithm results (Kahn et al., 2012). ***(R. Ralph Kahn)***

New AERONET Product: Cloud Optical Depth

Cloud optical depth is the most important of all cloud optical properties, and vital for any cloud-radiation parameterization. Satellites retrieve cloud optical depth but satellite methods alone cannot solve the optical depth problem. Aerosol Robotic Network (AERONET) cloud mode is the first ground-based global network for clouds. AERONET is a ground-based network designed to measure microphysical and optical properties of aerosols. In addition to measuring aerosols, a method for monitoring cloud optical properties using the Cimel™ sun photometer to take measurements of zenith radiance at 0.44 and 0.87 μm was proposed. Working in a new "cloud" mode every 15 minutes, if the Sun is blocked, the Cimel™ radiometer points straight up and takes 10 measurements with a 9-second time interval. Surface reflectance properties are updated twice a month using standard Terra and Aqua atmospherically corrected surface reflectance products. The retrieved cloud optical depth will be used not only for validation of satellite retrieved cloud properties but also for studying local climatology and the diurnal cycle not available from satellites. ***(S. Huang, A. Marshak, C. Chiu and B. Holben)***

Continual Intercomparison of Radiation Codes to Fill Critical Need

The computer codes that calculate the energy budget of solar and thermal radiation in Global Climate Models (GCMs), have to be fast in order to work efficiently in climate simulations, but the approximations used to gain execution speed lead to loss of accuracy. International efforts to evaluate the approximate schemes have taken place in the past, but they have suffered from the drawback that the accurate (but slower) standards were not themselves validated for performance. This issue was addressed in a recent effort headed by the Lab, the “Continual Intercomparison of Radiation Codes” (CIRC). CIRC’s Phase I test cases for evaluating the approximate models where based on observations where the performance of the accurate codes was verified against radiation measurements. One main finding was that the solar atmospheric absorption is still underestimated by the approximate codes (see Figure 2.3). The initiative is endorsed by international organizations such as GEWEX and the International Radiation Commission. For more info: http://circ.gsfc.nasa.gov. ***(Lazaros Oreopoulos)***

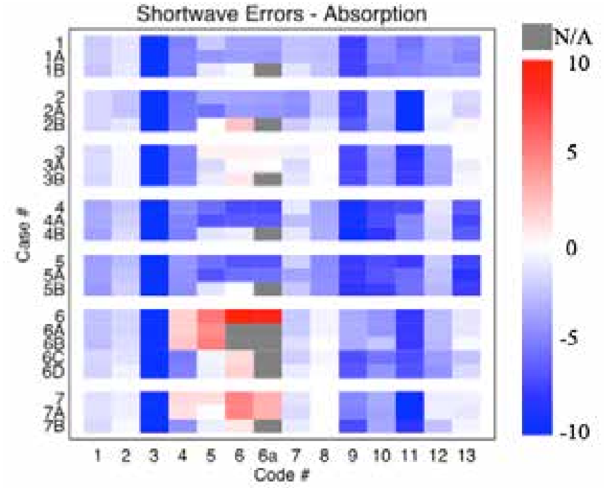

Figure 2.3: Percentage errors committed by radiative transfer (RT) codes (identified only by their index no from 1 to 13) when calculating solar atmospheric absorption for CIRC *Phase I cases. The “A” and “B” indicate simpler version of the main cases 1 through 7. Blue indicates underestimates.*

Online Calculator of Atmospheric 3D Radiative Transfer

The Intercomparison of 3D Radiation Codes (I3RC) project sponsored the development of a community model of 3D radiative transfer. This model has now been expanded to create the first online calculator of atmospheric 3D radiative processes. The calculator offers researchers, students, and the public a simple way to perform quick simulations to test new hypotheses and to explore 3D radiative processes. For cloud fields specified by users, the calculator can yield the spatial distribution and scene average value of radiances, fluxes, and absorption at selected visible and near-infrared wavelengths, and it can perform 1D calculations. Since its public release in January 2012, 100 unique visitors from 15 countries have tried the calculator. The online calculator and the source code of the I3RC community model of 3D radiative transfer are available at http://i3rc.gsfc.nasa.gov/i3rcmodel. Better understanding cloud radiative effects is critical for reducing uncertainties in human impacts on climate, because much of the uncertainties stem from gaps in understanding how anthropogenic aerosols change the radiative impact of clouds. The importance of studying this issue is highlighted in the Decadal Survey, and is a goal for current NASA missions such as Terra or Aqua and future missions such as PACE or ACE. ***(T. Várnai, S. Huang, A. Marshak, and R. Cahalan)***

The First Study to Suggest Bias Corrections in Wildfire Emissions for Global Models

Emissions of smoke particles from biomass burning (BB) impact air quality, visibility, and human health, and therefore make important contributions to aerosol climate forcing. While chemistry transport models are the major tools in studying aerosol environmental impacts, simulations of BB emissions in these models strongly depend on the inventories that provide emission source locations and strengths. One way to constrain emission estimates in the model is to use aerosol observations. A detailed study was performed with 13 global biomass burning emission estimates. Each of the 13 emission estimates were used as inputs to the global aerosol model, GOCART. The simulated aerosol optical depth (AOD) was compared to AOD measured from MODIS for 124 fire cases around the globe. The comparisons revealed spatial regional biases in each emission inventory. This is the first study to comprehensively compare several widely used BB aerosol emission inventories on several scales, providing insight into possible sources of discrepancies, and suggesting an approach to correcting regional biases and using satellite-measured AOD to constrain strength of individual fire sources. This work provides a reference for both emission inventory developers and modelers who use these estimates. ***(Mariya M. Petrenko, Ralph Kahn, and Mian Chin)***

Tornado and Hailstorm Behavior for 2011 Consistent with Cycles Observed in Earlier Years

Two recent papers (Rosenfeld and Bell 2011; and Bell et al. 2008) contained figures showing the day of the week with the highest likelihood of hailstorms, tornadoes, and rainfall based on estimates from a multi-satellite system including TRMM. Data was collected for hailstorms and tornadoes each summer during 1995–2009 and for rainfall during 1998–2006. There is a clear tendency for storms to occur on weekdays—particularly hailstorms and rainfall; there are many more hailstorms and rain events than tornados so, consequently, the statistics for hailstorms and rainfall are clearer. This study reinforces and extends the conclusions reached in earlier studies using TRMM that showed that both rainfall area and rain intensity increase in the middle of the week over the southeastern United States during the summertime. These changes, when averaged over 15 years of data, have high statistical significance. If the theory for the changes observed in these averages is correct, then human pollution can change weather in profound ways that are entirely distinct from "greenhouse warming." Current weather forecast models do not include the effects of changing aerosol pollution, partly because it is not well observed. Weather forecasts are therefore not yet capable of warning us of changes in storm intensities caused by different pollution levels. ***(Thomas L. Bell)***

Dust's Direct Radiative Effects: A Longwave Assessment

Studies have shown that the longwave (LW) direct aerosol radiative effects (DARE) of dust can significantly impact the energetics of our atmosphere, which represents an important component in the study of regional climate variation. An on-going effort to complete a global assessment of the LW DARE of dust for major source regions, worldwide, is underway using NASA SMARTLabs measurements. Results from the 2008 Asian Monsoon Years (AMY) field campaign are compared with those found from the 2006 NASA African Monsoon Multidisciplinary Activities (NAMMA) study. The former is representative of Asian dust at Zhangye, China, a semi-arid region between the Taklimakan and Gobi deserts while the latter characterizes transported Saharan dust at Sal Island, Cape Verde, along the west coast of Africa. The surface DARE of dust at Zhangye was found to be approximately a factor of two larger. This stems from differences in the environmental and surface conditions between the two sites. The IR radiative effects of dust aerosols over desert land sites, where hotter surfaces emit more thermal energy, can interact more readily with larger-sized particles near the source region. These radiative effects likely play an important role in the regional changes of surface temperatures and in the distribution of moisture, which can therefore be a key component in regional climate variation. ***(R.A. Hansell)***

How Tropical Cloud Regimes Contribute to the Global Water Budget

In order to understand the water budget of the planet it is important to measure the rainfall distribution. We can now achieve relatively good rainfall estimates from satellites over almost the entire planet. Measuring only rainfall amounts is however not enough to understand the underlying physical processes determining where, when, and how much rainfall occurs. We must also observe and measure other atmospheric characteristics related to rainfall, such as cloud properties.

We have proposed a method to help us better understand what cloud regimes the precipitation of the extended tropical region originates from. Tropical precipitation can be "mapped" by weather state by combining different satellite measurements targeted to rainfall and joint cloud optical thickness/cloud top height distributions. We found that about half of the total rainfall in the tropics comes from one particular type of cloud mixture, associated with deep storm systems. Since clouds are the most prominent regulators of radiation and precipitation, the connections between precipitation, radiation, and the state of the atmosphere as a function of cloud regime using a weather state framework should be further explored. The results may be used to investigate whether climate models partition precipitation in accordance with observations and, therefore, indirectly assess whether predictions of future precipitation in a changed climate can be trusted. ***(Dongmin Lee and Lazaros Oreopoulos)***

Multi-Sensor Evaluation of Aerosol Retrievals Shows Large Errors due to Multiple Aerosol Layers

Atmospheric aerosols exert a considerable impact on air quality, the hydrological cycle, and climate, and represent the greatest uncertainty in climate research. Satellite sensors routinely measure aerosols. However, the discrepancies and differences existing between the sensors and their aerosol products prevent the utilization of these resources to their full potential. The Multi-sensor Aerosol Products Sampling System (MAPSS) was developed to bridge this gap. MAPSS consistently samples spaceborne aerosol products over global Aerosol Robotic Network (AERONET) ground-based locations and generates the relevant statistics. Since the AERONET data are carefully inspected and quality-assured, they provide a suitable reference for integrated characterization of the spaceborne aerosol products. The simultaneous comparison of aerosol optical depth (AOD) retrieval from multiple satellite sensors over Dakar, Senegal, against corresponding AERONET observations highlights intrinsic differences and trade-offs that exist between the aerosol products. It was observed that AOD differences are higher in the presence of multiple aerosol layers. In part, this difference can be explained by the possibility that multiple layers in a column can indicate multiple aerosol types and a multimodal size distribution. Studies based on the MAPSS framework aim at identifying and quantifying uncertainties associated with aerosol retrievals from spaceborne sensors with the goal of improving and eventually unifying these products in a coherent manner, thereby reducing the overall uncertainty associated with aerosol forcing calculations required for predicting future climate. ***(Maksym Petrenko and Charles Ichoku)***

Above-Cloud Absorbing Aerosol Effects and Direct Radiative Forcing

Aerosols remain a poorly constrained component of the Earth's atmosphere. Aerosols such as smoke strongly absorb solar radiation, particularly at ultraviolet and visible/near-infrared (VIS/NIR) wavelengths, and their presence above clouds can have considerable implications. In clear, cloud-free skies, aerosols have previously been shown to have a negative direct aerosol radiative forcing (DARF), i.e. a cooling effect, because they act primarily as a scattering layer. Absorbing aerosols overlying bright clouds, however, can have positive DARF, i.e. a warming effect, because their absorption is enhanced by increased reflection by the underlying clouds. This above-cloud absorption can also cause biases in estimates of the underlying cloud properties derived from satellite observations, specifically for passive retrieval techniques that rely on measurements of reflected solar radiation at VIS/NIR wavelengths. MODIS data from southeast Atlantic Ocean during August and September was studied, focusing on where smoke from extensive agricultural burning in Africa was persistently transported westward over low-altitude marine boundary layer clouds. The strength of the above-cloud aerosol absorption was estimated using aerosol optical depth (AOD) from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on CALIPSO. Using this information to produce new unbiased MODIS cloud retrievals, increases were found in both the mean cloud optical thickness (COT) and the effective particle radius, r_e. Bias-adjusted cloud retrievals can therefore yield better estimates of the above-cloud DARF of absorbing aerosols. ***(Kerry Meyer, Steve Platnick, Lazaros Oreopoulos, and Dongmin Lee)***

A Novel Atmospheric Correction for Better Aerosol Retrievals

The Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm makes aerosol retrievals from MODIS data at 1km resolution providing information about the fine scale aerosol variability. This information is required in different applications such as urban air quality analysis, aerosol source identification etc. The quality of high resolution aerosol data is directly linked to the quality of cloud mask. Often, bright smoke plumes from strong fires are masked as clouds while presenting most interest for the aerosol analysis. We have developed a “smoke” test to reliably discriminate biomass burning aerosols from clouds based on MODIS data [Lyapustin et al., 2012]. This test relies on a relative increase of aerosol absorption at MODIS wavelength 0.412 mm as compared to 0.47-0.67 mm region due to multiple scattering and enhanced absorption by organic carbon released during combustion [e.g., Russell et al., 2010]. This general principle has been successfully used in the OMI detection of absorbing aerosols based on UV measurements [Torres et al., 2007]. Here, for the 1st time we show a reliable discrimination of absorbing aerosols from the visible measurements and aerosol type classification capability from MODIS, as shown by the “Smoke Mask.” ***(Alexei Lyapustin)***

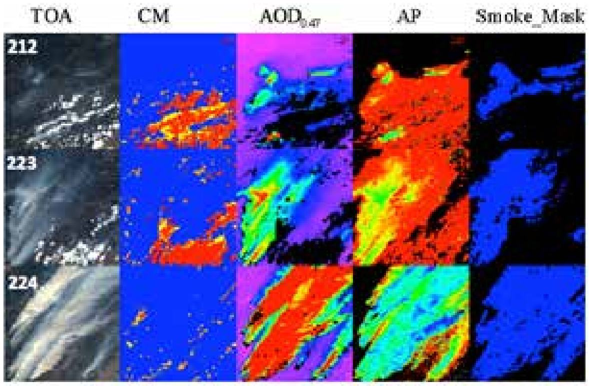

Figure 2.4: MAIAC *performance for case of forest wildfires the Rocky Mountains for a (150 km)^2 area. The images show* MODIS *Aqua* RGB *images (*TOA*), the* MAIAC *cloud mask (CM), aerosol optical depth (*$\mathrm{AOD}_{0.47}$*), absorption parameters (AP) and the smoke mask. CM legend: Blue – clear, Red/Yellow – cloud*

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. The Division has had a prominent satellite instrument, aircraft instrument, and modeling presence in the community. Both U.S. science teams for the EOS Aura satellite and the OMI instrument 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 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=2012.

Aura Ozone Monitoring Instrument Sees BrO Enhancements Over the North Pole

Hypobromite (BrO) plays an important role in tropospheric ozone chemistry and the resulting oxidation capacity of the polar boundary layer. Ground- and satellite-based data, primarily from remote sensing, has long indicated that numerous areas with large enhancements of BrO, were thought to be occurring near the surface, and researchers have hypothesized that bromine is released from blowing snow. The enhancements were linked to events of severe ozone depletion also near the surface because bromine radicals catalytically destroy ozone. One of the objectives of the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) field campaign was to fly into these regions and analyze the chemical composition of the air. When the aircraft were guided to the BrO "hot-spot" areas using satellite data, researchers were very surprised to find neither BrO enhancements nor ozone depletions. Salawitch et al. (GRL, 2010) showed that much of the BrO seen by satellites in these hot-spot areas was, in fact, due to compressed BrO in the stratosphere. This study showed for the first time a rapid activation of bromine chemistry at high temporal resolution, and gives further weight to the hypothesis that there is a tropospheric source of bromine. The future NASA Decadal Survey mission that could measure Arctic BrO is the tier 3 GACM. ***(Sunny Choi and Joanna Joiner)***

Aura/OMI Measurements Show Enhancements in NO_2 and SO_2 Over the Canadian Oil Sands

Data from the Ozone Monitoring Instrument (OMI) show distinct enhancements in nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) over a region of surface mining in the Canadian oil sands. The oil sands are located in the north-east corner of the province of Alberta, Canada and contain the second largest global reserve, after Saudi Arabia). It is expected that oil production will double and annual capital investments will reach $20B by 2020, further highlighting the need for monitoring pollution in this region. The study's results make use of improved mapping techniques that are able to resolve detail down to 10 km. This is a first study of the abundance of NO_2 and SO_2 over the Canadian oil sands, based on UV/visible nadir-viewing satellite instruments. A trend in the mass of the NO_2 enhancement—the quantity most representative of NO_2 emissions—found 10.4±3.5% per year (2005–2010) resulting from increases in both the maximum pollution levels and the total area of the enhancement. This highlights the importance of satellite observations in providing a macroscopic or comprehensive view. The Geostationary Coastal and Air Pollution Events (GEO-CAPE) tier 2 mission is planned to launch after 2020. It will allow more frequent monitoring of anthropogenic NO_2 and SO_2 pollution over North America, including the oil sands region. ***(Nickolay Krotkov and Chris McLinden)***

First Balloon Profile Measurements of SO_2 for Validation of OMI Retrievals

SO_2 is both a significant pollutant in urban regions and an important trace gas emitted by volcanoes around the world with importance both to human health and to the natural environment. Since we began making regular ozone soundings in Costa Rica (Selkirk et al, 2010), numerous satellite ozone profiles have shown deep notches below 5 km. We speculated that these were due to interference in the ozone measurement from SO_2 emitted from Turrialba, an active volcano 35 km ENE of our launch site in San José. To test this, we launched a dual ozonesonde payload and were able to detect a 15 ppbv layer of SO_2 just below 4 km as well as a lower layer about 500 m above the surface. While the lower layer is likely due to urban pollution, trajectories showed that the source of the upper layer was very likely to have been the volcano. Satellite retrievals are sensitive to SO_2's vertical structure, hence the importance of in situ profiling. OMI will continue monitoring anthropogenic and natural volcanic SO_2 pollution sources from space to detect trends in this important pollutant and aerosol precursor to provide an overlap with recently launched Ozone Monitoring and Profiling Suite (OMPS) on the U.S. Next generation weather satellite Suomi-NPP. ***(Henry B. Selkirk, Gary Morris, Jorge Andrés Diaz, Nickolay Krotkov and Holger Vömel)***

The Response of Ozone and Nitrogen Dioxide to the Eruption of Mt. Pinatubo

On June 15, 1991 the Mt. Pinatubo eruption produced increased aerosols in the lower stratosphere by up to two orders of magnitude. Pinatubo aerosols were transported throughout the stratosphere, where reactions on their surfaces altered stratospheric composition at middle latitudes. Observations revealed the expected depletion of NO_2 in both hemispheres, depletion of O_3 in northern midlatitudes, and surprising O_3 increases at southern midlatitudes. The lack of ozone depletion at southern midlatitudes after the eruption of Mt. Pinatubo has been a long-standing problem. Models including only the volcanic perturbation to the chemistry simulate significant ozone depletion. We used the Goddard Earth Observing System chemistry-climate model (GEOSCCM) to quantify the changes in composition due to Pinatubo aerosols Our study showed that an increase of the aerosol layer might significantly affect ozone not only through chemical mechanism, but also through heating-induced changes of the stratospheric dynamics.

Recent observations have reported an increase of the stratospheric aerosol layer. A study based on CALIPSO data attributes such increase to a series of small, volcanic eruptions, but there might be an additional contribution from increasing tropospheric emissions. Long-term observations of the stratospheric aerosol layer are required to detect trends and identify the sources of such changes. ***(Valentina Aquila, Luke D. Oman, Richard S. Stolarski, Anne R. Douglass, and Paul. A Newman)***

New and Improved Global Measurements of Fluorescence from Space

Remote sensing of terrestrial vegetation fluorescence from space is of interest because it can potentially provide global coverage of the functional status of vegetation. For example, fluorescence observations may provide a means to detect vegetation stress before chlorophyll reductions take place. Although there have been many measurements of fluorescence from ground- and airborne-based instruments, there has been scant information available from satellites until our initial work with GOSAT.

In this work, we use high-spectral resolution data GOSAT of the strong potassium (K) I solar Fraunhofer line near 770 nm and other solar lines near 758 nm to derive chlorophyll fluorescence and related parameters at those wavelengths. We also examined the filling-in of the Ca II line at 866 nm with SCIAMACHY. We developed and employed a general state-of-the-art method to both GOSAT and SCIAMACHY data that is able to account for complex temporally- and spatially-varying instrumental artifacts. Our work shows that potentially lower-cost instrumentation with moderate spectral resolution may have the ability to derive fluorescence information from aircraft and ground (and possibly from space) with a relatively simple algorithm (i.e., complex atmospheric correction is unnecessary). There is currently no Decadal Survey mission specifically designed to measure fluorescence. ***(Joanna Joiner, Yasuko Yoshida, Alexander Vasilkov, Yukio Yoshida, Akihiko Kuze, Petya Campbell, and Elizabeth Middleton)***

Simulation of the Effects of Bay Breeze Circulations on Air Quality during the Maryland DISCOVER-AQ Mission

Bay breezes magnify air pollution events by causing near-surface air pollutants to accumulate to unhealthy levels where the bay breeze converges with the larger-scale flow. We studied a Chesapeake Bay breeze event on July 11, 2011 to investigate how this local scale circulation pattern impacted surface air quality using surface and aircraft observations obtained during the Maryland DISCOVER-AQ field campaign and model simulations using the WRF meteorological and CMAQ air quality models. The bay breeze was initiated on the western coastline of the bay due to a strong temperature gradient between the relatively warm land and cool water surfaces. The bay breeze penetrated inland throughout the day. Strong surface convergence caused pollutant concentrations to accumulate in a localized area—at the bay breeze convergence zone. Strong vertical mixing at the bay breeze convergence zone allowed surface pollutants to be transported to the top of the boundary layer where they were horizontally advected toward a region with a shallower planetary boundary layer in northeastern Maryland. The pollutants aloft were transported out of the boundary layer and into the free troposphere. As the pollutants entered the free troposphere, they gained longer chemical lifetimes. In addition, they became susceptible to long-range transport and capable of impacting surface air quality far downwind after subsiding back down into the planetary boundary layer. ***(Christopher Loughner, ESSIC and Kenneth Pickering)***

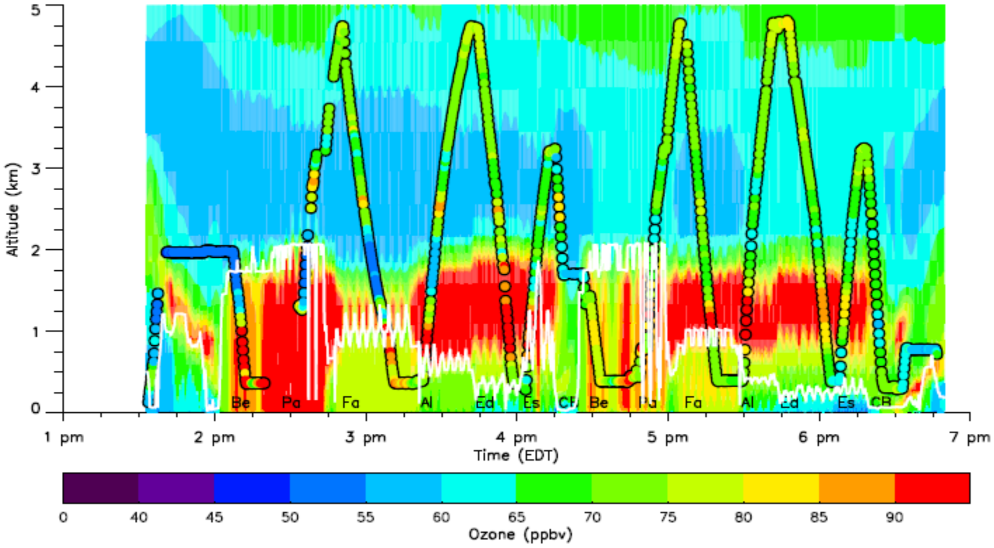

Figure 2.5: CMAQ *simulated (background) and observed (overlaid circles) ozone concentrations along a flight track on July 11, 2011. The observations were made onboard the* NASA *P-3B aircraft. The white line shows the location of the top of the boundary layer as calculated by the* WRF *model. The black letters at the bottom of the figure stand for the aircraft spiral locations: "Be" Beltsville; "Pa" Padonia; "Fa" Fair Hill; "Al" Aldino; "Ed" Edgewood; "Es"Essex; and "CB" Chesapeake Bay.*

NASA's Aura Satellite Illuminates the Signature of ENSO in Lower Atmospheric Ozone

The El Niño Southern Oscillation (ENSO) is the dominant mode of tropical variability on inter-annual timescales. It is well known to have significant influence on the Walker Circulation in the tropical Pacific. Large pertñurbations to the circulation as well as resulting changes in water vapor can change ozone concentrations in the lower atmosphere. The largest changes in ozone from ENSO are seen near the tropopause, which is a particularly sensitive region of the climate system. The response of tropospheric to lower stratospheric ozone to ENSO was derived using measurements from the Microwave Limb Sounder (MLS) and Tropospheric Emission Spectrometer (TES) onboard NASA's Aura satellite. Changes as large as -20%/K were found over the tropical Pacific near the tropopause and increases of 4%/K to 8%/K were seen in the midlatitude Pacific near the tropopause and throughout much of the troposphere over Indonesia and the Indian Ocean. The typical range of the Niño 3.4 Index is about 3 K from a moderate La Niña to a moderate El Niño. Observations of the ozone sensitivity could provide a useful way to evaluate the representation of processes such as ENSO in chemistry-climate models. ***(Luke Oman, Anne Douglass, Jerry Ziemke, and Jose Rodriguez)***

An Unexpected Atmospheric Response to the 11-Year Solar Cycle

The solar forcing of climate is presently thought to be an order of magnitude smaller than anthropogenic factors. A study looked at how the atmosphere responded to the 11-year solar cycle using two, state-of-the-art chemistry–climate models (CCMs): the 3D GEOSCCM and the GSFC 2D-coupled model. The models were compared and contrasted on how the model atmosphere responds to both the long-accepted solar cycle typically used in climate projections, developed at the Naval Research Laboratory (NRL), and the solar cycle inferred from NASA's SORCE satellite mission. Several significant scientific conclusions were drawn: (1) significantly different responses of the middle atmosphere are predicted for SORCE-derived solar flux changes in the ultraviolet compared to traditional (NRL)-derived solar cycle variability, (2) coupled chemistry is required to accurately model the temperature response, and (3) the anti-phase ozone response (with respect to total solar irradiance) is explained by the mostly linear combination of the solar cycle in difference solar flux wavelength regions. This work is directly related to the ongoing SORCE mission as well as NASA's planned TSI Calibration Transfer Experiment (TCTE) and the Total and Spectral Solar Irradiance Sensor (TSIS) instruments on JPSS. ***(William H. Swartz, R. S. Stolarski, Luke D. Oman, Eric L. Fleming, and Charles H. Jackman)***

Vertical Transport of Pollution by Thunderstorms

Updrafts in thunderstorms entrain pollutants like formaldehyde (CH_2O) from the boundary layer of the earth's surface and transport them to the upper atmosphere. The pollutants lofted by these storms can alter ozone and clouds that impact the Earth's climate. Quantifying transport of short-lived species in convective events and studying the chemical, temporal, and spatial evolution in their vicinity is a high-priority objective laid out by the Decadal Survey. Of particular interest is the role of short-lived species that are emitted from anthropogenic and biogenic sources in the planetary boundary layer. NASA joined with the National Center for Atmospheric Research (NCAR) in the Deep Convective Clouds and Chemistry (DC_3) campaign to study the chemistry of thunderstorms over the central United States. NASA provided the new GSFC In situ Airborne Formaldehyde (ISAF) instrument that measures CH_2O. These experiments show that 40% of the CH_2O in the boundary layer is transported to the upper atmosphere. This quantity is surprisingly high, because CH_2O is soluble in water and is thought to be removed by wet deposition. The sampling of the outflow as it ages shows how CH_2O is removed by ultraviolet light, a process that leads to the production of ozone. These types of measurements will be used to quantify the role of anthropogenic and biogenic emissions on ozone photochemistry and cloud microphysics in the upper troposphere and lower stratosphere. ***(Thomas F. Hanisco)***

MODIS Characterization of Absorbing Aerosols Above the Cloud Deck

Particulate matter suspended in the atmosphere, called aerosols, scatter as well absorb the incoming solar light and thus play a vital role in determining the Earth's radiation balance and climate change. Carbonaceous aerosols such as those generated from biomass burning activities and wind-blown dust particles are major absorbing types of aerosols found in the atmosphere. They can lead to cooling or warming of the Earth's environment. When located above the cloud deck, the absorbing aerosols heat the atmosphere and reduce the light measured by satellite. This effect is called "cloud darkening," and it can be seen in satellite images. Quantification of aerosol load above clouds has been a challenge for the remote-sensing community. We have used the spectral reflectance data collected by the EOS Moderate Resolution Imaging Spectroradiometer (MODIS) to quantify the optical depth of above-cloud aerosols. The technique uses color-ratio information measured by MODIS to deduce aerosol load and cloud brightness simultaneously. The results from the research will provide much needed information on the aerosol and cloud optical properties for the overlap regions, which are critical in determining the aerosol impact on the Earth's radiation balance and thus on climate change. The satellite-based detection and quantification of aerosols above cloud is a huge leap in the ongoing era of the remote sensing. ***(Hiren Jethva, Omar Torres, P. K. Bhartia and Lorraine A. Remer)***

A New Fast Simulator for Cloud Optical Centroid Pressure

The cloud optical centroid pressure (OCP) can be thought of as the mean pressure (inside a cloud) reached by solar light. The OCP is needed for trace-gas retrievals (e.g., total column ozone, NO_2, SO_2) that use reflected solar light. The OCP is distinct from the cloud-top pressure (derived from thermal IR measurements); the two measurements are complimentary and can be used to detect multi-layered clouds. Full simulators for cloud OCP require expensive radiative transfer calculations (approximately one day for 1,000 cloud profiles). Our simulator transforms cloud optical extinction profiles into cloud OCP, as retrieved with the Aura Ozone Monitoring Instrument (OMI), and does this in less than one second. The A-train provides a unique opportunity to evaluate cloud OCP pressures owing to the combination of MODIS radiances and CloudSat radar reflectivities that can be combined to produce an estimate of the cloud optical extinction profile. The most detailed evaluation of cloud OCPs to date shows generally good agreement when we compared cloud OCPs derived from OMI with near-coincident CloudSat/MODIS measurements run through the fast simulator. Some differences have been traced back to unidentified snow/ice or low clouds missed by CloudSat (as verified by CALIPSO also in the A-train) and biases in the fast simulator as well as in the retrievals. This study demonstrates that cloud OCPs derived independently from two different approaches provide similar results and compare well with values predicted by CloudSat and MODIS. ***(Joanna Joiner, Alexander Vasilkov, Pawan Gupta, P. K. Bhartia, Pepijn Veefkind, Maarten Sneep, Johan de Haan, Igor Polosky, and Robert Spurr)***

Well-Calibrated Ground Stations Help Mitigate against Upcoming Gap in Global Ozone Profile Measurements

Recent work (Steinbrecht et al., 2009) has illustrated the capability for a few well-calibrated ground-based stations making frequent measurements to reproduce the long-term global behavior in both ozone and temperature as measured by satellite instrumentation. This ability is especially important with a looming gap in satellite measured ozone profiles. Goddard scientists have developed a mobile, ground-based lidar instrument for the validation of NDACC lidar instrumentation at NDACC sites around the world (McGee, 1995). The Stratospheric Ozone (STROZ) lidar simultaneously measures ozone, temperature, aerosol, and water vapor profiles. This lidar, as part of the NDACC Validation Protocol has validated all five of the stations used in the Steinbrecht study (four of them multiple times). High-quality measurements require periodic and ongoing validation if long-term changes are to be detected. The Goddard lidar has provided an important and independent way to tie ozone and temperature profile measurements together across a large, quasi-global network. This is especially important since the work of Steinbrecht shows that in the absence of global satellite profile measurements, ground-based ozone profiles can provide a way to maintain the long-term data record, given that the instruments are validated periodically, particularly after instrumental changes. ***(Thomas J. McGee, L. Twigg, G. Sumnicht, and D. Swart)***

Long-term Ozone Measurements: Monitoring the Antarctic Ozone Hole

Scientists in the Earth Sciences Division at Goddard have been leaders in monitoring the Earth's ozone layer since the launch of BUV on Nimbus 4 in 1970. This was followed by the very successful TOMS (Total Ozone Mapping Spectrometer) and SBUV (Solar Backscatter Ultraviolet) instruments on Nimbus 7. As concern grew about depletion of the ozone layer because of the release of CFCs into the atmosphere, data from these instruments were used to track the long term change in ozone. Ozone measurement has been an important priority in the Earth Sciences Division ever since. The TOMS instrument on Nimbus 7 (1978–1993) was followed by TOMS instruments on Meteor 3 (1991–1994) and on Earth Probe (1996-2005), and the OMI instrument (2004-present) on Aura. We now have a 40-year record of ozone measured by NASA instruments.

No one predicted the sharp decline in ozone over Antarctica each October that was observed in the early 1980's, the well-known ozone hole. While credit goes to British scientists for discovery of the ozone hole, NASA scientists were simultaneously trying to understand the unusually low ozone measured by TOMS in their October 1982 data. Once the significance of the ozone hole was understood, congress charged NASA and NOAA with monitoring the ozone layer.

Figure 2.6 shows the maximum area of the ozone hole each year. The size of the ozone hole increased each year throughout the 1980's, reaching a maximum around the year 2000. Superimposed on this overall trend are large year-to-year variations. Unusual atmospheric dynamics in 2002, for example, led to early break-up of the polar vortex and a small maximum area of the ozone hole.

For the first time this year, the ozone hole was observed by an ozone-monitoring instrument on the Suomi NPP (National Polar-orbiting Partnership) satellite. Figure 2.7 shows the ozone hole on September 21, 2012. NPP is a bridging mission leading to the next-generation polar-orbiting environmental satellites called the Joint Polar Satellite System, which will extend ozone monitoring into the 2030s. ***(Richard McPeters)***

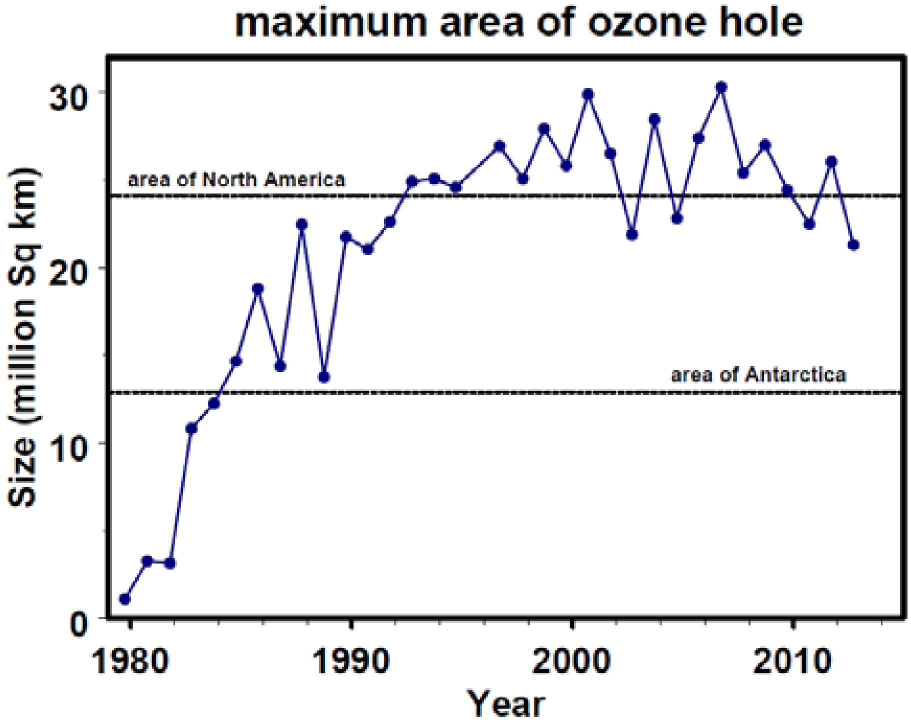

Figure 2.6: This graph shows the variations in the area of the ozone hole from 1979 to 2012. Note that the year-to-year fluctuations are superimposed on a trend extending over the last three decades.

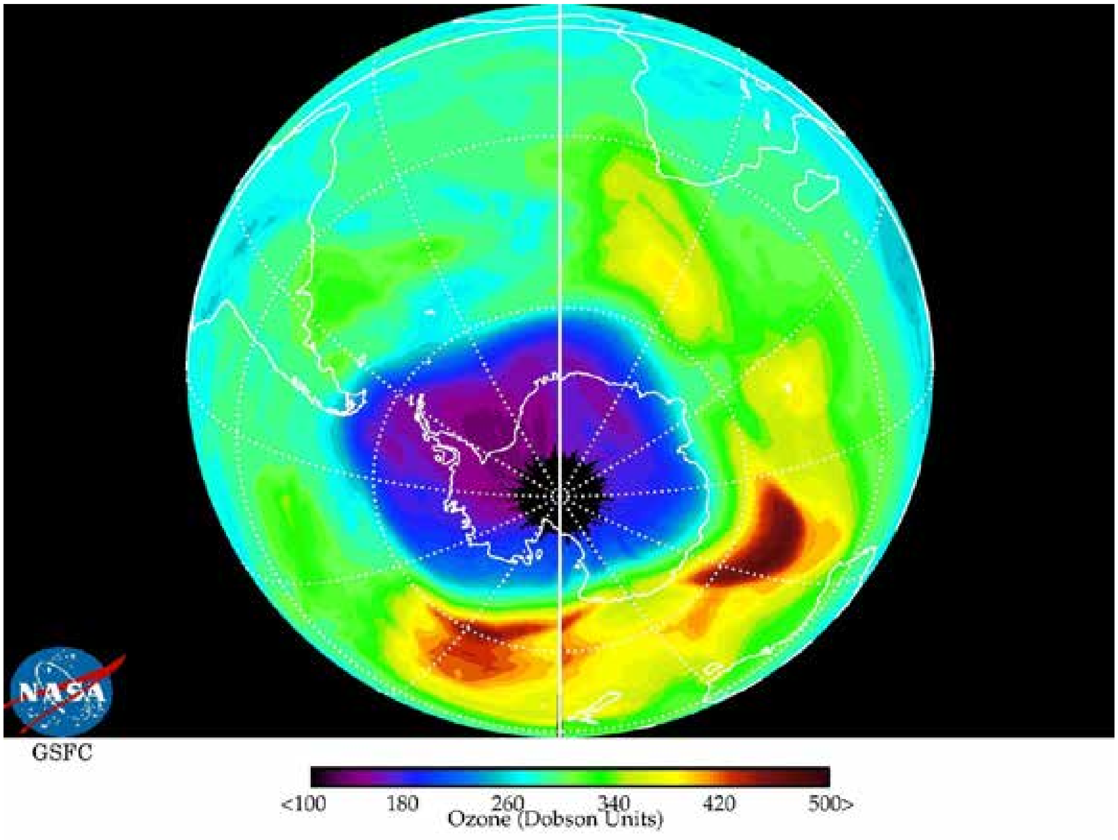

Figure 2.7: This image shows the Antarctic ozone hole for September 21, 2012, as measured by the new OMPS *instrument on Suomi* NPP.

2.4. Wallops Field Support Office

The Wallops Field Support Office supports the Earth science research activities of Code 600 scientists at the Wallops Flight Facility. The Office also conceives, builds, tests, and operates research sensors and instruments, 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. The Office provided instrumentation and scientific research expertise to several NASA missions and field efforts in 2012.

Wallops Precipitation Research Facility

Based at Wallops Flight Facility (WFF), during 2012 the Precipitation Research Facility (WWF-PRF) was 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 measurements of precipitation physical characteristics in the context of testing and improving Tropical Rainfall Measurement Mission (TRMM) and Global Precipitation Measurement Mission (GPM) precipitation remote sensing algorithms. The PRF instrument assets include: the NASA

S-band dual-polarimetric radar (NPOL); the TOGA C-band radar; 6 2D-video disdrometers (2DVDs); 24 Parsivel disdrometers; over 100 tipping bucket rain gauges, including a high-density autonomous network deployed on the Delmarva Peninsula and a dual-pit gauge reference site located at WFF; 4 Micro Rain radars; 9 Pluvio weighing gauges; 7 Yankee Environmental Hotplate sensors; and 5 Snow VideoImagers. When not deployed in remote field campaigns, PRF's instruments are stationed in a network around the WFF region to test instrumentation performance, validate new sampling methodologies, conduct new PMM science, and maintain instrument readiness for future deployments. For further information see the PRF Web site: http://wallops-prf.gsfc.nasa.gov/ or contact: walt.petersen@nasa.gov. (***Walt Petersen and David Wolff***)

NASA Polarimetric Radar

The NASA Polarimetric Radar (NPOL) is a research grade, S-band, scanning dual-polarimetric radar. It was first developed in 2001 and later upgraded in 2011 is used to make accurate volumetric measurements of precipitation including rainfall rate, particle size distributions, water contents and precipitation type. The NPOL's flexible scanning capability (e.g., scanning in plan-position sector volume, range-height, or vertically-pointing modes) allow maximum temporal and spatial sampling of precipitation processes. These measurements, and the physical process information provided, are fundamental to remote sensing-based retrievals of precipitation made from the ground and from space. GPM GV Science Manager Walt Petersen gave an interview to WBOC-TV describing the NPOL radar, its use for GPM precipitation algorithm validation, and a general overview of polarimetric radar use in operational weather decision support applications. For further information, please contact: walt.petersen@nasa.gov or david.b.wolff@nasa.gov. ***(Walt Petersen and David Wolff)***

Precipitation Video Imager-II

The WFF-PRF developed a new instrument, the Precipitation Video Imager-II (PVI-II). The PVI-II is a high-speed imaging system that records high-resolution images of liquid and frozen precipitation particles at camera frame rates of approximately 400 fps. The image data for each precipitation particle is fed into tracking software and stored in a database. Integration of the particles in the database subsequently enables retrieval of volumetric distributions of precipitation fall-velocities, sizes, and types (e.g., discriminating between rain, snow and mixed-phase precipitation). The PVI-II was tested at WFF during several snow events and appears to be particularly well-suited for the Global Precipitation Measurement Mission (GPM) Ground Validation (GV) activities in cold climates. Note that the PVI-II evolved from an earlier generation PVI that currently is used by the WFF-PRF to support the GPM GV program in both Finland (Finnish Meteorological Institute) and Canada (Environment Canada). For further information, please contact: francis.l.bliven@nasa.gov. ***(Larry Bliven, Walt Petersen, and David Wolff)***

SMART/ACHIEVE

During the week of July 16, 2012, a field collaboration exercise was conducted at WWF. Teams lead by Si-Chee Tsay and Colby S. Goodloe, respectively, collaborated closely with Walt A. Petersen, Head of Code 610W, in addition to many supporting scientists and engineers from university and private sector organizations as well as visiting college interns. A W-band (94 GHz) and an X-band (10 GHz) radar, both operating in NASA's SMARTLabs' ACHIEVE mobile laboratory (http://smartlabs.gsfc.nasa.gov), participated in the calibration. Calibration targets were positioned off of a 150-ft water tower at WFF, atop a 45-ft mobile telescoping tower, or from a tethered aerostat approximately 500 ft above the WFF Airfield. These targets were located and scanned successfully by ACHIEVE radars and followed by ongoing analyses of the calibration datasets are. The exercise will help streamline future campaigns elsewhere, improve accuracy of data collected from the field, and advance knowledge of aerosol-cloud interactions. For further information, please contact: walt.petersen@nasa.gov or si-chee.tsay-1@nasa.gov). ***(Walt Petersen and Si-Chee Tsay)***

Airborne Topographic Mapper

The Airborne Topographic Mapper (ATM) lidar instruments based at NASA's WFF have provided climate change scientists with accurate (<10 cm) surface elevation measurements of polar land and sea ice on an annual basis for more than 20 years. In 2012, the WFF Airborne Topographic Mapper flew 42 missions aboard the NASA P3C aircraft over the Arctic and 17 missions onboard the DC-8 over Antarctica in support of NASA Operation Ice Bridge. For further information, please contact: william.b.krabill@nasa.gov. ***(William Krabill)***

Mini-ATM P3 Test Missions

The Mini-Airborne Topographical lidar (mini-ATM) is a smaller version of the ATM lidar instrument and was designed to measure the surface elevation of glaciers and ice caps from a small UAV platform at altitudes between 400 and 800 meters above ground level. The mini-ATM measures topography to an accuracy of ten to twenty centimeters by incorporating lidar data with measurements from global positioning system (GPS) receivers and inertial navigation system (INS) attitude sensors. In 2012, the mini-ATM was flown onboard the NASA P3 and DC_8 aircraft (during the IceBridge Antarctica operations) in a testing and validation mode. Analysis of data and instrument performance are ongoing. For further information, please contact: geoffrey.l.bland@nasa.gov or james.k.yungel@nasa.gov. ***(Geoff Bland amd Jim Yungel)***

Wallops Wave Tank Facility

As part of the final research work at the WWF Air-Sea Interaction Facility Wave Tank prior to its decommissioning, a paper titled "Water Surface Topography Retrieved from Color Images," (Koskulics et al. 2013, in press) is slated to appear in the Journal of Atmospheric and Oceanic Technology. An imaging system using a color-gradient sub-surface light source was used to reveal features of small-amplitude waves in the wind-wave tank. A nonlinear model of image formation was developed based on the geometry of refraction, spectral emission from the light source, radiative transfer through the water and surface, and camera spectral response. The high-resolution topographic data revealed small-amplitude waves spanning wavelength scales from capillary through short gravity wave regimes. The system capabilities were demonstrated in the retrieval of test surfaces, and in the case of wind-driven waves, using data collected at high spatial and temporal resolution in the wave tank. The approach of using a physical model of image formation with inverse solution methods provides an example of how surface topography can be retrieved and may be applied to data from other similar instruments. This wavelength regime has been shown to play a critical role in the transfer fluxes of heat and gases between the atmosphere and ocean in the study of climate change. The facility now ends its work at WFF, and is scheduled to move to the University of Washington Applied Physics Laboratory in Seattle later in 2013 for continued research. For further information, please contact: steven.r.long@nasa.gov. ***(Steven Long)***

AeroPods

A patent was issued for a novel instrumentation package for kites and tethered balloons, the "AeroPod". This system was used extensively for the In situ Validation and Calibration of Remotely Sensed Volcanic Emission Data and Models project (Pieri, et al.), which focused on local-scale observations of gases and particles distribution from volcanic eruptions. The 2012 field campaign at Turrialba, Costa Rica, was supported with AeroPod instrumentation including temperature, humidity, winds, and carbon dioxide sensors. Additional experiments were also conducted in support of snow-cover observations (USGS/ Selkowitz) and wildlife monitoring (Fish and Wildlife Service/Hinds, Holcomb). For further information, please contact: geoffrey.l.bland@nasa.gov. ***(Geoff Bland)***

The Remotely Operated Vehicle for Environmental Research

The Remotely Operated Vehicle for Environmental Research (ROVER) IRAD project enabled students and faculty at the University of Maryland Eastern Shore (UMES) to explore in-water measurements using a novel platform system. A prototype ROVER system was initially tested to develop training and operating procedures, and a second system was successfully built, instrumented, and operated by a student team. A multidisciplinary approach focused on specific coastal research objectives, which engaged students and faculty with engineering, aviation sciences, biology, computer science, and technology interests. For further information, please contact: geoffrey.l.bland@nasa.gov. ***(Geoff Bland and Ted Miles)***

Microspectrometer Instrument Suite

Preparations for the Marginal Ice Zone Observations and Processes Experiment "(MIZOPEX) (Maslanik, et al.) included further development of the Wallops Microspectrometer Instrument Suite (MIS). This experiment is the latest in a series of unmanned, aircraft-based missions aimed to capitalize on miniaturized instruments to explore the benefits of these new platforms, particularly for arctic research. The Wallops team developed two configurations of the MIS package, one for NASA's Ikhana (DFRC), and one for NASA's SIERRA (ARC) missions. For further information, please contact: geoffrey.l.bland@nasa.gov. ***(Geoff Bland, James Yungel, Matt Linkswiler, Kyle Krabill, Carl Shirtzinger and Ted Miles)***

Ocean Color and Phytoplankton Types

An algorithm was developed to determine phytoplankton functional types in coastal areas where the influence of atmospheric deposition of nitrogen is high in an area of high stratification. The algorithm was developed based on an inverse modeling approach applied to hyperspectral remote sensing of ocean color. The algorithm expands the number of pigments that can be retrieved and associates these pigments with phytoplankton functional types. Algorithms such as these can contribute to future NASA ocean color missions and our understanding of how climate and its taxonomic composition can influence carbon cycle dynamics and linkages. A publication describing the algorithm can be found in the *Continental Shelf Research* 55 (2013) 17–28. For further information, please contact: tiffany.moisan@nasa.gov. (***Tiffany Moisan and John Moisan)***

Ecosystem Modeling

In 2012, a project to develop a method of using genetic programming to model the microbial diversity of the ocean was jointly funded by NASA Headquarters and The Gordon and Betty Moore Foundation. This is a 3-year project to create an artificial intelligence capability that is able to evolve systems of coupled differential equations. Initial development of the code has been completed and is configured to carry out the initial "twin-experiments" necessary to validate the code's capabilities. This very abstract, large-payoff effort can potentially be used for development of other NASA science needs, such as algorithm development. For instance, an antenna on a past Mars Rover was engineered using genetic algorithm, which is a subset of genetic programming. For further information, please contact: john.r.moisan@nasa.gov. ***(John Moisan)***

Upper-Air Instrumentation Research Project

Upper-air observations have continued for the longest sustained operational ozone measuring site at the Wallops Flight Facility. Of the 55 ozonesonde flights scheduled for either "routine" weekly observations or satellite overpass support, 54 resulted in success (i.e., balloon termination altitude surpasses 13 hPa) and 4 were partially successful (i.e., balloon altitude surpasses the tropopause) flights producing vertical flight-profile data sets. Of these ascensions, 10 flights were routine observations, 41 supported the satellite A-Train (i.e., AURA, AQUA, TERRA), and 7 instruments supported the Suomi NPOESS Preparatory Project (NPP) satellite.

The Ozone Research Facility (ORF) continued in operation with the Dobson spectrophotometer, the ground-based UV radiometer (GUV-51C), and the NovaLynx WS-16 Weather Station following the end-of-year 2011 to early 2012 calibration and repair processes. The Dobson spectrophotometer operated a total of 80 "acceptable sky days" for a total of 293 total column ozone measurements. Data acquisition and management was continued for the NOAA National Geodetic Survey's Trimble NetRS GPS water vapor instrument for the Continuously Operating Reference Station (CORS) network at the Wallops Island "VAWI" site. The VAWI instrument sustained high data rate collection without interruption throughout Superstorm Sandy in late October. The radiosonde temperature sensor improvements program concluded the measurements campaign comparing thermal vacuum calibrated glass bead thermistors on the NASA/UAIRP Accurate Temperature Measuring (ATM) radiosonde against the commercially available Lockheed Martin Sippican (LMS) multiple thermistor (MTM) radiosonde fitted with the production "chip" thermistor array. A total of eight dual-instrument balloon flights were conducted at Wallops in January and February, including one day-night series. For further information contact: francis.l.bliven@nasa.gov. ***(Larry Bliven and 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 in global change during the 2020's, especially with regards to characterizing and understanding the 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. With respect to aerosol and cloud measurements, ACE is the successor to the aging A-Train satellite constellation, specifically CloudSat, CALIPSO, MODIS, POLDER (ended) and GLORY (which failed to achieve orbit). 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 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.

NASA's Goddard Space Flight Center plays a pre-eminent leadership role in developing ACE. A comprehensive report has been released to the community, including detailed science traceability matrices for each science discipline and each cross-discipline area. This report and associated briefing materials from 2011 are available at: http://acemission.gsfc.nasa.gov/.

Further maturation of mission requirements will occur in 2013, as will advances in technical readiness of the instrument concepts and algorithms in preparation for formal entry into mission formulation. For further information, contact David Starr (david.starr@nasa.gov).

3.1.1.2 GEO-CAPE

Geostationary Coastal and Air Pollution Events (GEO-CAPE) is one of the missions recommended by the National Research Council's Decadal Survey. This mission will deploy a geostationary satellite over the continental United States, which would carry out measurements of tropospheric pollutants (O_3, NO_2, SO_2, aerosols) and ocean color in coastal areas with high spatial and temporal resolution. Such resolution would allow fine mapping of pollution emission and events, which would provide a better understanding of the processes involved in pollution transformation and transport. This is a Tier-2 mission, with expected deployment after 2020. Recent mission science and cost assessment suggest that separating the ocean color and atmospheric instruments and looking for windows of opportunity to deploy some instruments in platforms already planned could best achieve.

Scientists in Codes 613 and 614 participated in several studies to better define goals and requirements for the atmospheric measurements to be made by the GEO-CAPE Decadal Survey Mission. Tasks concerning potential GEO-CAPE aerosol observations included: examining of the potential benefits of using high-temporal-resolution aerosol measurements from GEO-CAPE to improve aerosol direct radiative forcing estimates; assessing the capabilities of GEO-CAPE to retrieve aerosol extinction optical depth (AEOD) and aerosol absorption optical depth (AAOD) of boundary layer aerosols; studying the aerosol retrieval availability due to clouds at several possible instrument pixel resolutions; and assessing improvement in the estimates of wildfire impacts on surface air quality. Tasks concerning potential GEO-CAPE trace gas observations included development of a satellite pixel averaging technique for detecting SO_2 and NO_2 emission trends from point sources over the GEO-CAPE domain, analysis of current satellite (Aura/OMI) retrievals of pollution trace gases (NO_2, SO_2) in relation to sub-orbital aircraft (ACAM) and ground-based (PANDORA) measurements during the first DISCOVER-AQ field campaign, and model simulations to investigate GEO-CAPE's ability to detect and quantify the enhanced, instantaneous radiative forcing due to ozone resulting from the production of NO_x by lightning. Trace gas and aerosol profiles from regional model simulations for the DISCOVER-AQ field mission (July 2011 in Maryland) were provided to JPL to run simulated retrievals for GEO-CAPE. For further information, please contact Jose Rodriguez (jose.rodriguez@nasa.gov).

3.1.1.3 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, expected in 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 2021–2022 timeframe.

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. Bill Heaps is principal investigator for an instrument development project for a broadband laser system with Fabry-Perot detection that may be a candidate for the ASCENDS instrument. Lab members also participate on technology projects, led by the Laser Remote Sensing Laboratory, which target instrument and mission development for ASCENDS. They play 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.

3.1.1.4 Global 3D-Winds

The NRC *Decadal Survey for Earth Science* has 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 0- 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 FY2012, we made significant advances in the technological readiness of the direct-detection Doppler lidar approach leading towards space. Highlights of these advances include the September through October 2012 flights of the TWiLiTE Doppler lidar system, a technology testbed for the space-based system from NASA's high-altitude ER-2 research. 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, demonstrate the data utility of the Doppler lidar wind system. Also in FY2012 engineering work to reconfigure TWiLiTE to fly on the NASA Global Hawk as part of the Hurricane and Severe Storm Sentinel (HS_3) Earth Venture Mission was completed. Reconfiguration and initial testing of TWiLiTE on the Global Hawk is planned in the spring of 2013. 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, a space-based mission study—jointly sponsored by NASA, NOAA, and the Air Force—was 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	ACE
Jose Rodriguez/John Moisan	GEO-Cape
Randy Kawa	ASCENDS
Bruce Gentry	Global 3D-Winds

3.1.2. NASA's Planned Missions

3.1.2.1 GPM

The Global Precipitation Measurement (GPM) is an international satellite mission to provide next-generation observations of rain and snow every three hours, worldwide. NASA and the Japanese Aerospace Exploration Agency (JAXA) will launch a "Core" satellite in 2014 carrying advanced instruments that will set a new standard for precipitation measurements from space. The data they provide will be used to unify precipitation measurements made by an international network of satellites provided by partners from the United States, Japan, France, India, and the European community 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-launch precipitation retrieval algorithm development, GPM has been conducting a series of field campaigns with international and domestic partners in the past 5 years. In 2012 GPM jointly conducted the GPM Cold-season Precipitation Experiment (GCPEx) field campaign with Environment Canada, north of Toronto, Canada in January and February 2012 to support the testing and validation of remote-sensing capabilities of GPM Core sensors for falling snow precipitation. (For data and more information on GCPEx, visit: http://pmm.nasa.gov/GCPEx) GPM also deployed a suite of ground instruments in France and Italy as a part of the European Hydrological Cycle in Mediterranean Experiment (HyMeX) from August through October. GPM launched a new education Web site for GPM and TRMM at http://pmm.nasa.gov/education/. The website provides information, lesson plans, and media resources about NASA's GPM and TRMM missions. Visitors and teachers can learn about how these missions measure precipitation measurement from space and how we can use this information to explore topics of extreme weather, rain and snow characteristics, societal applications, and satellite engineering. GPM also continued Facebook postings and tweets in 2012, and has garnered more than 4100 Facebook "likes" and 1800 Twitter followers. For further information about the GPM Mission, please visit the GPM homepage at http://gpm.nasa.gov, or contact Arthur Y. Hou (arthur.y.hou@nasa.gov).

3.1.2.2 LDCM

The Landsat Data Continuity Mission (LDCM) is the successor mission to Landsat 7. Landsat satellites have continuously acquired multispectral images of the global land surface since the launch of Landsat 1 in 1972. The Landsat data archive constitutes the longest moderate-resolution record of the global land surface as viewed from space. The LDCM mission objective is to extend the ability to detect and quantitatively characterize changes on the global land surface at a scale where natural and man-made causes of change can be detected and differentiated.

The LDCM is on schedule for a February 11, 2013 (at the time of printing of this article, the satellite had launched on schedule) launch from Vandenberg Air Force Base, California. The satellite system is fully prepared to meet the scientific requirements of the mission. Both instruments in the payload, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) were rigorously calibrated and characterized in pre-launch tests. The pre-launch performance of each instrument exceeded specification in many respects. A plan to maintain calibration and monitor sensor performance is in place with the same rigor. The ground system also exceeds specifications in terms of its capacity to capture, archive, process, and distribute data from the two sensors. LDCM will be the most capable Landsat satellite ever launched with regards to data quality and quantity.

The LDCM is the eighth satellite in the Landsat series. The development of LDCM is a partnership between NASA and the U.S. Geological Survey (USGS). The NASA's Goddard Space Flight Center (GSFC) is responsible for the development of the overall mission. USGS is responsible for ground system development and will operate LDCM after launch. The LDCM satellite was built by Orbital Sciences Corporation and will accommodate two instruments, the Operational Land Imager (OLI) built by Ball Aerospace and Technologies Corporation (BATC) and the Thermal Infrared Sensor (TIRS) built by GSFC. NASA's Kennedy Space Center is responsible for the Atlas V launch vehicle. The USGS Earth Resources Observation and Science (EROS) Center will receive, archive, and distribute LDCM data.

Both the OLI and TIRS represent an evolutionary advancement in technology relative to previous Landsat sensors. All of the earlier Landsat satellites carried optical-mechanical scanners that used oscillating mirrors to sweep the cross-track field-of-view across the orbital ground paths. The LDCM sensors will both use long arrays of detectors aligned across the focal planes to view the cross-track swath. The major advantage of the long detector arrays is a substantial improvement in signal-to-noise-ratio performance leading to improved capabilities for characterizing land cover and detecting change over time. The design also presents challenges to achieving uniformity in radiometric and spectral response and to calibration across the long detector arrays. The Advanced Land Imager (ALI), flown aboard the Earth Observing-1 (EO-1) spacecraft, demonstrated the potential and challenges of this technical approach for remote imaging.

OLI will acquire data for eight visible, one near-infrared, one short-wave infrared spectral bands with a spatial resolution of 30 m, and one panchromatic band with a resolution of 30 m. Seven of the bands are comparable to the seven bands sensed by the Enhanced Thematic Mapper-Plus (ETM+) aboard Landsat 7. Two new bands are added to OLI: one blue band for sensing coastal watercolor and atmospheric aerosol attenuation, and one shortwave infrared band for sensing the presence or absence of cirrus clouds.

TIRS will collect data for two thermal infrared bands with a spatial resolution of 100 m. In comparison, the Thematic Mapper (TM) sensors on Landsat 4 and Landsat 5 collect data for one thermal band with a spatial resolution of 120 m while the Landsat 7 ETM+ collects data for one thermal band with a resolution of 60 m. The two TIRS thermal bands will facilitate atmospheric correction of the thermal data leading to more accurate retrievals of surface temperature. The TIRS focal plane employs an advanced detector technology called Quantum Well Infrared Photodetectors (QWIP's). GSFC played a prominent role in developing this technology and TIRS will be one of the first instruments to use QWIP's in space. The QWIP's focal plane requires active cooling to less than 40 K by a two-stage cryocooler that will fly as part of TIRS on the LDCM.

The fundamental LDCM operations concept is to collect, archive, process, and distribute science data in a manner consistent with the collection, archiving, processing, and distribution of science data from the Landsat 7 mission. To that end, the LDCM observatory will operate in a 716 km near-circular, near-polar, sun-synchronous orbit. The observatory will have a 16-day ground track repeat cycle with an equatorial crossing at 10:00 a.m. (+/-15 min) mean local time during the descending node of each orbit. In this orbit, the LDCM observatory will follow a sequence of fixed ground tracks (also known as paths) defined by the second Worldwide Reference System (WRS-2). WRS-2 is a path/row coordinate system used to catalog the image data acquired from the Landsat 4, 5, and 7 satellites. These three satellites have all followed the WRS-2 paths and all of the science data are referenced to this coordinate system. The LDCM science data will likewise be referenced to the WRS-2.

Similarly, the LDCM will produce data products that closely resemble the ETM+ Level 1 data products currently produced and distributed by the USGS at no cost to those requesting data. Radiometrically corrected, co-registered and terrain corrected OLI and TIRS data will be merged to create a single integrated Level-1 data product known as a Level 1T scene. The data will be resampled to provide 30-m pixels (with the exception of 15-m pixels for the panchromatic band, oriented north-up, and registered to the Universal Transverse Mercator (UTM) cartographic projection. USGS will retain the no-cost data distribution policy for LDCM data and this relatively new policy, implemented in October 2008, has resulted in an explosion of Landsat data use.

The Office of Science and Technology Policy (OSTP) declared the Landsat Program a national asset. The Landsat data archive is unmatched in quality, detail, coverage, and value. The data record is essential to studies of land cover and land use change and as such is necessary to understanding the causes and consequences of climate change. Additionally, Landsat data are used operationally for a wide range of agricultural, environmental, economic, water management, disaster recovery, and national security applications. Following the February 11, 2013 launch, the LDCM will begin to expand and improve upon the Landsat data record after the required 90-day checkout period. USGS plans to rename the satellite "Landsat 8" when they assume responsibility for operations after the checkout period. More information can be found on the internet at the following URL's: http://ldcm.gsfc.nasa.gov/ and http://www.nasa.gov/landsat.

3.1.2.3 JPSS

As background, the National Polar Orbiting Environmental Satellite System (NPOESS) was a tri-agency program between NASA and the Department of Commerce (specifically the National Oceanic and Atmospheric Administration, or NOAA), and the Department of Defense (DoD, specifically the Air Force). It was designed to merge the civil and defense weather satellite programs in order to reduce costs and provide global weather and climate coverage with improved capabilities above the current system.

The President's FY2011 budget contained a major restructuring of the NPOESS Program. Under the restructured system, NASA and NOAA will take primary responsibility for the afternoon orbit, and DoD will take primary responsibility for the early morning orbit. The agencies will continue to partner in those areas that have been successful in the past, such as a shared ground system. The NASA/NOAA portion was notionally named the Joint Polar Satellite System (JPSS). The satellite system is a national priority—essential to meet both civil and military weather forecasting, storm-tracking, and climate-monitoring requirements. In 2012, the JPSS program focused its near-term efforts on supporting the commissioning and early 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. After the instruments were successfully commissioned, the Suomi NPP observatory operations were successfully transferred from the NASA NPP Project to the JPSS program in March 2012.

The future JPSS missions, J1 and J2, are currently scheduled for November 2016 and November 2021 launches. The J1 mission will be very similar to NPP, using the same spacecraft and instrument complement. The JPSS system requirements review was held in May 2012 with the preliminary design review scheduled for early 2013. For further information, please contact James Gleason (james.gleason@nasa.gov).

3.1.2.4 JPSS Free Flyer (TSIS)

NASA, as part of the JPSS partnership with NOAA, is working to fly the Total and Spectral Solar Irradiance Sensors (TSIS) on the Free Flyer Mission. Free Flyer will also carry the climate sensors package. The TSIS sensor package's build has completed at University of Colorado, and was thoroughly tested during 2012. Launch is planned for Fall 2016. As SORCE is now 5 years beyond its original 5-year design life, and showing signs of its age especially in battery degradation, a new mission, the "TSI Calibration Transfer Experiment (TCTE)" is scheduled for launch in Fall 2013 as part of an Air Force payload on STPSat3, on a Minotaur out of Wallops Flight Facility. TCTE will serve as a "gap filler" for TSI only, not SSI, and is intended to ensure a continuous TSI record that connects the SORCE TIM record with the new TSI record from TSIS. TSIS will consist of two instrument sensors—a new Total Irradiance Monitor (TIM) and a new Spectral Irradiance Monitor (SIM)—both continuing the heritage of the first generation of TIM and SIM currently flying onboard SORCE.

The new TIM and SIM will each be fully traceable to the respective cryogenic radiometer facilities located at University of Colorado's Laboratory for Atmospheric and Space Physics (LASP.) These facilities are unique in the world, providing direct comparison in vacuum to cryogenic radiometers, using optical sources with power comparable to the Sun. The full characterization and traceability has been critical for meeting the required absolute accuracy. Equally important is the exacting degree of stability and precision met by these instruments, critical for any possible future direct determination of a decadal or longer trend in the Sun's variability. This will determine whether the Sun may be enhancing or reducing global warming that would otherwise occur if changes in atmospheric composition, due to greenhouse gases, volcanic or other aerosol emissions, or to natural atmosphere-ocean variations, were the only forcing mechanisms. Since the Sun's changing irradiance is the only well-established, external mechanism forcing the Earth's climate, it is critical to determine its sign and magnitude. For further information, please contact Robert Cahalan (robert.f.cahalan@nasa.gov).

3.1.2.5 DSCOVR

In 2011, Goddard's Atmospheric Research scientists were involved in the refurbishment of the two instruments on board the Deep Space Climate Observatory (DSCOVR) spacecraft. These instruments are National Institute of Standards (NIST) Advanced Radiometer (NISTAR), and Earth Polychromatic Imaging Camera (EPIC). The four-channel radiometer, NISTAR, provides measurements to improve estimates of the Earth's radiation budget, while the 10-channel telescope–spectroradiometer, EPIC, measures global ozone levels, aerosol index, aerosol optical depth, scene reflectivity, cloud height, vegetation, and leaf area indices. As part of the refurbishment program, NISTAR and EPIC were recalibrated, stray light for EPIC was corrected, and cloud height measurements were improved by replacing the older channels with the new oxygen-A and -B bands channels. After refurbishment, the instruments were returned to GSFC and integrated with the spacecraft. Algorithms development, ground systems, data reception and transmission are awaiting future direction from NASA. For further information, please contact Alexander Marshak (alexander.marshak@nasa.gov) or Jay Herman (jay.r.herman@nasa.gov).

3.1.3. NASA's Active Flight Missions

3.1.3.1 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 13 years, the Terra mission has been providing the worldwide scientific community with an unprecedented number of high-quality quantitative datasets making a significant contribution to all of NASA's Earth Science focus areas. The year 2012 made the record books as the hottest year and a year of both temperature and precipitation extremes for the United States on a statewide and seasonal level. After 13 years of continuous operation and more than 7,600 refereed publications (more than 103,300 citations and numerous press releases) using Terra products, the project office coordinated closely with the science and engineering team to advocate that the EOS science to maintain a strong Terra program. For further information, please contact Si-Chee Tsay (si-chee.tsay-1@nasa.gov).

3.1.3.2 Aqua

The Aqua spacecraft, launched on May 4, 2002, carries six Earth-observing instruments: AIRS, AMSU, AMSR-E, CERES (two copies), HSB (no longer operating), and MODIS. In the report of the 2011 Senior Review panel for satellite missions in extended operations (available at http://nasascience.nasa.gov/earth-science/missions/operating/), Aqua received the highest score for scientific merit, scientific relevance, and scientific product maturity, and was one of three missions to receive the highest ranking for utility. Aqua's overall score from the National Interests Panel was the highest of all current NASA missions, and it was the only mission rated as "Very High Utility“ by every agency doing the rankings. In addition to collecting data pertaining to Earth's water in all its phases, as highlighted in the name "Aqua," mission instruments also provide measurements (among others) about radiative energy flux, atmospheric temperature and composition, aerosols, cloud properties, land vegetation, phytoplankton and dissolved organic matter in the oceans, surface albedo, temperature, and emissivity. These measurements help scientists to quantify the state of the Earth system, validate climate models, address key science questions, 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. He helped organize a celebration event on May 4, 2012 at the GSFC Visitor Center on the occasion of the 10th anniversary of Aqua's launch. For further information, please contact Lazaros Oreopoulos (lazaros.oreopoulos@nasa.gov).

3.1.3.3 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. It has now been more than eight years 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.

In 2012, Aura data revealed new aspects of the Earth composition while it continues to build a multiyear, global dataset that will show connections between chemistry and climate. Measurements of water vapor mixing ratio and cloud water ice from MLS and from other A-train satellites are used by modelers from the world's major climate modeling centers in close collaboration with members of the MLS team to establish performance metrics for climate models. Novel analysis techniques have made it possible to quantify the industrial emissions of SO_2 from OMI measurements, confirming major reductions in the pollution from power plants in the eastern United States. OMI SO_2 measurements are now being used to estimate the emissions of this industrial pollutant worldwide. TES measurements were used along with a model to build a bridge between air quality and climate change. The TES has measured the thermal radiation absorbed by ozone, while the model has quantified the connections between ozone and pollutant emissions from different regions (e.g., the United States or Eastern Asia).

Although HIRDLS is no longer operational, analysis of high vertical-resolution profiles has provided a measure of the momentum flux in the stratosphere due to gravity waves, a quantity that is routinely parameterized in Earth System models. More information on Aura science highlights can be found at http://aura.gsfc.nasa.gov/ or contact Anne Douglass (anne.r.douglass@nasa.gov).

3.1.3.4 GOES

NOAA's Geostationary Operational Environmental Satellites (GOES) satellites are built, launched, and initialized by Goddard's GOES Project Office under an inter-agency program. 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 assures the scientific integrity of the GOES sensors throughout the mission definition, design, development, testing, operations, and data analysis phases of each decade-long satellite series. The project scientist also operates a popular 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. During 2012, five new and improved instruments were under construction for the next generation of GOES satellites, which are expected to be launch-ready in 2015.

The GOES Project Science Web site (http://goes.gsfc.nasa.gov/) offers real-time GOES imagery and digital movies overlaid on a true-color background—an attractive and popular format. For example, in a non-hurricane month (May 2006), the site served 50 GB/day to 46,000 distinct hosts at the average rate of two requests-per-second.

During a hurricane, the Web server typically hits its limit of 10 requests per second to 150 simultaneous guests. For further information, please contact Dennis Chesters (dennis.f.chesters@nasa.gov).

3.1.3.5 SORCE

Since its launch in January 2003, the Solar Radiation and Climate Experiment (SORCE) has achieved its goal of simultaneously measuring total solar irradiance (TSI) and solar spectral irradiance (SSI) in the 0.1- to 27-nm and 115- to 2400-nm wavelength ranges with unprecedented accuracy and precision. SORCE has successfully completed its 5-year core mission (January 2003 to January 2008) and is now in the fourth year of its extended mission. SORCE has accomplished unique new observations of the solar irradiance and has improved understanding of solar radiative forcing of Earth's climate and atmosphere during the descending phase of solar activity cycle 23 and now into the rising phase of solar cycle 24.

Variations in the Sun's total and spectral irradiance impose key natural forcings on the climate system, and the solar ultraviolet (UV) radiation is a key driver for atmospheric photochemistry and composition. Accurate and precise long-term records of TSI and SSI are thus important components of NASA's Earth Science program (e.g. NASA Science Plan, 2010). Current TSI and SSI measurements by NASA SORCE, future TSI measurement by NASA TCTE (TSI Calibration Transfer Experiment), and planned TSI and SSI measurements by NOAA/NASA JPSS Free-Flyer-1 TSIS (Total and Spectral Solar Irradiance Sensor) are essential measurements for our national climate program as discussed in the NRC Earth Science and Applications from Space report [2007].

Major accomplishments of the SORCE mission include accurate determination of TSI levels lower than previously thought, continuation of the over 30-year TSI and SSI UV record, initiation of the first record of SSI in the visible and infrared (IR), and the construction of reference spectra spanning the entire wavelength domain of terrestrial relevance. SSI variability has been unequivocally detected across the electromagnetic spectrum, including during flares. Improved synergistic models of total and spectral irradiance variations based on direct SORCE observations have been extended to longer time scales with proxy indicators, and are facilitating an increasingly wide array of climate and atmospheric model studies.

A series of extensive radiometric laboratory and field measurements involving SORCE and other TSI instruments established that the most accurate measurement of TSI during the 2008 solar minimum period is 1360.8±0.5 W/m-2, as measured by SORCE (Kopp and Lean, 2011). Previous TSI values reported by ACRIM have been revised downward, as a result of new understanding of scattered light revealed by the laboratory measurements. The composite TSI record has been improved and revised to reflect this new absolute value that SORCE has established.

SORCE's SSI observations suggest that solar cycle variations at some visible and near infrared wavelengths, in contrast to TSI, are out of phase with solar activity, i.e, the sunspot numbers in Figure 3.3(Harder et al., 2009). While observed short-term solar rotational (27-day) variability results are consistent with understanding of solar sunspot and facular influences, these new SORCE spectral irradiance results challenge this understanding for solar cycle variability. Two SORCE-sponsored workshops involving NIST calibration experts and the broader SSI community were held in 2012 to better understand SSI instrument degradation processes and trends. Progress is significant but the SORCE SSI results still require additional understanding or validation, which is in progress.

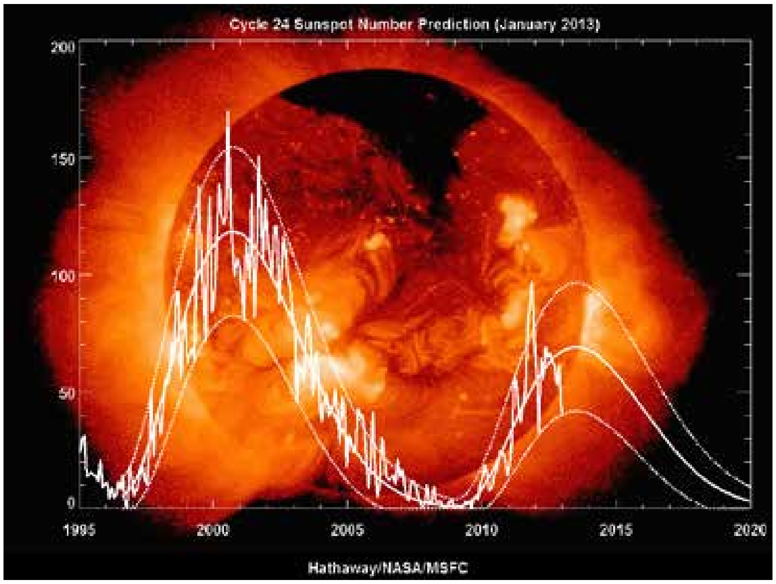

Figure 3.3: Solar activity and total solar irradiance variations since 1995. SORCE *has tracked the decline of solar irradiance in solar cycle 23, through the solar cycle minimum in 2008, and is now entering the maximum phase of solar cycle 24, at least according on predictions of sunspot numbers. By continuing for at least two more years,* SORCE *will track the maximum of solar cycle 24 and overlap with* NOAA*'s* TCTE TSI *instrument. Potential overlap with* JPSS TSIS *with its* TIM *and* SIM *instruments will likely require additional* SORCE *extensions considering that* TSIS *may not launch until 2016.*

The SORCE SSI measurements continue the UV irradiance record and the magnesium index implemented by SBUV, SME, and UARS instruments. SORCE's data are the critical elements in a new solar spectra reference throughout the X-ray, UV, visible, and IR ranges (e.g Woods et al., 2009).

Models of solar irradiance variations have been improved by the SORCE TSI and SSI observations, which provided insight into physical sources of solar variability and enabled investigations for studying solar influence on climate and atmosphere changes (Kopp and Lean, 2011; Haigh et al., 2010; Cahalan et al., 2010).

During the proposed extended mission in 2014 to 2015, solar activity will be near the maximum levels of cycle 24, but the amplitude of the cycle maximum is trending a factor of two lower than that of cycle 23 and possibly lower than all prior 16 cycles. SORCE's extended mission has the three primary objectives tailored to investigate this current "peculiar" state of solar activity, while aligned overall with SORCE's original mission objectives.

Key to achieving the first objective is the continuation of SORCE TSI measurements during solar cycle 24 maximum, and overlap with new TSI measurements to be made by the NOAA-NASA TSI Calibration Transfer Experiment (TCTE) aboard the Air Force STPSat-3 (launch planned for August 2013) and JPSS Total Solar Irradiance Sensors (TSIS) mission (launch planned in 2016). The second objective focuses on extensive, quantitative validation and interpretation of SORCE's SSI results, in addition to continuing the new SSI record. Planned is better understanding, specification and modeling of instrument degradation that impacts all space-based radiometers. The third objective is important for Earth Science missions and advancing Sun-climate relationships.

The next few years will provide a natural laboratory to critically study terrestrial responses in a period of low solar activity, as compared with the higher cycles that have dominated the space era. The maximum of solar cycle 24 in the next two years offers a unique opportunity to contrast solar cycle irradiance variability of a low cycle maximum that is almost a factor of two lower in amplitude than the recent solar cycle 23 maximum. This uniquely low cycle 24 follows a long solar activity minimum in 2008–2009, and may heralds the onset of regular low cycles such as during the Gleissburg Minimum in the early 1900s or the Dalton Minimum in the early 1800s (Russell et al., 2010).

All of the SORCE instruments have remained in functional good health and are expected to perform well during the extended mission. Because of instrument redundancies SORCE has successfully acquired a full set of solar irradiance data records over the entire SORCE mission, and this is expected to continue during the extended mission. Data processing algorithms to convert raw instrument signals into irradiances are very mature; however, significant data analysis of instrument degradation trends is still needed to maintain the most accurate irradiance products during the extended mission phase.

The SORCE spacecraft is a robust Orbital spacecraft with a redundant set of subsystems except for the battery. Two notable spacecraft anomalies are the deactivation of one of the four reaction wheels in early 2009 and the degradation of the battery performance that began in 2009. The SORCE mission operations team consists of LASP (lead), Orbital, and GSFC. They have worked closely on the spacecraft anomalies to understand the technical issues, to change operations and flight software to mitigate the risks, and to minimize the impact on the science observations. The battery degradation has continued steadily since the first cell anomaly, and the life of the SORCE mission is possibly limited to about two years because of the declining battery voltage level. All instruments are now power-cycled off during orbit eclipse. The instruments have wider temperature variations in this power-cycling mode, thus SORCE irradiance data quality has degraded some, but remains high enough for SORCE extended observations to continue providing high quality TSI and SSI climate records.

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3.1.3.6 TRMM

The Tropical Rainfall Measuring Mission (TRMM) launched in late 1997 as a joint mission between NASA and JAXA, the Japanese space agency. 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 instrumentsinclude 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 16th 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.

TRMM fuel levels are sufficient for continued operations until at least early 2014. Given uncertainties in the amount of remaining fuel and future solar activity (which causes drag on the satellite), fuel depletion could occur as late as mid-2016. The TRMM mission also completely implemented Version 7 of the rainfall retrieval algorithms. The biggest advance was in the algorithm for the TMI, which replaced its core database of numerical-model-derived hydrometeor profiles with precipitation profiles derived from the precipitation radar. In addition, the algorithm divides scenes by sea-surface temperature and total precipitable water to improve detection of regional differences in rainfall. Reprocessing of individual sensor products for the entire TRMM rainfall record was completed by mid-August 2011. Latent heating and multi-satellite products were completed in 2012.

The TRMM Web site (http://trmm.gsfc.nasa.gov/) provides near-real-time precipitation estimates every three hours, with daily and weekly accumulations, as well as flood potential maps. A brief synopsis of most 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).

3.1.3.7 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. 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.

Figure 3.4: This spectacular Blue Marble image from Suomi NPP*'s Visible Infrared Spectrometer (*VIIRS*) instrument uses a number of stitched together swaths of the Earth's surface taken on January 4, 2012. Credit:* NASA/NOAA/GSFC/*Suomi and* NPP/VIIRS/ *Norman Kuring*

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 that 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 provide a continuation of the EOS record of climate-quality observations after EOS Terra, Aqua, and Aura.

Since launch, Suomi NPP's instruments have been in nominal operations. Just after launch a VIIRS instrument anomaly was discovered. Following an investigation, the team was able to solve and characterize the mirror degradation attributed to tungsten oxides, an anomalous material on the surface of the mirror. Tungsten oxides caused the surface of the mirror to darken. The degradation is expected to plateau and remain the same for the rest of the mission, and VIIRS is expected to meet its design requirements. Suomi NPP's Level 1 instrument data has been publicly released.

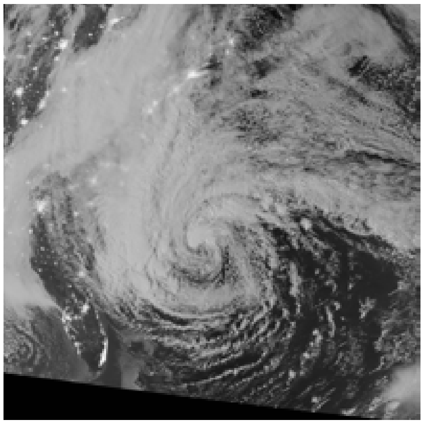


Figure 3.5: During powerful storms like Hurricane Sandy, researchers were able see how the storm made landfall at night using the VIIRS *"day-night band." Credit:* NASA *Earth Observatory*

Since May 2012, ATMS radiance data has being fed into operational numerical weather prediction models 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 product evaluation and test elements (PEATE) are doing an excellent job in supporting the science team's analysis. Level 1 data is ready for data continuity studies. The existing Interface Data Processing Segment (IDPS) instrument operational collaboration is progressing.

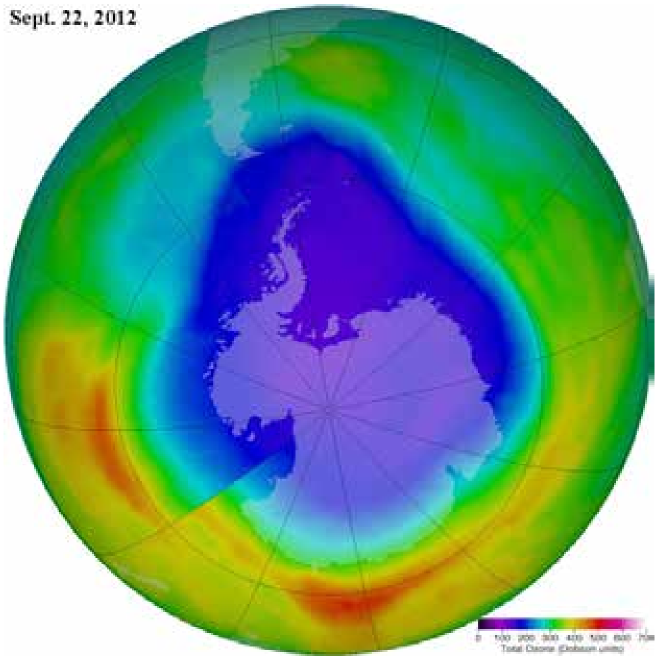


Figure 3.6: OMPS *will continue the three-decade record of satellite total ozone measurements. Credit:* NASA

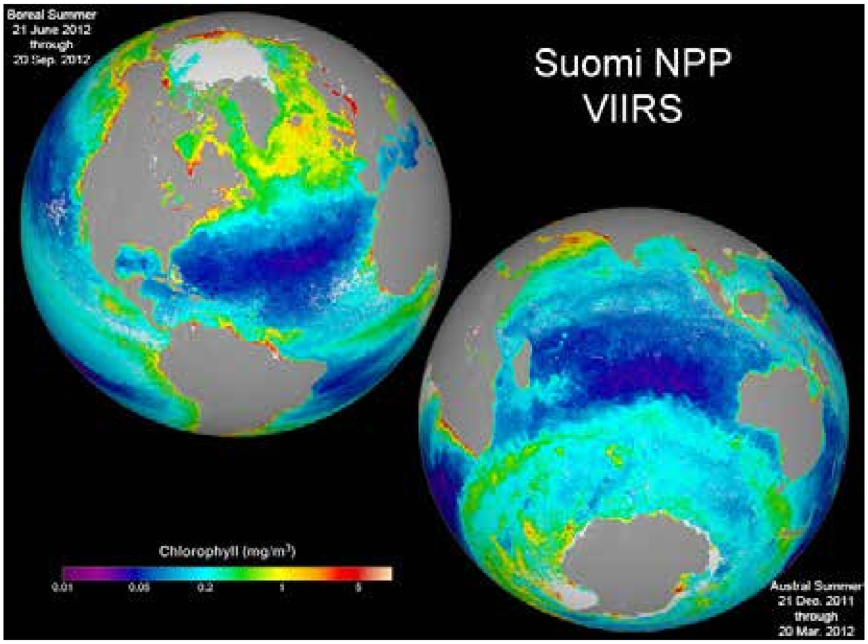


Figure 3.7: The ocean color team made some phenomenal improvements in their data retrievals for VIIRS *ocean color; using algorithms consistent with the existing* NASA *ocean color data record, a continuous instrument calibration, and multiple sets of reprocessing to asses and refine the results, they have demonstrated the capability of* VIIRS *instrument to continue some of the basic parameters contained in the 15-year SeaWiFS*-MODIS *global ocean color time series. Image Credit: Norman Kuring*

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 in 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	Warren Wiscombe	ARM
Steve Platnick	EOS	Bryan Duncan	Aura
Dennis Chesters	GOES	Joanna Joiner	Aura
Arthur Hou	GPM	Alex Marshak	DSCOVR
James Gleason	JPSS/NPP	Gail Jackson	GPM
James Irons	LDCM	Christina Hsu	NPP
PawanK. Bhartia	OMI	Si-Chee Tsay	Terra
Robert Cahalan	SORCE and TSIS		
Scott Braun	TRMM		

Table 3.3 Atmospheres Validation and Mission Scientists, and Major Participants/Instruments

Validation Scientists		Field/Aircraft Campaigns	
Name	**Mission**	**Name**	**Campaign**
David Starr	EOS	Kenneth Pickering	DISCOVER-AQ
Ralph Kahn	EOS/MISR	John Gerlach	DYNAMO/CINDY
		Charles Gatebe	ECO-3D
		Walter Petersen Gail Jackson	GCPEx
		Walter Petersen	GPM GV
		Scott Braun	HS3
		Walter Petersen	MC3E
		Judd Welton	MPLNET
		William Krabill	Operation IceBridge
		Judd Welton Si-Chee Tsay	SEAC4RS

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 2012, atmospheric research personnel supported activities in the planning and coordination phases as scientific investigators or as mission participants.

4.1. ALVICE

The mobile Code 612 ALVICE system completed its deployment to the University of Western Ontario (UWO). Experimental operations took place from May 16 to June 13, 2012 with 11 measurement nights, approximately 60 hours of lidar data, 18 RS-92 and 3 CFH balloon launches, and Suomi Net GPS-integrated precipitable water. The purpose of the campaign was to compare, calibrate and validate other ALVICE Raman water vapor lidar and the water vapor lidar at UWO under the auspices of the Network for the Detection of Atmospheric Composition Change (NDACC). During the campaign, the ALVICE system was used for the first time to its full capabilities. The measurement systems that were deployed to the field and used successfully included: Raman water vapor and temperature lidar; Vaisala RS-92 radiosondes, Cryogenic Frostpoint Hygrometer sondes, SuomiNet GPS total column water vapor; surface reference station with continuous NIST traceable T, P, RH measurements; and ventilated chamber for pre-launch characterization of radiosonde accuracy. The preliminary results of the experiment indicate that both Raman lidar systems offer measurement capability extending into the lower stratosphere but there is currently a systematic bias between the two systems in the upper troposphere and lower stratosphere. For further information, please contact David Whiteman (david.n.whiteman@nasa.gov).

4.2. GPM Cold Season Precipitation Experiment (GCPEX)

GCPEX took place in Ontario, Canada during the months of January and February during 2012. The experiment was led by GPM in collaboration by its international partners, Environment Canada, who hosted the field effort (Petersen, Skofronick-Jackson, and Hudak, 2012). The field effort focused on collection of detailed ground and airborne physical measurements of frozen precipitation (e.g., snowfall) toward characterizing the ability of spaceborne, multi-frequency active and passive microwave sensors to detect and estimating liquid-equivalent amounts and rates of falling snow. During the experiment, three instrumented aircraft were used: the NASA DC-8 “satellite simulator” carrying the CoSMIR radiometer and APR-2 dual-frequency radar, and the two in situ cloud microphysics platforms, which included the University of North Dakota Citation and Canadian National Research Council Convair 580. These aircraft were flown in stacks over a dense network of multi-frequency, ground-based radars; a snowfall measurement gauge; a disdrometer; and imaging instrumentation in order to provide a continuous measurement of snowfall physical properties from the ground through the atmospheric column under the umbrella of a GPM core satellite “simulator” (i.e., the DC-8). Sampling during the GCPEX campaign was very successful, with cases covering a broad spectrum of snowfall and cold rain event types. The resultant datasets will enable GPM algorithm developers to quantify satellite-instrument detection thresholds for snowfall and to further investigate the physical coupling between snowflake properties, snowfall bulk-water-equivalent contents/rates, and remote-sensing signals used to infer and quantify those processes from space. For further information, please contact Walter Petersen (walt.petersen@nasa.gov) and Gail Skofronick-Jackson (gail.s.jackson@nasa.gov).

4.3. Hurricane and Severe Storm Sentinel (HS3)

The Hurricane and Severe Storm Sentinel (HS3) mission was designed to use two of NASA's Global Hawk (GH) unmanned aircraft to explore the formation and intensification of Atlantic hurricanes during approximately one-month-long deployments in the hurricane seasons of 2012 through 2014. In essence, HS3 will give scientists something they've never had before—a sustained look at storms as they evolve over an extended period of time. To study environmental conditions surrounding storms, one aircraft carrying four instruments—including the Cloud Physics Lidar and the Tropospheric Wind Lidar Technology Experiment—was developed by Goddard scientists Matt McGill and Bruce Gentry, respectively, using IRAD funds; NOAA and the University of Wisconsin have provided the other two instruments. The second aircraft carried Gerry Heymsfield's HIWRAP and two other instruments provided by the Marshall Space Flight Center and Jet Propulsion Laboratory. These instruments were designed to measure conditions within the storms from a vantage point directly above the hurricane's vortex.

The 2012 campaign took place between September 6 and October 5 at NASA's Wallops Flight Facility in Virginia. The HS3 team had planned to have both Global Hawks deployed, but the second aircraft (used for inner-core measurements) experienced a number of problems that prevented its participation at Wallops.

Using the environmental GH, HS3 conducted seven flights during the deployment. The first flight was the ferry from Dryden to Wallops on September 6–7 during which time the GH flew along the outflow region of Hurricane Leslie, obtaining unprecedented information on the cloud, thermodynamic, and wind characteristics of this difficult-to-observe feature of hurricanes. The next five flights were in Hurricane Nadine, the only storm to occur during the major portion of the deployment, but one that occurred virtually throughout the period. On September 11–12, the GH overflew Nadine as it first became a tropical depression and then a tropical storm, sampling the environment around the developing storm, including the well-defined Saharan Air Layer on the storm's northern and eastern sides.

The second flight was on September 14–15 as Tropical Storm Nadine was moving northward in the central Atlantic under the influence of strong vertical wind shear. While dry air was observed to be wrapping into Nadine, initial inspection of the data suggests that it was not of Saharan origin. The vertical wind shear produced a major burst of convection near the center, allowing Nadine to strengthen into a hurricane.

The third flight into Nadine occurred on September 19–20 when Tropical Storm Nadine was near the Azores over cooler waters and under the influence of shear. HS3 observations showed that Nadine was still a vigorous tropical storm with a well-defined warm core through most of the troposphere. Data from HS3 was used by the National Hurricane Center to maintain Nadine as a tropical storm during this time instead of downgrading the storm to post-tropical status. The last two flights, also in the Azores region on September 22–23 and 26–27, investigated Nadine's interaction with an extratropical trough. Nadine intensified into a hurricane again on September 28. The last flight of the deployment consisted of two north-south tracks under the Aqua and NPP satellites. The goal was to compare data from AIRS and ATMS to the University of Wisconsin Scanning High-resolution Interferometer Sounder (S-HIS) on the GH.

The issues with the second aircraft were resolved by early November at which point the team conducted a test flight in the central and eastern Pacific to ascertain the performance of the instruments in a high-wind region. The aircraft and instruments performed well and are now ready for the deployments in 2013 and 2014. For further information, please contact Scott Braun (scott.a.braun@nasa.gov).

4.4. HyMEX

Hydrology in the Mediterranean Experiment (HyMEX) is a 10-year international effort designed to better understand, quantify, and model the hydrologic cycle in support of improved forecasts and warnings of flash floods in the Mediterranean region. NASA GPM participated in the first HyMEX Special Observation Period (SOP) during the months of September through November 2012. The 2012 SOP focused on heavy precipitation events that often cause catastrophic flooding in the Mediterranean Region. Focused measurements of the rainfall were made using multiple ground-based polarimetric radars and gauge networks, together with airborne sampling of cloud and ambient storm environment properties. GPM interest in the SOP revolved around the couplings among rain physics, the rainfall processes in complex terrain, uncertainties in measurements acquired from space-based remote-sensing retrievals of precipitation, and the impacts of those uncertainties on hydrologic applications related to flood forecasting. The GPM GV activity housed at the GSFC/Wallops Field Support Office contributed 12 disdrometers with accompanying rain gauges to measure raindrop size distributions and coincident rainfall rates respectively, together with three Micro Rain Radars designed to profile raindrop size distributions in the lowest 1000 meters of the atmosphere. These instruments were deployed within HyMEX observational networks located in south-Central France, central Italy, and northeastern Italy. During the campaign several cases of heavy rain and at least one flood event were captured. Several other cases of moderate to heavy rain without flooding were also observed. The field effort concluded in mid-November 2012, and instruments were shipped back to Wallops in December 2012. Datasets are currently being quality controlled and prepared for distribution via the HyMEX data archive. “For further information, please contact Walter Petersen (walt.petersen@nasa.gov).

4.5. 7-SEAS

The Micro-Pulse Lidar Network (MPLNET) and SMARTLabs projects have participated in ground-based and satellite observations as part of the Seven SouthEast Asian Studies (7-SEAS) mission. The 7-SEAS mission was established in 2007 to characterize aerosol-meteorological interactions in Southeast Asia. The 7-SEAS program was organized through a collaborative effort with the U.S. State Department and governments in Southeast Asia, NCAR Research Applications Laboratory, NASA, and the Office of Naval Research international field offices. Atmospheres members Judd Welton and Si-Chee Tsay have been part of 7-SEAS planning teams since its inception. Both long-term network and short-term field campaign observations have been conducted in Singapore, Thailand, Laos, Taiwan, Vietnam, Indonesia, and Malaysia. Long-term MPLNET sites in the region are co-located with NASA Aerosol Robotic Network (AERONET) sites, and the number of permanent network sites continues to grow. Field campaign activities are divided into spring and summer campaigns aligned with the monsoon seasonal North-South shift. Spring campaigns are conducted along the northern Southeast-Asian countries from Thailand, Laos, Vietnam, to Taiwan. Summer campaigns focus on the Malay Pennisula (mainland Malaysia and Singapore), the Indonesian islands of Sumatra and Java, and both Malaysian (Sarawak) and Indonesian (Kalimantan) regions of Borneo.

During 2012, SMARTLabs/AERONET participated in the spring campaign and MPLNET and AERONET conducted the summer campaign. Studies focus on the characterization of smoke aerosol properties, transport, and interactions with clouds. 7-SEAS data are also used to investigate observability issues in SE Asia because the region provides many challenges for space-based remote sensing. The upcoming SEAC4RS campaign in summer 2013 will provide an intensive aircraft observation component that has been missing in the long-term 7-SEAS mission. MPLNET and AERONET will conduct another ground-based summer campaign to support SEAC4RS aircraft observations, and to place the short-term but intensive aircraft data in context with the longer network observations. More information about MPLNET and SMARTLabs 7-SEAS and SEAC4RS data is available at http://mplnet.gsfc.nasa.gov with contact Judd Welton (judd.welton@nasa.gov), and http://smartlabs.gsfc.nasa.gov with contact Si-Chee Tsay (si-chee.tsay@nasa.gov).

4.6. DISCOVER-AQ

Ken Pickering, Project Scientist for the Earth Venture-1 Deriving Surface Conditions from Vertical Profile and Remotely-Sensed Data Relevant to Air Quality (DISCOVER-AQ) mission, reported that the analysis and modeling associated with the first deployment in the Baltimore-Washington area in 2011 proceeded smoothly during 2012. In this deployment, over 250 profiles of trace gases and aerosols were collected over six Maryland Department of the Environment air quality monitoring stations. The field program also entailed extensive ground-based and airborne remote sensing. Considerable work was accomplished on retrievals of trace gases from the ground-based Pandora UV/Visible spectrometer network and from the Airborne Compact Atmospheric Mapper (ACAM), both of which are Goddard-developed instruments. Comparisons were made between the data for trace gas columns from these two instruments, the OMI instrument on the Aura satellite, and integrations of in-situ profiles measured by instruments on the NASA P-3B aircraft. A dense network of AERONET sun photometers was also deployed, and these data have been used in evaluation MODIS aerosol optical depth retrievals.

One of the main science objectives of DISCOVER-AQ is to collect data to better understand the relationships between column trace gas and aerosol observations and surface air quality. Therefore, correlation analyses were conducted between the column abundances measured by the aforementioned instruments and surface observations conducted by the Maryland Department of the Environment. Better correlations were obtained for O_3 than for NO_2. The meteorological conditions for the July 2011 deployment period were simulated with the Weather Research and Forecasting (WRF) model, and these data were used to drive simulations of air quality with the Community Multi-scale Air Quality (CMAQ) model at horizontal resolution as fine as 1.3 km. Simulations of this period were also conducted with the WRF-Chem model (WRF meteorology with on-line chemistry). Deficiencies in the models have been identified based on comparisons with the DISCOVER-AQ data. The latter part of 2012 was devoted to preparing for the second deployment, which is to take place from mid-January to mid-February 2013 in the San Joaquin Valley of California. A Houston, TX deployment will take place in September 2013, followed by a fourth deployment in 2014 at a location yet to be determined. For further information, please contact Ken Pickering (kenneth.e.pickering@nasa.gov).

4.7. GPM Ground Validation

GSFC has played a prominent role in advancing space-based precipitation measurement, analysis, and applications (e.g., the TRMM, and now GPM missions). One important component of these missions is robust ground validation; i.e., field measurement activities designed to evaluate physical assumptions made in satellite-based precipitation retrieval algorithms, and to characterize errors and uncertainties in the associated precipitation products. As such, in 2012 WFF-FSO further developed the PRF as a "base" to manage GPM GV Science, conduct precipitation research, and to maintain state-of-the-art PMM/GPM GV radar, disdrometer, and rain/snow gauge instruments, both on sight and for deployments to GPM GV field campaigns. In January and February 2012, the PRF provided both PI leadership and snow measurement instrumentation to the GCPEX field campaign (GPM snowfall algorithm development), and later in the year contributed instruments to the European-led HyMEX field campaign (heavy precipitation and flooding in orographic terrain in the context of satellite measurement uncertainties). For GCPEX, PRF instruments (disdrometers and hot plate). For the HyMEX field effort the PRF provided 12 disdrometers to measure rain drop number concentration, shape, and size, and rain profiling instrumentation in the form of three Micro Rain Radars. At Wallops Flight Facility, the PRF made significant progress in establishing a quasi-fixed, GPM GV, high-quality precipitation data collection network (http://wallops-prf.gsfc.nasa.gov/). The network is comprised of the NPOL dual-polarimetric radar, Micro Rain radars, a dense dual-rain-gauge network, and disdrometer platforms. For further information, please contact Walter Petersen (walt.petersen@nasa.gov).

4.8. ECO-3D: Exploring the Third Dimension of Forest Carbon

Charles Gatebe (GESTAR/USRA, 613), Miguel Román (619), Crystal Schaaf (University of Massachusetts Boston), Tamas Varnai (UMBC, 613) and Alexander Marshak (613) were funded for a one-year pilot study by NASA's Terrestrial Ecology Program to demonstrate tree-height retrieval from Cloud Absorption Radiometer (CAR) multiangular/multispectral data. The CAR data was obtained during the ECO-3D field campaign, out of Wallops Flight Facility on the NASA P3 aircraft. The campaign duration was three weeks in August and September of 2011 and covered areas as far north as Quebec, Canada and as far south as the Florida Everglades, USA. Three primary instruments developed at GSFC were involved in this campaign: CAR, [PI Charles Gatebe]; the Digital Beamforming SAR (DB-SAR) [PI Rafael Rincon/Lola Fatoyinbo/Jon Ranson]; and Swath-Imaging Multi-polarization Photon-Counting Lidar (SIMPL) [PI David Harding]. The instrument suite provided novel, complimentary information on forest canopy structure properties. The campaign acquired data for six, well-characterized ecology study sites from Quebec to Florida, in order to assess new methods for forest biophysical parameter estimation including above-ground biomass. The campaign also acquired data for two planetary-analog surfaces, sand dunes, and glacial boulder fields to evaluate retrieval of roughness characteristics at multiple length scales. For further information, please contact Charles Gatebe (charles.k.gatebe@nasa.gov).

Table 4.1 Instrument Scientists/ Managers

Name	Instrument Systems	2012 Campaigns
Gerry Heymsfield	HIWRAP	MC3E and HS3
William Krabill	ATM	Operation IceBridge
Bruce Gentry	TWILITE	HS3
Mathew McGill	UAV-CPL	HS3
Charles Gatebe	CAR	ECO-3D
John Gerlach/Walter Petersen	NPOL	MC3E
John Gerlach/Walter Petersen	TOGA Radar	DYNAMO/CINDY2011
James Wang/Gail Jackson	CoSMIR	MC3E and GCPEX
Jay Herman	Pandora UV/VIS	DISCOVER-AQ
Judd Welton	MPLNET	7-Seas
SI-Chee Tsay	SMARTLabs	SEAC4RS

5. AWARDS AND SPECIAL RECOGNITION

5.1. Goddard and NASA Awards and Special Recognition

Table 5.1: List of GSFC Awards Received in CY 2012

GSFC Award	Recipient
Exceptional Achievement for Outreach	Ginger Butcher

Table 5.2: List of NASA Honor Awards Received in CY 2012

NASA Awards	Recipient
Outstanding Leadership Medal	Anne Douglass
Exceptional Achievement Medal	James Gleason
Exceptional Scientific Achievement Medal	Robert Meneghini

Table 5.3: List of NASA Team Awards Received in CY 2012

Group Awards	Recipient(s)
TIRS Instrument Development Team	
Landsat 40th Anniversary Team	Jim Irons, Ellen Gray, Aries Keck, Laura Betz, Matt Radcliff, Michael Taylor, Jesse Allen, Robert Simmon, Holli Riebeek, Tassia Owen, Michael Carlowicz, Adam Voiland, Horace Mitchell, Trent Schindler, Greg Shirah, Jeff Masek, Tom Loveland, Jennifer Brill
WFF Field Support Office Radar Engineering Team	John Gerlach, Michael Watson, Nathan Gears, Gary King, Joseph Hardin

5.2. External Awards and Special Recognition

William Lau, (610) has been elected President-Elect for the Atmospheric Sciences Section of AGU for 2013–2014. His term will begin January 1, 2013 for two years; he will then serve as President for the next two years. Election results for all AGU council members and secretaries can be found at: http://sites.agu.org/elections/files/2012/06/Council.pdf and profiles of elected officers at http://sites.agu.org/elections/section/.

P. K. Bhartia (610) was awarded the prestigious Yoram J. Kaufman Award from the AGU for 2012, "For his broad influence in atmospheric science through exceptional creativity, inspiration of younger scientists, mentoring, international collaborations, and unselfish cooperation in research." The award was presented at the Atmospheric Science Banquet at the fall AGU meeting.

S. Joseph Munchak (612) received the Robert Leviton Award at the 92nd meeting of the American Meteorological Society held in New Orleans, LA for his paper, "A Modular Optimal Estimation Method for Combined Radar-Radiometer Precipitation Profiling." The Robert Leviton Award is given for the best student paper on the development or evaluation of atmospheric instrumentation or unique measurement techniques.

As part of its 50th anniversary celebration, the paper "Numerically Stable Algorithm for Discrete-Ordinate-Method Radiative Transfer in Multiple Scattering and Emitting Layered Media," by K. Stamnes, **S. Chee Tsay** (613), **Warren Wiscombe** (613) and Kolf Jayaweera was selected as "top of the list" of the 50 most cited *Applied Optics* articles of all times, with a total citation of 1444 citations since the launch of the journal in 1962.

Alexander Marshak (613) was invited to attend the Flux Retrieval from EarthCARE BBR Observations (FLURB) workshop in Toronto Canada, January 26–27. He gave an invited presentation "Application of the Spectral Invariant Approximation to the EarthCARE Atmospheric Radiation calculations."

David Whiteman (612) was appointed to membership on the Scientific Organizing Committee for the GCOS Reference Upper Air Network (GRUAN) "Workshop to Develop Design and Expansion Criteria," to be held in Lindenberg, Germany, June 13–15, 2012.

The paper "Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols," by K. M. Lau (610), M. K. Kim, K.-M. Kim (613), and W.-S. Lee, published in Environmental Research Letters since 2006, was selected as one of 25 best papers, based on novelty, scientific impact, readership, broad appeal and wide media coverage

William Lau (610) has been appointed a guest editor of the special issue on the *Atmospheric Chemistry and Physics* (ACP) journal on "Saharan dusts and impacts on air quality and climate."

George J. Huffman (SSAI/612) was re-appointed as an Associate Editor for the AMS Journal of Hydrometeorology on March 16, 2012.

Chris Kidd (ESSIC/University of Maryland/612) was re-appointed as an Associate Editor for the AMS *Journal of Hydrometeorology*.

Walt Petersen (610.W) was appointed to the NCAR Observing Facilities Assessment Panel (OFAP) for a five-year term. The OFAP provides technical reviews and assessments for use of NSF Lower Atmospheric Observational Facilities.

Tiffany Moisan (610.W) was selected to serve as an Associate Editor for the *Journal of Dataset Papers in Ecology*, a peer-reviewed, open-access journal devoted to the publication of dataset papers in all areas of ecology.

The second edition of the popular reference book, *Intraseasonal Variability in the Atmosphere-Ocean Climate System*, by Co-chief Editors **William Lau** (GSFC/610) and Duane Waliser (JPL), was republished by Springer Praxis Publishing. First published in 2004, this book provides a comprehensive reference for low-frequency atmospheric phenomena (20–60 day time scales), with special focus on the Madden–Julian Oscillations (MJO) and their global and regional influences.

Eyal Amitai (Chapman University/612) was invited to participate as an honored guest at the International Seminar on Extreme Hydrometeorological Events over Consideration of Global Climate Change held at the Nanjing University of Information Science and Technology on May 9-10 in Nanjing, China. Eyal presented the talk entitled "Rainfall Intensities from Satellite and Ground Observations During Extreme Hydrometeorological Events."

David Whiteman (612) traveled to La Paz, Bolivia, to begin a SED-sponsored fellowship working with members of the Laboratory of Atmospheric Physics at the Universidad Mayor de San Andres. The work relates to the recently initiated Global Atmospheric Watch station located at Mt. Chacaltaya (CHC, 5.2 km elevation).

Eyal Amitai, (Chapman University/612) was re-appointed as an Associate Editor for the AMS *Journal of Hydrometeorology.*

Nickolay Krotkov (614) was selected to serve as an adjunct professor at the UMBC Department of Physics.

Mian Chin (614) **and Xiaohua Pan** (Morgan State University/614*):* On September 11, GOCART was implemented to GFS (the weather forecast system of NOAA). Louis W. Uccellini, the director of NOAA NCEP, mentioned it in his speech, titled "Advancing the Forecast Enterprise" at NASA.

Robert Levy (SSAI/613) was awarded the International Radiation Commission (IRC) Young Scientist Award for "Outstanding contributions to radiation studies that improve retrieval of aerosol properties and related critical climate parameters from satellite data. Introducing new data analysis and interpretation to address difficult challenges." The award was presented at the quadrennial meeting of the IRC held in Berlin, Germany, August 6–10.

Hongbin Yu (ESSIC/613) received the GSFC Earth Sciences Division—Atmospheres Contractor Award for Best Senior Author Publication for the paper "Aerosols from Overseas Rival Domestic Emissions over North America, Hongbin Yu, Lorraine Remer, Mian Chin, Huisheng Bian, Qian Tan, Tianle Yuan, Yan Zhang, *Science*, 337, 566-569, 2012. The award citation states: "For innovative use of satellite data to quantify the transport of dust and pollution aerosols across the Pacific Ocean and to estimate the impact of such transport on North America's climate and air quality."

Alexander Marshak (613) was awarded an SED research fellowship to spend three months at the Department of Atmospheric Sciences at University of Washington. While there, he collaborated with Professors Tom Ackerman, Qiang Fu, and Rob Wood, and he co-taught a class on advanced radiative transfer and remote sensing.

A manuscript authored by **Amitai, E.** (Chapman University/612), W. Petersen, X. Llort, and S. Vasiloff, was selected by IEEE for the front cover of the March 2012 issue of TGRS: "Multiplatform Comparisons of Rain Intensity for Extreme Precipitation Events." *IEEE Trans. Geosciences and Remote Sensing*, 50(3), 675-686.

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 to increase the public's understanding of why and how such advances affect their lives through formal and informal education and in 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) and Interactions with Howard University. The latter activity is discussed below as an example of collaboration with special emphasis on recruiting and training underrepresented minorities for careers in Earth Science.

6.2. Interactions with Howard University

Howard University was awarded a NASA University Research Center grant that establishes the Howard University Beltsville Center for Climate System Observation (HCCSO) in late 2008. This grant is administered by the GSFC Education Office and involves several GSFC personnel from Code 610 in joint areas of Climate System Research. Collaboration at the Beltsville facility and at GSFC in the atmospheric sciences places special emphasis on laser remote sensing, and assisting in mentoring the site. students and advising with instrument acquisition. The following cooperative programs were active in 2012.

6.2.1. Partnerships with Howard University/University Research Center-BCCSO

Howard University, with the support of NASA, endeavors to have an impact on Earth Science and to provide a diverse and well-qualified workforce. Howard University's Beltsville Center for Climate System Observation (BCCSO) is a Group 4 NASA University Research Center. It plays a pivotal role in assisting Howard University's unique program to establish the capacity for sustainable research that is valuable to NASA Science Mission Directorate's (SMD) long-term goals and in helping provide a diverse, well-qualified workforce to achieve those goals. David Starr (612) serves as technical monitor and chairs its technical review committee. BCCSO leverages a talented cadre of atmospheric science, physics, chemistry, and engineering faculty as well as important partnerships at NASA Goddard Space Flight Center and other universities. BCCSO is on pace to meet its fifth year research and educational goals. Key BCCSO accomplishments:

- In partnership with NASA GSFC and LaRC, BCCSO conducted a series of experiments to study urban air pollution (DISCOVER-AQ) over the Baltimore-Washington traffic corridor. BCCSO successfully processed and delivered this data, then engaged in an extensive study and analysis that lead to publication.

- Publications are under development in each of BCCSO's areas of study, and several publications have been completed that include BCCSO students as co-authors.
- The program collaborated with Pennsylvania State University (PSU) to achieve most of the proposed in-situ aerosol and gas sensor capabilities at the BCCSO.
- Graduate student Monique Calhoun developed the Lamp Mapping technique to determine the calibration constant of the water vapor mixing ratio for the Howard University Raman LIDAR (HURL) system. BCCSO made significant progress towards transfer of this technology to ALVICE.
- BCCSO supported of eight graduate students for the 2011-2012 academic year.
- BCCSO hosted a successful undergraduate summer internship program where seven interns directly worked with BCCSO principal investigators, Howard University faculty, GSFC scientists, and others on BCCSO research projects.
- They organized a graduate student professional development retreat focused on successful strategies for developing and publishing scientific manuscripts in refereed journals.
- BCCSO hosted numerous outreach events targeted at audiences from K-12 through professionals in the science and academic communities.

6.2.1.1 WAVES

During the summers of 2006 and 2007 and the winters of 2009 and 2011, students from Howard University participated in the Water Vapor Validation Experiments Satellite and Sondes (WAVES) field campaigns at the Beltsville site. The WAVES activities are focused on providing data for satellite validation and intercomparison of various remote and in situ sensing technologies. One of the main goals has been to acquire statistically robust sets of measurements of atmospheric water vapor, aerosols, and trace gases useful for Aura and Aqua satellite retrieval studies as well as to perform instrument accuracy assessments and case studies of regional water vapor and aerosol variability. WAVES_2006 was the first major experiment held at HURB and required coordination within Howard University and with GSFC, NOAA/Boulder, NWS/Sterling. Many universities were involved as well, including the University of Maryland, College Park; the University of Maryland, Baltimore County; Pennsylvania State University; Bowie State, MD; Trinity University, DC; the University of Virginia, Charlottesville; Smith College, NH; the University of Wisconsin; and with universities in Brazil, Italy, and Bolivia. The initial WAVES funding activities were carried forward as components of the Atmospheric Chemistry program in support of the Network for the Detection of Atmospheric Composition Change.

During the winters of 2011–2012, students from Howard University participated in a Water Vapor Validation Experiments Satellite and Sondes (WAVES) field campaign at the Howard University/Beltsville site. The WAVES activities were focused on developing calibration techniques and providing data in support of the Network for the Detection of Atmospheric Composition Change (NDACC). One of the main instruments within NDACC for quantifying water vapor profiles for the purposes of satellite validation and climate trend detection is the Raman lidar. During the WAVES campaign, extensive work was done on developing a new independent calibration technique for Raman water vapor lidar. This work was done collaboratively between NASA/GSFC and Howard University with much of the work being accomplished by graduate student Monique Walker. Ms. Walker is scheduled to defend herPhD dissertation in 2013 using the results obtained from this WAVES experiment. For further information please contact David Whiteman (david.n.whiteman@nasa.gov).

6.2.1.2 Wind Lidar Intercomparison

In 2012, a three-year program was completed that assessed the performance of NASA's ground-based wind lidar systems operating at the Howard University, Beltsville Research Facility. The goal of the experiment was to compare two of NASA's state-of-the-art wind lidar instruments and candidates for NASA's Decadal Survey 3D-Winds Mission: VALIDAR, an aerosol-based coherent Doppler lidar system from LaRC and Goddard Lidar Observatory for Winds (GLOW), a molecular-based Doppler lidar from GSFC. This is the first experiment where these two techniques have been compared in side-by-side experiments. In addition, the commercial wind lidar from Leosphere, a 915 MHz profiler, ACARS winds, and different types of radiosondes were also included. The wind lidar intercomparison experiment was funded by NASA's SMD for three years under as part of the wind lidar science program. In FY2012 we completed analysis of the data sets from the three-lidar systems and performed intercomparisons of the lidar wind profiles and also comparisons with independent observations from GPS radiosondes and a radar wind profiler located at Howard's Beltsville facility. For further information, contact Bruce Gentry (bruce.m.gentry@nasa.gov) or Belay Demoz (bbdemoz@howard.edu).

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 were the lectures presented in 2012 among the various laboratories.

Table 6.1: Atmospheric Sciences Distinguished Lecture Series

Date	Speaker	Title
January 19	Gregory R. Carmichael and Karl Kammermeyer University of Iowa	*Sensitivity analysis of aerosol feedbacks on chemistry and climate at urban and regional scales*
February 16	George Bryan National Center for Atmospheric Research	*Estimates for surface exchange coefficients and turbulence length scales within hurricanes based on numerical simulations*
March 15	L. Ruby Leung Pacific Northwest National Laboratory	*Mega-Droughts of the Future: The Role of Biosphere-Atmosphere Feedbacks*
April 19	Irina N. Sokolik Georgia Institute of Technology	*Towards an improved understanding of processes and multiscale variability of dust aerosol through the integration of a regional fully-coupled dust modeling system WRF-Chem-DuMo and multi-satellite, multi-sensor data*
May 3	K. N. Liou University of California	*Light-Absorbing Aerosols and Snow-Albedo Feedback in Regional Climate Change*
May 17	Michelle Santee JPL	*Trace gas distributions and their variability in the upper troposphere and stratosphere deduced from Aura Microwave Limb Sounder measurements*
June 21	Stephen G. Warren University of Washington, Seattle	*Light-absorbing impurities in Arctic snow and their effect on surface albedo*

Date	Speaker	Title
September 27	Arlindo M. da Silva, Jr. NASA GSFC	*Assimilation of Cloud and Aerosol Observations in GEOS-5*
October 18	Pao K. Wang University of Wisconsin, Madison	*Physics and Dynamics atop Severe Thunderstorms and Their Implications*
November 15	Ross Salawitch UMCP/ESSIC	*An Empirical Model of Global Climate: Reduced Impact of Volcanoes Upon Consideration of Ocean Circulation & Implications for Future Temperature*

Table 6.1: Mesoscale Atmospheric Processes

Date	Speaker	Title
February 16	George Bryan National Center for Atmospheric Research	*Estimates for surface exchange coefficients and turbulence* *length scales within hurricanes based on numerical simulations*
March 2	P. Chambon, R. Roca, I. Jobard, N. Viltard, J. Aubanc and M. Capderou Laboratoire de Meteorologie Dynamique, Ecole Polytechnique, Palaiseau, France	*The Megha-Tropiques accumulated rainfall algorithm TAPEER-BRAIN: investigateng the error budget of satellite QPE*
March 2	Da-Lin Zhang UMCP	*The Importance of Convective Bursts and the upper-level warm core in the Rapid Intensification of Hurricane Wilma (2005)*
May 10	Ian Adams Remote Sensing Division, Naval Research Laboratory	*Dichroism in Precipitating Atmospheres*
October 26	Christopher Ruf University of Michigan	*The NASA EV-2 Cyclone Global Navigation Satellite System (CYGNSS) Mission*

Table 6.2: Climate and Radiations

Date	Speaker	Title
January 4	Temilola Fatoyinbo Agueh NASA GSFC	*Estimation of mangrove structure and biomass from SAR and lidar remote sensing*
January 18	Robert F. Adler ESSIC UMCP	*Global Variations of Precipitation—From Climate Scale to Floods*
February 1	Miguel O. Román NASA GSFC	*Evaluation and validation of global land surface products derived from Landsat, MODIS, and VIIRS*
February 22	Oreste Reale GESTAR/USRA and NASA GSFC	*AIRS impact on analysis and forecast of tropical cyclones and extreme precipitation events in the tropics*

Date	Speaker	Title
March 7	Ritesh Gautam, GESTAR/USRA	*Absorbing aerosols in the Gangetic-Himalayan region: distribution, properties and radiative effects*
April 4	Derek Posselt University of Michigan	*Uncertainty Quantification in Weather and Climate Models*
April 18	Maudood Khan USRA and NASA MSFC	*Designing 21st Century Human Settlements: Instruments, Models and Institutions*
May 2	Dong L. Wu NASA GSFC	*What's Missing in the Arctic Warming?*
May 3	David Peterson University of Nebraska – Lincoln	*A Sub-Pixel-Based Calculation of Fire Radiative Power from MODIS Observations: Initial Assessment, Sensitivity Analysis, and Fire Weather Application*
May 16	Michael Bosilovich NASA GSFC	*MERRA: Overview, recent results and next steps*
June 6	Richard A. Hansell University of Maryland/ESSIC and NASA GSFC	*Dust Aerosols: A Longwave Perspective of Their Radiative Effects*
September 19	Benjamin T. Johnson UMBC and NASA GSFC	*Rain and Snowfall Retrievals for the Global Precipitation Measurement Mission -- Progress and Challenges*
October 3	Prasun K. Kundu JCET, UMBC	*Rainfall: A Statistical Conundrum*
October 17	Teppei J. Yasunari, GESTAR, USRA	*Snow darkening effect over land simulated by the NASA GEOS-5 model: Performance and possible validation avenues*
November 14	Thorwald Stein University of Reading	*The evaluation of model cloud physics using satellite and ground-based radar observations*
November 28	Jerald W. Harder University of Colorado	*Measured and Modeled Trends in Solar Spectral Irradiance Variability and their Application to Earth Atmospheric Studies*
December 19	Wei-Kuo Tao NASA GSFC	*A Robust Multi-scale Modeling System for the Study of Cloud and Precipitation Processes*

6.3.1. Manic Talks

Maniac talks are monthly talk series to promote scientific interaction between young and experienced scientists in order to learn/improve/revise the knowledge of basic/fundamentals of science and scientific methods for research. The format of the talk is very informal and healthy discussion is encouraged.

Table 6.3: Maniac Talk Series

Date	Speaker	Title
January 18	Compton James Tucker NASA GSFC	*Remote Sensing of Vegetation: Past, Present and Future*
February 22	Alexander Marshak NASA GSFC	*From Single Scattering Albedo to Radiative Smoothing; Having Fun with Radiative Transfer*
March 28	Pawan K. Bhartia NASA GSFC	*Four Decades of Ozone Measurement from Space Effects of clouds and aerosols on UV radiation*
April 23	Richard S. Stolarski NASA GSFC	*Stratospheric Ozone: How we came to understand its chemistry and response to perturbations*
May 21	Robert Bindschadler GESTAR and NASA GSFC	*What Ice Sheets Hate*
June 27	Gene Carl Feldman NASA GSFC	*Satellites, Seabirds, and Seals: A thirty year retrospective of Ocean Color from Space*
July 25	Mian Chin NASA GSFC	*Modeling Atmospheric Aerosols: Opportunities, Excitements, and Danger*
August 22	Claire Parkinson NASA GSFC	*From Math to Civil Rights to Sea Ice to Geo-engineering to an Attempt at a Balanced Perspective on Climate Change*
October 24	Robert Cahalan NASA GSFC	*Angel Hair, Ice Cream Castles, Dripping Faucets & Euler Fractals*
November 28	Pier Sellers NASA GSFC	*Infiltrating NASA ...*

Table 6.4: Atmospheric Chemistry and Dynamics

Date	Speaker	Title
February 16	Ted Kostiuk NASA GSFC	*A New Method to Explore the UTLS and Beyond*
February 23	Mian Chin NASA GSFC	*Group research activities and highlights*
March 1	Sunny Choi	*Investigation of tropospheric BrO using OMI*
March 8	Pete Colarco NASA GSFC	*Aerosol Modeling in GEOS-5 and the CCM*
April 5	Anne Douglass NASA GSFC	*The Goddard Earth Observing System Chemistry and Climate Model: Past successes, present challenges, and future directions*
April 19	Birgit Hassler, Research Scientist NOAA CIRES	*Ozone data for climate models: A comparison of three datasets and their climate impact*
April 26	Joanna Joiner NASA GSFC	*New fluorescence measurements from SCIAMACHY and GOSAT*
May 3	Bryan Duncan NASA GSFC	*A summary of Bryan's efforts*
May 10	Cynthia Randles Morgan State University and NASA GSFC	*Aerosol-Climate coupling in GEOS-5*

Date	Speaker	Title
May 17	James Gleason NASA GSFC	*Confessions of a Project Scientist: Lessons from NPP*
June 7	Tom Hanisco NASA GSFC	*In Situ Airborne Formaldehyde: First results*
June 11	Olaf Morgenstern National Institute of Water and Atmospheric Research	*The tropospheric oxidizing capacity: Is it influenced by stratospheric change?*
June 14	Maggie Hurwitz Morgan State University and NASA GSFC	*The Southern Hemisphere Response to Warm Pool El Nino Events*
June 28	Bill Heaps NASA GSFC	*AMIGO: A new instrument for Greenhouse Gas Measurement employing GLINT*
July 12	Henry Selkirk USRA and NASA GSFC	*Balloon Sonde Measurements of Volcanic and Urban* SO_2 *and Coincident OMI Column Measurements*
July 26	Charles Jackman NASA GSFC	*Two-Dimensional Modeling, Solar Proton Events, and the AIM Satellite*
August 16	Matus Matini, Research UMCP	*Tropospheric ozone and its radiative effects due to anthropogenic and lightning emissions: Global and regional modeling*
August 30	Claire Orbe Columbia University	*Stratosphere-Troposphere Flux Distributions in Goddard Chemistry Climate Model* *(GEOSCCM)*
September 13	Scott Janz NASA GSFC	*ACAM High Spatial Resolution Measurements of* NO_2, CH_2O, *and* O_3 *for Discover-AQ*
September 27	Randy Kawa NASA GSFC	*Atmospheric Carbon Cycle Science: Modeling, Data Analysis, Measurements, and Mission/Instrument Development*
November 15	Nick Krotkov NASA GSFC	*OMI* NO_2 *and* SO_2 *measurements: applications for climate, air quality, and aviation safety*
December 13	Luke Oman NASA GSFC	*From the Surface to the Stratosphere: A Journey with GEOSCCM*

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. 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 the 2011–2012 season, AeroCenter invited 32 seminars with typical 30 to 40 physical attendees, and 5 to 10 WebEx attendee most from outside from GSFC. Initiated by Lorrain Remer and Yoram Kaufman, for more than 10 years AeroCenter has played a primal role in exchanging up-to-date aerosol science across NASA laboratories and other institutions since 2001. Recent major topics include 1) updates of aerosol retrieval algorithms using the Aqua/Terra MODIS, the Terra MISR, the Aura OMI, the SeaStar SeaWiFS, and the CALIPSO CALIOP sensors, 2) updates of algorithm and networks of in-situ aerosol measurements from the AERONET, and 3) evaluation of aerosol transport simulations from the GEOS-5 and the GOCART models against satellite and in-situ datasets. For further information, please contact Toshihisa Matsui (toshihisa.matsui-1@nasa.gov).

6.5. Public Outreach

January

Alexander Marshak (613) was invited to attend the FLURB (Flux Retrieval from EarthCARE BBR Observations) workshop in Toronto Canada on January 26–27. He gave an invited presentation "Application of the Spectral Invariant Approximation to the EarthCARE Atmospheric Radiation calculations."

During the week of January 16, **David Whiteman** (612) was an invited lecturer at a weeklong course on lidar offered at the Center for Optics and Photonics (CEFOP) in Concepcion, Chile. During the week, Dr. Whiteman also consulted with CEFOP personnel on their development of a new Raman lidar system. CEFOP was established in 2009 at the University of Concepcion to bring together researchers and students focusing in various areas of electro-optics.

February

David Whiteman (612) has been appointed as a member of the Steering Committee for the WMO Global Atmospheric Watch (GAW) Station at Mt. Chacaltaya in Bolivia. The Steering Committee consists of scientists from Bolivia, France, Sweden, Italy, Germany and the United States. The initial meeting of the Steering Committee will be in April in La Paz, Bolivia to establish procedures and objectives for accomplishing the goals of the site. More information about the site can be found at http://www.chacaltaya.edu.bo/.

Kevin Vermeesch (612/SSAI) and **David Whiteman** (612) participated as judges in the Greenbelt Middle School STEM Fair on February 10.

Robert Cahalan (613) presented a webinar on February 16 to members of the National Park Service, Fish and Wildlife Service entitled "Reasons to be Hopeful about Climate Change."

Mian Chin (614) visited the Desert Research Institute (DRI) and the University of Nevada at Reno on February 27-28. Mian Chin was invited to give a technical lecture at the DRI on her recent research on multi-decadal aerosol trends and impacts. She gave a public lecture at the Diamonte Range High School entitled "Atmospheric aerosols: What they do to your health and climate". She was also interviewed by a local NPR-affiliated radio station during her visit.

March

David Whiteman (612) participated as a judge in the Greenbelt Elementary STEM fair on March 6.

David Whiteman (612) has been appointed as a member of the Steering Committee of the WMO Global Atmospheric Watch (GAW) Station at Mt. Chacaltaya in Bolivia. The Steering Committee consists of scientists from Bolivia, France, Sweden, Italy, Germany and the US. The initial meeting of the Steering Committee will be in April in La Paz, Bolivia, to establish procedures and objectives for accomplishing the goals of the site. More information about the site can be found at http://www.chacaltaya.edu.bo/.

Richard Kleidman (SSAI/613) and **Pawan Gupta** (USRA/614) gave a course on "Remote Sensing for Air Quality Applications" sponsored by the Lake Michigan Air Quality Directors Consortium (LADCO) in Madison, WI, on March 12–16.

Alexander Marshak, Warren Wiscombe and Dong Wu (all 613) attended the 2012 U.S. Department of Energy's Atmospheric System Research (ASR) Science Team Meeting in Arlington, VA, on March 12–16.

Ralph Kahn (613) attended the PACE Science Definition Team Meeting, Arlington, VA, March 14–16.

Robert Cahalan (613) delivered a talk entitled "Global Warming: Reasons for Hope" on March 23 at the Appalachian Studies Conference at Indiana University of Pennsylvania.

GPM scientists and EPO team members participated and distributed materials at the National Teachers Association annual meeting in Indianapolis (March 29–April 1) the NASA booth for Earth day on the National Mall (April 20–22), and the USA Science and Engineering Festival at the Washington, DC, Convention Center (April 27–29).

Santiago Gassó (GESTAR/613) attended the final thesis dissertation of Matthew Johnson ("Understanding the transport, chemical transformation, and biogeochemical impact of mineral dust") at North Carolina State University. Dr. Gassó was a member of the thesis committee and has an ongoing collaboration with Dr. Johnson's thesis advisor, Professor Nicholas Meskhidze. Dr. Gassó has advised Matthew Johnson since 2007 and he was a summer program visiting intern in 2009. This interaction resulted in two papers led by the student and co-authored by Drs. Meskhidze and Gassó. Matthew Johnson accepted a civil servant at NASA Ames and will continue his work in aerosol modeling combined with satellite observations. Dr. Gassó is currently a thesis advisor to another graduate student at NCSU.

April

The second edition of the popular reference book" Intraseasonal variability in the Atmosphere-Ocean Climate system" by Co-Chief Editors, **William Lau** (610/GSFC) and Duane Waliser (JPL) is published by Springer Praxis Publishing. First published in 2004, this book is a comprehensive reference for low-frequency atmospheric phenomena (20–60 day time scales), with special focus on the Madden and Julian Oscillations (MJO) and their global and regional influences. The MJO was first discovered in the early 1970's based on crude sounding observations, and did not attract much attention in the research community at the time. The phenomenon was confirmed by satellite observations in the early 1980's, as a ubiquitous and intrinsic phenomenon of the tropical atmosphere with strong influences on extra tropical weather.

Since then over thousands of refereed publications on the subject have appeared in the literature. At present, a realistic simulation of the MJO is considered a prerequisite for establishing model credibility to produce reliable predictions of interannual variability, and longer-term projections of regional impacts and extreme events associated with climate change. The MJO and associated regional intraseasonal oscillations represent the critical linkage between weather and climate, and is considered the centerpiece to the new "seamless prediction" paradigm to address the continuum of prediction across scales, adopted by the international science community. In the second editions, all the original chapters have been updated. New chapters on vertical structure, and chemical and biological impacts of MJO deduced from NASA satellite observations, and a new multi-scale theory of the MJO have been included. This book became available on amazon.com.

The GPM team presented a booth at the Second USA Science and Engineering Festival, April 27–29, at the Washington Convention Center, Washington, D.C., **Dorian W. Janney** (ADNET/612) organized and led, while **Ellen T. Gray** (ADNET/612), **George J. Huffman** (SSAI/612), **Gail Skofronick**

Jackson (612), **Christopher Kidd** (UMCP/ESSIC/612), and **Jacob B. Reed** (TELOPHASE/612) staffed the booth. Described as the largest celebration of science in the United States, the festival featured over 3,000 exhibits, more than 100 stage shows, and 33 author presentations regarding science, technology, engineering, and math. The GPM booth was part of a large NASA presence and covered a range of topics appropriate to K–12 and adult visitors, from the global water cycle to the function of the GPM instruments.

May

Dorian Janney (Montgomery County Public Schools/612) developed and led a hands-on presentation at the recent Howard B. Owens Science Center "Family Science Night" that allowed participants to interact with water and to understand why we need to measure precipitation with satellites. This event, held on May 6, attracted over 250 participants from Prince George's County Public Schools.

Joe Munchak (612/ESSIC) gave a presentation on May 30 entitled "Insights from a Decade of NASA's Earth Observing Missions" at the 4th annual Thomas Jefferson Symposium To Advance Research (TJSTAR) at Thomas Jefferson High School for Science and Technology in Alexandria, VA. This presentation covered the various Earth-observing satellites launched in the past 10–15 years and the key discoveries that researchers have made towards climate change research. Examples included: temperature, water vapor, and radiation budget measurements, cloud and aerosol properties, and precipitation. The major technologies behind these measurements were also discussed.

June

A number of 612 scientists took part in staffing the GPM desk at the GSFC Science Jamboree on June 5; they included **Gail Jackson, Arthur Hou, Jacob Reed, Chris Kidd, Ryan Fitzgibbons, and Ben Johnson.**

July

On July 24, **Scott Rabenhorst** (ESSIC/612) successfully defended his PhD dissertation entitled "Field Observations and Model Simulations of Low-Level Flows over the Mid-Atlantic During 1-5 August 2006". The observations were acquired during the first of the Water Vapor Variability Satellite/Sondes *WAVES) field campaigns in 2006 at the Howard University Research Campus in Beltsville Maryland. The results of the research include a new understanding of low-level flows, such as low-level jets and downslope winds, in the mid-Atlantic under summertime conditions. **David Whiteman** (612) was Mr. Rabenhorst's research advisor.

August

Joanna Joiner attended the Keck Institute for Space Studies workshop on "New Methods to Measure Photosynthesis from Space" at the California Institute of Technology, August 26–31. She led a discussion on satellite measurements of fluorescence.

September

A five-week-long online webinar series on "Introduction to NASA Remote Sensing for Air Quality Applications" started on September 19. **Pawan Gupta** (USRA/614), **Jacquelyn C. Witte** (SSAI/614) along with **Richard Kleidman** (613) gave lectures on various aspects of NASA' remote-sensing observations for air quality applications. For more details on the course visit: http://airquality.gsfc.nasa.gov/webinar/

Gail Skofronick Jackson (612) gave a "Global Precipitation Measurement Summary" presentation and provided career advice to more than 100 high school students at Leon High School in Tallahassee, Florida on September 21.

Ken Pickering (614) visited Cairo University and the Egyptian Meteorological Authority on September 12–13 for a series of meetings under a joint U.S. Agency for International Development project to build capability in these Egyptian organizations for regional chemistry and climate modeling. Pickering gave presentations about applications of the WRF-Chem and Climate-WRF models, as well as on use of NASA satellite products for air quality applications. He also hosted a Cairo University graduate student during the week of September 17th for further training on running these models and using the satellite products.

NASA announced the signing of a Space Act Agreement between NASA and The Nature Conservancy of Virginia (TNC) for long term GPM GV operations of the NPOL radar at Oyster, Virginia was prepared.

October

Tom Hanisco (614) was interviewed by CTV News, the Prince George's County Community Television News station, about his new In situ airborne formaldehyde (ISAF) instrument. It flew on the DC-8 during the DC_3 campaign in Salina, KS in May–June, 2012. He discussed the role of formaldehyde in deep convection.

Maggie Hurwitz (614) participated in the American Meteorological Society's "Climate Café" on improving climate change communication in Washington, DC.

NASA's Applied Remote Sensing Training Program (ARSET), a 5-week online course, ended October 17th. The course was attended by nearly 80 applied end-users from state and Federal agencies in the United States and abroad learned about aerosol and trace gas products relevant to air quality applications. The project lead was **Ana Prados** (614) and the course was taught by **Pawan Gupta** (614), **Richard Kleidman** (613), **and Jacquie Witte** (614) (http://airquality.gsfc.nasa.gov/). This program also had a hands-on course component taught by **Pawan Gupta** on October 17–19 at the University of North Carolina, Chapel Hill**.**

NASA's Applied Remote Sensing Training Program (ARSET) was featured in the Spanish section of NASA's Earth Science Week Blog on October 18, http://climate.nasa.gov/esw2012espanol/blogs/?FuseAction=ShowBlog&NewsID=31. The blog discussed why teaching NASA science to decision makers is so important from the perspective of program lead **Ana Prados** (614).

The Aura, Aqua, and Terra missions have launched the REEL Science communication contest. This video contest challenged high school students to produce a two-minute video for younger students. The videos focused on one of 3 topics: ozone in the stratosphere, ship tracks and our environment, or the water of the water planet. Winning videos will be posted on NASA's website and winners will get to work with NASA scientists and communications staff to produce an earth science feature video next summer. Visit http://aura.gsfc.nasa.gov/reelscience for more information. **Virginia Butcher** (614).

November

Scott Braun (612) presented a talk on "NASA Tropical Cyclone Research—Applications of the Global Hawk" at a mini-workshop on Unmanned Aircraft Systems (UAS) for Environmental Monitoring in Silver Spring, MD, on November 8 organized by the Office of the Federal Coordinator for Meteorology (OFCM). The meeting summarized UAS activities and interests of federal government agencies and explored their needs, requirements, and priorities, with special emphasis on the potential use of the NASA Global Hawks for hurricane reconnaissance flights by NOAA and DoD.

Angie Kelly, EOS Mission Operations Manager and **Ginger Butcher** (614), Aura Education and Public Outreach Lead presented to the girls at Mount de Sales Academy in Catonsville on November 14. Angie spoke about growing up in the Philippines, raising a family in the United States, and then going on to be the first woman mission operations manager at NASA. She talked about her work managing the morning and afternoon constellations of Earth observing satellites and highlighted of a few other careers from the Women of Goddard book (http://www.nasa.gov/centers/goddard/news/features/2011/women-heritage.html). The talk concluded with a presentation about a career in Education and Public Outreach by Ginger and her activity "Engineer a Satellite" where students learn about instruments and subsystems of a satellite (http://aura.gsfc.nasa.gov/outreach/engineerAsatellite.html).

Rigoberto Roche, a summer intern under **Ali Tokay** (UMBC/612) was selected as the runner-up in the Science category during the NASA University Research Centers (URC) Virtual Poster Session and Symposium. Rigo is a biomedical engineering student at the Florida International University and was awarded for a summer internship at the NASA Goddard Space Flight Center through NASA Water Escapes program. His poster was entitled "An Experimental Study of the Small-Scale Variability of Rainfall."

NASA Applied Remote Sensing Training Program (ARSET) 5-week online course on flood and drought applications was held from November 6 - December 4. This live online course had over 100 registrants from state, federal, and international organizations in the US, Africa, Latin America, and Asia. NASA data and decision support tools relevant to applications were presented, including live demonstrations on data access. Project lead: **Ana Prados** (614). Course taught by **Amita Mehta** (612) and Cindy Schmidt (NASA/JPL). http://water.gsfc.nasa.gov/webinars/

December

Daniel Perez-Ramirez (U. Granada/612) presented a 5-day course on "Atmospheric Aerosol Measurements with Science Applications" at the Laboratory for Atmospheric Physics at the Universidad Mayor de San Andres in La Paz, Bolivia. Dr. Perez-Ramirez's visit to Bolivia is supported by a grant he received from Spain's Santander Bank. The goal of this grant program is to foster interaction between Spanish researchers and Latin American colleagues.

David Whiteman (612) presented two seminars at the Laboratory for Atmospheric Physics of the Universidad Mayor de San Andres (UMSA), La Paz, Bolivia. He first reviewed the history of lidar and laser development during the "Golden Era" of the 1960's. The second seminar gave an overview of Rayleigh and Mie scattering and the solutions of the lidar equation using the Klett and Raman approaches. UMSA possesses a backscatter lidar system that was the focus of much of Dr. Whiteman's activity during his fellowship. The lidar system has been upgraded so that the optical noise has been decreased by a factor of 25, the electrical noise by more than a factor of 10, and the signal has been increased by a factor of 2. Initial measurements with the upgraded system are now being taken.

7. ATMOSPHERIC SCIENCE IN THE NEWS

The following pages contain news articles and press releases that describe some of the Laboratory's activities during 2012.

NASA Cold Weather Airborne Campaign to Measure Falling Snow

01.12.12

WASHINGTON – Beginning Jan. 17, NASA will fly an airborne science laboratory above Canadian snowstorms to tackle a difficult challenge facing the upcoming Global Precipitation Measurement (GPM) satellite mission—measuring snowfall from space

GPM is an international satellite mission that will set a new standard for precipitation measurements from space, providing next-generation observations of worldwide rain and snow every three hours. It is also the first mission designed to detect falling snow from space.

"Snow is notoriously hard to measure as it falls," said Walter Petersen, the GPM ground validation scientist at NASA's Wallops Flight Facility in Virginia. "Snowflakes contain varying amounts of air and water, and they flutter, wobble and drift as they leave the clouds."

Knowing how "wet" a snowflake is allows scientists to measure overall water content. A wet, heavy snow can shut down a city, and melted snow is a crucial source of freshwater in many areas.

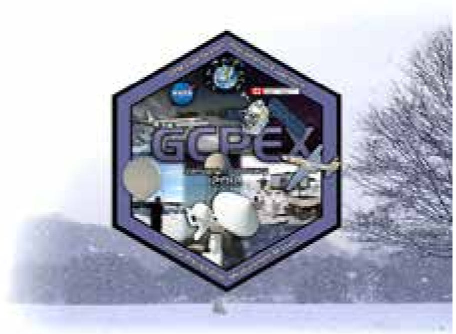
Working with Environment Canada, NASA's GPM Cold-season Precipitation Experiment (GCPEx) will measure light rain and snow in Ontario from Jan. 17 to Feb. 29. The field campaign is designed to improve satellite estimates of falling snow and test ground validation capabilities in advance of the planned launch of the GPM Core satellite in 2014.

NASA's DC-8 airborne science laboratory will fly out of Bangor, Maine, carrying radar and a radiometer that will simulate the measurements to be taken from space by GPM. At an altitude of 33,000 feet (10 kilometers), the DC-8 will make multiple passes over an extensive ground network of snow gauges and sensors at Environment Canada's Center for Atmospheric Research Experiments north of Toronto.

The GCPEx field experiment will help scientists match measurements of snow in the air and on the ground with the satellite's measurements.

"We will be looking at the precipitation and the physics of precipitation, such as snowflake types, sizes, shapes, numbers and water content," Petersen said. "These properties affect both how we interpret and improve our measurements."

GPM's Core satellite is being built at NASA's Goddard Space Flight Center in Greenbelt, Md., with instruments provided by NASA and its mission partner, the Japanese Aerospace and Exploration Agency (JAXA). The spacecraft will orbit Earth at a 65-degree inclination, covering the world from the Antarctic Circle to the Arctic Circle.



GCPEX logo. Credit: NASA

NASA Goddard engineer Zhaonan Zhang adjusts the Conical Scanning Millimeter-wave Imaging Radiometer, or CoSMIR, scan head prior to installation in NASA's DC-8 flying science laboratory. The instrument is being used in the GCPEx airborne study of snowfall in Canada and the northeastern United States. Credit: NASA / Tom Tschida

GPM will carry a microwave radiometer and a dual-frequency precipitation radar that distinguishes a snowflake's size and shape, which affects how much water it holds. Knowing these microphysical properties will lead to more accurate estimates of rain and snowfall, especially during winter and at high latitudes where snow is the dominant form of precipitation.

The Ontario region is prone to both lake effect snow squalls and widespread snowstorms. If the opportunity exists, the DC-8 also will fly over blizzards along the northeastern United States. While the DC-8 flies above the clouds, two other aircraft, one from the University of North Dakota and another from Canada, will fly through the clouds, measuring the microphysical properties of the raindrops and snowflakes inside.

Advanced ground radars will scan the entire air column from the clouds to the Earth's surface."These multiple measurements of snowfall provide a complete picture, a complete model, of the snowfall process from top to bottom," Petersen said.

NASA's Dryden Flight Research Center in Edwards, Calif., manages the DC-8 flights for the GCPEx mission. The aircraft is based at the center's aircraft operations facility in Palmdale, Calif. NASA's Marshall Space Flight Center in Huntsville, Ala., is providing aircraft tracking and guidance through the Real Time Mission Monitor, as well as GCPEx real-time data and personnel support for the ground instruments in Canada.

For more information on the GCPEx ground validation, visit: http://www.nasa.gov/gpm For broadcast video or imagery, visit: http://svs.gsfc.nasa.gov/goto?10890

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e! Science News

e! Science News

NASA's GCPEx mission: What we don't know about snow

Published: Wednesday, February 1, 2012 - 19:34 in Astronomy & Space

Predicting the future is always a tricky business -- just watch a TV weather report. Weather forecasts have come a long way, but almost every season there's a snowstorm that seems to come out of nowhere, or one that's forecast as 'the big one' that turns out to be a total bust. In the last ten years, scientists have shown that it is possible to detect falling snow and measure surface snowpack information from the vantage point of space. But there remains much that is unknown about the fluffy white stuff.

"We're still figuring out how to measure snow from space," says Gail Skofronick-Jackson, a specialist in the remote sensing of snow at NASA's Goddard Space Fight Center, Greenbelt, Md. "We're where we were with measuring rain 40 years ago."

Skofronick-Jackson is part of a team of scientists from NASA and Environment Canada who are running a large experiment in Southern Ontario to improve snow detection. Their GPM Cold-season Precipitation Experiment (GCPEx) supports the new Global Precipitation Measurement (GPM) mission whose Core satellite is scheduled to launch in 2014.

GPM is an international satellite mission that will unify and set new standards for precipitation measurements from space, providing the next-generation observations of rain and snow worldwide every three hours.

As part of their snow detection efforts, the GCPEx science team is collecting as much data as they can to improve understanding of snow dynamics inside clouds, because they relate to how snow moves through Earth's water and climate cycles.

Accurate snowfall measurements are important for more than just weather forecasts. Snow is one of the primary sources of water in mountainous regions. For example, the snow pack on the Sierra Nevada Mountains accounts for one-third of the water supply for all of California. The snowmelt that enters the water cycle in spring and summer provides both drinking water and irrigation for California's $37.5 billion dollar agricultural industry. Droughts and climate change are making the snow pack a shrinking water resource, and managers have a greater need than ever to know exactly how much water is locked in snow.

But to know that, scientists first have to know just how much water snow carries as it falls to the ground.

Rain vs. Snow

Figuring out how much water comes down as snow first requires being able to tell snow from rain. On the surface, it's obvious, rain is liquid and wet, snow is solid and frozen. But rain and snow often happen at the same time or snow can melt into rain.

To tell the difference between rain and snow from space, scientists use an instrument called a microwave radiometer. It works by measuring the microwaves that naturally radiate from Earth all the time. Different natural phenomena radiate at different frequencies. For example rain causes a response at lower frequency microwaves while falling snow affects higher frequency microwave measurements. A radiometer, like a car radio picking up different stations, picks up responses at different frequencies and thus distinguishes between rain and snow. The signal gets stronger for heavy rain or intense snow rates.

Currently radiometers on some satellites can tell the difference between rain and snow -- but only to a point. Complications occur where the frequencies respond to both liquid rain and falling snow or even to Earth's surface, says Skofronick-Jackson. "There's a mixed response in those channels, so you kind of have to know what you're looking at."

In those overlapping frequencies, what distinguishes rain from snow is temperature, size and shape, a current unknown in most precipitation detection.

"What we know about rain is that raindrops are spherical or slightly flattened spheres. So they all basically have one shape," says Skofronick-Jackson. "With snow we have so many different shapes."

Needles in a Stack of Snowflakes

Snowflakes come in a wide variety of shapes and sizes. Individual flakes can be long thin needles, hollow columns, or flat plates with millions of different patterns. Their fluffy shapes and sheer variety are what make measuring snow rates tricky.

"Raindrops are going to pretty much fall straight down as fairly dense liquid particles. Snowflakes wobble; they're blown by the wind. They're going to have all these different characteristics as to how they fall. And that makes a difference in what the satellite sees," says Skofronick-Jackson.

The variety of snowflake shapes also complicate estimates of how much water snow holds. A "wet" snow of fluffy flakes has more water per unit volume than "dry" snow. On the ground, the same physical volume of those types of snow contain very different amounts of water, and this water, called snowmelt, is what ultimately ends up in reservoirs, rivers and other sources of freshwater.

The GPM satellite will measure global precipitation, be it heavy tropical rain, moderate rain, light rain or snow. GPM's radar instrument, built by mission partner, the Japanese Aerospace Exploration Agency, provides essential measurements of the size of the flakes and how much water they hold. The radar works by actively sending out microwaves on two different frequencies. When the microwave pulses encounter a raindrop or snowflake, it reflects part of both pulses back to the radar's sensors. By timing the interval between when the pulse was sent and then received the radar knows how far away the particles are in the cloud.

Add up all the particles and you get a full picture of all the rain and snow in one weather event. "It's like a CAT-scan," says Skofronick-Jackson. "You can actually see layer by layer what's in the cloud."

Atmospheric Layer Cake With Marble Swirl Frosting

The atmosphere does not lend itself to easy understanding. Temperature, humidity and winds change with altitude, creating many layers of air with different properties. The topography of land surfaces and oceans affect global weather patterns. Those conditions then combine to create both short-term weather and long-term climate. Part of resolving that picture at high latitudes is to understand snow's dynamics inside clouds.

"We know most clouds don't have just one classic snowflake shape, but what we don't know is what are the mixtures of snowflake types," says Skofronick-Jackson.

By combining the broader radiometer measurements that distinguish liquid from ice and tell how much water the clouds hold with the vertical details provided by the radar, the GPM science team may be able to see what mixture of particles are falling to the ground, or if a snowflake makes it all the way to the ground at all.

"As they're falling, snowflakes will sometimes go through warm layers and start to melt and start to look like raindrops," says Skofronick-Jackson. "So do you call that rain or do you call that snow?"

Finding that line is one of the goals of the cold-season experiment.

How Many Ways Can You Measure a Snowflake?

The GPM GCPEx field mission is currently underway just north of Toronto, Canada in Egbert, Ontario. Located near Lake Huron, the region is prone to both lake effect snow squalls and widespread snowstorms. NASA is working with Environment Canada to measure snow as many ways as possible to match snow on the ground with snow in the clouds and with simulated satellite passes measured from aircraft flying overhead.

Instruments on the ground at the Center for Atmospheric Research Experiments measure the quantity of snow, how fast it falls and how much water it holds. Radar and radiometers on the ground also get an up-close look at the snow as it falls from clouds to the surface. Meanwhile, two research planes, the University of North Dakota's Citation and the Canadian National Research Council Convair 580, fly though the clouds measuring snowflake sizes and water content, temperature and cloud water. "They'll do spirals so you can see all the way from the top of the cloud to the bottom of the cloud," says Skofronick-Jackson.

Above the clouds at 33,000 feet, a third plane, NASA Dryden's airborne laboratory DC-8, carries NASA Goddard-developed Conical Scanning Millimeter-wave Imaging Radiometer (CoSMIR) radiometer and NASA's Jet Propulsion Laboratory-developed Airborne Precipitation Radar-2 (APR-2). Together these two instruments simulate the instruments that the GPM satellite will carry into orbit.

The datasets will complement current measurements made by radiometers on Earth-observing satellites Aqua and Soumi NPP and the Cloud Profiling Radar on CloudSat.

"What we can do with all these measurements is learn these relationships between what the radar and the radiometer sees, what's in the cloud, and what's falling out," says Skofronick-Jackson.

The GCPEx campaign, running from January 17 through February 29, is on its way to filling in that picture.

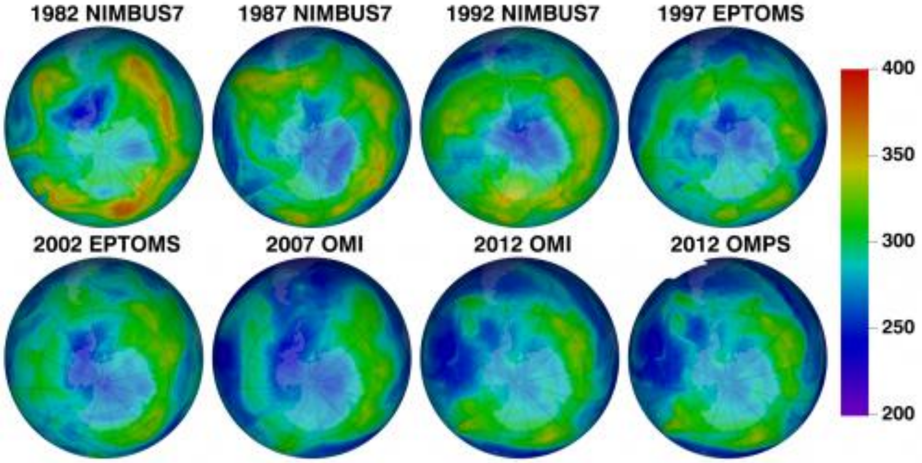
Source: NASA/Goddard Space Flight Center

Ozone suite on Suomi NPP continues more than 30 years of ozone data

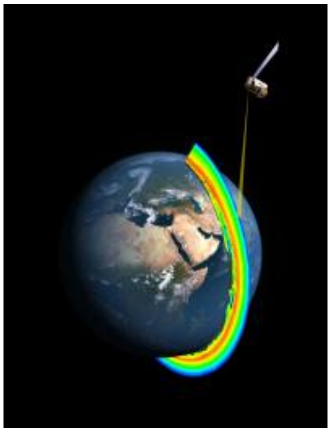
February 24, 2012
By Cynthia O'Carroll and John Leslie

A new satellite instrument suite is now sending back detailed information about the health of the Earth's ozone layer, the shield that protects the world's population from harmful levels of the sun's ultraviolet radiation.

The Ozone Mapper and Profiler Suite, or OMPS, is one of five new instruments flying aboard NASA's Suomi National Polar-orbiting Partnership satellite (NPP), which was launched on Oct. 28, 2011. Suomi NPP is the result of a partnership between NASA, the National Oceanic and Atmospheric Administration and the Department of Defense. OMPS continues an over three decade-long partnership between NASA and NOAA in studying ozone. OMPS consists of three instruments: the downward-looking nadir mapper and nadir profiler, and a new instrument called the limb profiler. OMPS data will contribute to observing the recovery of the ozone layer in the coming years. The layer is expected to recover from the effects of the ozone depleting substances like halons or chloroflurocarbons (CFCs) over the coming few decades. This recovery comes as a result of a world-wide agreement in 1987 that phased out the use of these ozone-depleting substances.



This shows the thickness of the Earth's ozone layer on January 27th from 1982 to 2012. This atmospheric layer protects Earth from dangerous levels of solar ultraviolet radiation. The thickness is measured in Dobson units, in this image, smaller amounts of overhead ozone are shown in blue, while larger amounts are shown in orange and yellow. These ozone measurements begin with the Nimbus 7 satellite; continue with the Earth Probe Total Ozone Mapping Spectrometer (EP TOMS); the Ozone Monitoring Instrument (OMI) aboard the Aura satellite; and the most recent, the Ozone Mapper Profiler Suite (OMPS) aboard the satellite Suomi National Polar-orbiting Partnership (NPP). Suomi NPP is a partnership between NASA, NOAA and the Department of Defense. Credit: NASA/NOAA



A cross-section of the Earth's ozone layer as measured by the limb profiler, part of the Ozone Mapper Profiler Suite that's aboard the Suomi NPP satellite. A new instrument, the limb profiler makes high vertical resolution measurements of the ozone layer, a shield that protects the Earth's surface from the sun's dangerous ultraviolet radiation. Smaller amounts of overhead ozone is shown in blue, while larger amounts are shown in orange and yellow. Suomi NPP is a partnership between NASA, NOAA and the Department of Defense. Credit: NASA/NOAA

"Ozone depletion has been a major concern for decades," said Mary Kicza, assistant administrator for NOAA's Satellite and Information Service. "Scientists need reliable observations of ozone from space and OMPS provides them."

"With the large ozone layer depletion seen in the Arctic in March 2011, it was critical to get OMPS into orbit for measurements in the Northern Hemisphere in March 2012", said Paul Newman, NASA scientist and co-chair of the United Nations Montreal Protocol Scientific Assessment Panel. It was the Montreal Protocol in the 1980s that identified and limited the use of ozone-depleting chemicals.

The nadir profiler measures the vertical distribution of ozone in a way that continues the long-term atmospheric ozone data record generated by the NOAA operational Solar Backscatter Ultraviolet Instruments (SBUV/2s) instrument. Ozone mapping began in 1978 with the NASA's Total Ozone Mapping Spectrometer (TOMS). The OMPS' nadir mapper transitions ozone mapping measurements from NASA research to NOAA operations, ensuring that this critical measurement will continue into the future.

The limb profiler is a experimental instrument that measures the distribution of ozone at higher vertical resolution by looking through the atmosphere on an angle. It's designed to continue NASA's measurements of high vertical resolution ozone profiles from the Microwave Limb Sounder on the EOS Aura, data key to understanding how changing greenhouse gases affect the recovery of the ozone layer.

The Suomi NPP team will continue initial checkouts as part of its commissioning activities until early March and then handoff operations to NOAA. NOAA will continue calibration and validation activities and leading to the processing and distribution of data to users around the world. The Suomi NPP mission is the bridge between NASA's Earth Observing System satellites and NOAA's Polar Operational Environmental Satellite (POES) to the next-generation Joint Polar Satellite System (JPSS), which NOAA will operate. The JPSS program, funded by NOAA, provides the ground segment for Suomi NPP.

NASA's Goddard Space Flight Center in Greenbelt, Md., manages the Suomi NPP mission for the Earth Science Division of the Science Mission Directorate at NASA Headquarters in Washington. NOAA and the Department of Defense funded the OMPS instrument. The Suomi NPP mission enables scientists to advance our knowledge of how the entire Earth system works by providing enhanced data for our nation's weather forecasting system and providing extended Earth system data records insight to scientists to better understand climate.

Provided by JPL/NASA
Read more at: http://phys.org/news/2012-02-ozone-suomi-npp-years.html#jCp

Dust dominates foreign aerosol imports to North America

08.02.12

NASA and university scientists have made the first measurement-based estimate of the amount and composition of tiny airborne particles that arrive in the air over North America each year. With a 3-D view of the atmosphere now possible from satellites, the scientists calculated that dust, not pollution, is the main ingredient of these imports.

According to a new analysis of NASA satellite data, 64 million tons of dust, pollution and other particles that have potential climate and human health effects survive a trans-ocean journey to arrive over North America each year. This is nearly as much as the estimated 69 million tons of aerosols produced domestically from natural processes, transportation and industrial sources. The results were published Aug. 2 in the journal Science.

"This first-of-a-kind assessment is a crucial step toward better understanding how these tiny but abundant materials move around the planet and impact climate change and air quality," says Hongbin Yu, lead author and an atmospheric scientist at the University of Maryland, College Park, and NASA's Goddard Space Flight Center in Greenbelt, Md.

Observing these microscopic airborne particles and quantifying their global impact on warming or cooling Earth remains one of the most difficult challenges of climate science. Dust and pollution particles rise into the atmosphere and can travel for days across numerous national boundaries before settling to Earth.

Data from several research satellites flying advanced observing technology developed and launched by NASA enabled the scientists to distinguish particle types and determine their heights in the atmosphere. They combined that information with wind speed data to estimate the amount of pollution and dust arriving over North America. The scientists used data from instruments on NASA's Terra satellite and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite, a joint effort between NASA and the French space agency, Centre National d'Etudes Spatiales.

Yu and colleagues estimated that dust crossing the Pacific Ocean accounts for 88 percent, or 56 milliontons, of the total particle import to North America every year. Dust movement is particularly active in spring, when the rise of cyclones and strong mid-latitude westerlies boost particle transport across the Pacific. Global aerosol transport models revealed Asia was a primary source of the dust reaching North America. About 60 to 70 percent comes from Asia, and the remaining 30 to 40 percent comes from Africa and the Middle East.

Dust particles are fine pieces of minerals that primarily come from dry, desert-like regions. Winds lift these lightweight particles high into the atmosphere where they meet even faster-moving winds capable of transporting them around the planet. Pollution particles, in contrast, come from combustion sources such as wildfires or agricultural fires and fossil fuel burning for power and industry. These particles are emitted close to the ground, making them of prime interest to air quality researchers and managers. High-altitude dust particles are less a concern for human health, but their impact on climate can be significant.

A dust plume arose over Inner Mongolia and on April 9, 2012, began its eastward journey over the Sea of Japan. New research shows that dust accounts for most of the 64 million tons of foreign aerosol imports that arrive in the air over North America each year. Credit: NASA Earth Observatory/Jeff Schmaltz

One such impact on climate is a cooling effect, brought about by dust and some pollution particles that reflect sunlight back to space. The team calculated that the imported particles account for one third of the reduction in solar radiation, or solar dimming, over North America. "Globally this can mask some of the warming we expect from greenhouse gases," says Lorraine Remer, an atmospheric scientist at University of Maryland, Baltimore County, and co-author on the study.

Climate change brought about by greenhouse gases could influence the relevance of dust in the future, according to Remer. "Desertification and reclamation – land use modifications that change the exposure of dusty soils to wind erosion – are going to have a big impact on particle distribution and climate around the planet," she says.

The study poses new questions about the magnitude of the particles' indirect effects on local weather and climate. Dust and pollution could alter wind circulation, foster cloud growth and affect rainfall patterns. Soot and dust particles that land on snow, most likely in the western United States, could speed the melt of the snowpack and affect water supplies.

Kathryn Hansen
NASA’s Earth Science News Team
Goddard Space Flight Center, Greenbelt, Md.

Interview With Scott Braun About NASA's Upcoming Hurricane Campaign

by Rob Gutro for Goddard Space Flight Center
Greenbelt MD (SPX) Aug 06, 2012

Dr. Scott Braun, Principal Investigator of the HS3 Mission. Credit: NASA.

Scott Braun is the Hurricane Severe Storm Sentinel (HS3) mission principal investigator and a research meteorologist at NASA's Goddard Space Flight Center in Greenbelt, Md. Scott studies hurricanes from the inside out. HS3 is a five-year mission specifically targeted to investigate hurricanes in the Atlantic Ocean basin.

In his role as Principal Investigator, Scott leads a diverse team of hurricane and instrument scientists to design and conduct experiments using NASA's two Global Hawk unmanned aircraft to understand better the meteorological conditions that favor storm formation and often lead to the development of major hurricanes.

The campaign is set to take to the sky this September from Wallops Island, Va. Scott recently answered some questions about the HS3 mission:

Q: What is the biggest difference between past NASA hurricane field campaigns and HS3? Will the two Global Hawks have different instruments onboard?

A: The key differences from previous NASA hurricane field campaigns is that HS3 is a multi-year (2012-2014) rather than single year effort.It will utilize two of the unmanned Global Hawk aircraft flying from the U. S. east coast rather than one Global Hawk flying from the west coast as was the case during the Genesis and Rapid Intensification Processes (GRIP) campaign in 2010. (For information about GRIP, go to: www.nasa.gov/GRIP).

Three of the instruments flying on the HS3 mission had flown in GRIP, but on two separate aircraft. Now they will fly together on one Global Hawk (called the over-storm aircraft) to observe the inner-core region of hurricanes. The second Global Hawk (called the environmental aircraft) will be equipped with instruments that were not part of previous campaigns and will sample the large-scale environment of storms to see if conditions are favorable for storm formation and intensification.

Q: How will the mission work? Every time a hurricane is approaching, will the Global Hawk fly to meet it? How far and how long the planes will fly?

A: We will not be flying every storm, but will select storms that are likely to yield the best science. We are in the field for only five weeks and have science flight hours for only about 10-11 flights. Depending on how we use the flight hours, we could do five flights each for two storms or two flights each for five storms, or something like that.

A lot will depend on the storms that occur and whether we think they are events from which we have a lot to learn. In previous campaigns with manned aircraft based in a specific location, we had to wait for storms to come close to the U.S.

Because the Global Hawks can fly for up to about 26-28 hours and have a range of more than 12,000 miles, we can reach anywhere in the Atlantic Ocean basin, so we can either choose to spend a smaller amount of time over a storm in the Central Atlantic or spend a great deal more time over storms in the Western Atlantic, Caribbean, or Gulf of Mexico.

Q: How these unmanned aircraft are controlled? They are equipped with all instruments on every flight?

A: The aircraft are controlled from a flight operations room on the ground. Normal autonomous control of the Global Hawk is conducted via the aircraft's autopilot system using a pre-programmed mission plan.

However, to accommodate changes in flight path requested by mission scientists, the pilot can alter the flight path at any time and conduct precise manual aircraft navigation with the insertion of custom "way points." At all times, however, the aircraft is under the control of the onboard mission computer that ensures that the aircraft is under controlled flight.

Since we have two [Global Hawk] aircraft with different instrument payloads, the instruments on a given flight will depend on whether we send our environmental or over-storm aircraft out to a storm. Often we may start with the environmental aircraft and then immediately upon landing, send out the over-storm aircraft. Depending on how the storm changes, we might then decide to repeat the sequence or alter the order of flights or stop flights all together.

Q: What is the Saharan Air Layer, and why do you think it has an impact on the intensity change of hurricanes? What is the importance of studying it?

A: The Saharan Air Layer, or SAL for short, is a very warm, dry dusty air mass that comes off of the Saharan desert along with the African Easterly Waves that often spawn hurricanes. There have been some studies in the past that have argued that the SAL actually enhances thunderstorm activity in such a way as to favor the growth of the waves and eventually tropical cyclones.

More recently, several studies have reached the opposite conclusion and have argued that the SAL actually suppresses storm development, so we are going out to try to determine what effect, if any, the SAL really has on Atlantic storms.

Q: How will you map the deep convection (rising air that forms thunderstorms) in the inner core? Will the Global Hawk fly through a hurricane?

A: The Global Hawk will not fly through the hurricanes. Because its flight altitude is about 18-19 km (11.1 to 11.8 miles), it will actually fly above the storms with sophisticated instruments that will be able to measure the precipitation and wind structure within the storm.

The most important of these on the over-storm aircraft is the High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), which is a Doppler radar capable of mapping out the three-dimensional patterns of winds and rain in the storm.

Also onboard will be a microwave radiometer that measures the surface rain and wind speed that will help to map out the extent of the strong surface winds in the core of the storm and another microwave instrument that will measure temperature and humidity in the near environment of the storm and the warming temperatures in the eye of the storm.

Q: Which of the instruments is the most important or precise? Why?

A: On the over-storm aircraft, the HIWRAP radar is the most important because of its ability to map the three-dimensional structure of the winds and rain in the eyewall and rainbands of the storm. It will provide the most information on how the storm is intensifying and the role that intense thunderstorms play in that process.

On the environmental aircraft, the most important instrument is the dropsonde system. It releases an instrument package from the aircraft that then descends down to the surface while measuring temperature, humidity, and winds. We can drop up to 88 of these over the course of a flight to map out the structure of the environment around the storm. Dropsondes are never released near land or when other aircraft are in the vicinity, so there is no hazard to anyone beneath the aircraft.

Q: Will instruments only be on the Global Hawks, or will there be some on the ground? How will all the data gathered be examined?

The HS3 mission only involves data collected from the aircraft, but of course, researchers will utilize all data available including any land-based observations and especially satellite observations. It is difficult to describe the method by which the data is analyzed since different researchers may use different methodologies.

However, the data will be combined usually by placing all of the observations in a reference frame that moves with the storm. In some cases, sophisticated software is used to merge all of the different types of data into a single analysis. In other cases, the data might be combined with a numerical forecast model through a process known as data assimilation.

This approach uses the model information and observations to produce the best possible analysis and, in some cases, simulations of storms that can then be used for analysis of the physical processes involved in storm formation and intensification.

Q: After the mission ends, will it be possible to better predict a hurricane's intensity and track?

It is certainly our goal to improve our understanding of how hurricanes form and what processes control their intensity, knowledge that should prove beneficial to predicting hurricanes. We expect the data will be used to improve the numerical forecast models that are used as guidance to forecast intensity changes, but which currently do not show sufficient skill.

The observations may reveal shortcomings in the model physics or in the way the [computer] models describe the initial structure of the storm or its environment. We also hope to demonstrate the utility of the Global Hawk and the instruments as an observing platform that could be used by operational agencies to better monitor storms in the future.

e! Science News

NASA's new way to track formaldehyde

Published: Thursday, August 9, 2012 - 15:06 in Astronomy & Space

NASA

NASA scientist Tom Hanisco is helping to fill a big gap in scientists' understanding of how much urban pollution -- and more precisely formaldehyde -- ultimately winds up in Earth's upper atmosphere where it can wreak havoc on Earth's protective ozone layer. He and his team at NASA's Goddard Space Flight Center in Greenbelt, Md., have developed an automated, lightweight, laser-induced fluorescence device that measures the levels of this difficult-to-measure organic compound in the lower troposphere and then again at much higher altitudes. The primary objective is determining how much pollution a storm can transport through convection and then using those insights to improve chemistry-climate models. "It's a major problem in modeling knowing how to treat transport and clouds," Hanisco explained.

In the spring, he flew the In-Situ Airborne Formaldehyde Instrument for the first time on a NASA DC-8 research aircraft, a former passenger airplane that can fly up to 43,000 feet.

Size and Sensitivity

"People like this instrument because it's small, sensitive, and easy to maintain," said Hanisco. The instrument weighs only 60 pounds, and therefore is easily installed inside other research aircraft, including NASA's ER-2, Global Hawk, and WB57, which fly at much higher altitudes. In addition, it's automated and doesn't require anyone onboard to operate it, Hanisco said.

Prior to its development, only one other airborne instrument could measure formaldehyde. That instrument, however, weighed 600 pounds, required an onboard operator, and used a less-sensitive measurement technique -- absorption spectroscopy -- to gather data.

"I've been doing laser-induced fluorescence on other molecules for a while," Hanisco said, explaining why he sought and received Goddard Internal Research and Development funds to apply the measurement technique to a formaldehyde-sensitive instrument. "Formaldehyde isn't measured well at high altitudes. There was a real need for improvement."

With laser-induced fluorescence (LIF), a laser first illuminates the species of interest and "then you watch it fluoresce. It is a single photon-counting instrument," Hanisco said. Consequently, it's faster and more sensitive -- even at concentrations in the parts per trillion, he said.

The DC-8 campaign in Kansas, sponsored by the National Center for Atmospheric Research's Deep Convective Clouds and Chemistry Project, bore out the wisdom of his pursuit, proving that his instrument offered a factor-of-10 improvement in size, sensitivity, and complexity. During that campaign, a DC-8 flew as low as 500 feet above the ground and sampled air entering a storm. It then spiraled up to 30,000 to 40,000 feet and measured the air coming out at the top of the storm.

'Big Step Forward'

The instrument found that 30 to 40 percent of the formaldehyde produced in the "boundary" layer -- the lowest part of the troposphere closest to Earth's surface -- was transported to the upper troposphere during storms. "That number is a rough guideline, but we didn't have it before. Every storm is different, but knowing how much air gets through is a big step forward."

Hanisco attributes the instrument's success to its greatly simplified design and a new fiber-laser system that is smaller and less expensive than those used in other LIF-type instruments. He also attributes its success to a new air-sampling system, which features a glass- and Teflon-coated tube that draws in and directs air into the instrument's detection cell. Though the polymer-coated sampling system allows air to flow quickly, its surface prevents particles from sticking -- particularly useful because they could corrupt results. "We had to work hard to ensure that the sampling system was every bit as good as the detection," Hanisco said.

Hanisco anticipates many other flight opportunities in the future. "There was a real need for this instrument. There aren't a lot of instruments out there doing this."

Source: NASA/Goddard Space Flight Center

The Washington Post

NASA drone spies on tropical storm Nadine

By Jason Samenow

Overnight, tropical depression 14 (TD14) gained enough intensity to earn the name Nadine, the 14th tropical storm of the 2012 Atlantic hurricane season. Our tropical weather expert, Brian McNoldy says he could only find two others years in 160 years of records in which the 14th storm formed sooner: 1936 and 2011.

Nadine is on a projected path that threatens no land area according to the National Hurricane Center, but a NASA field campaign is taking full advantage of this storm to get deeper insight into how hurricanes develop and intensify.

Flight path of NASA unmanned aircraft and its position over then tropical depression 14 (now Nadine) as of 5:30 p.m. EDT Tuesday. Its altitude at the time was 60,300 feet. (NASA)

Related: From tropical disturbance to hurricane: To be or not to be?

On Tuesday, NASA sent an unmanned Global Hawk into TD14/Nadine on a 26 hour mission to sample the storm's environment. It is the longest continuous period a storm has ever been investigated, considerably longer than the capabilities of manned Air Force Hurricane Hunter planes. Climate Central's Andrew Freedman put it this way: "To put that [26 hour flight] in further perspective, the longest regularly scheduled passenger flight is between Singapore and Newark, N.J., which clocks in at a comparatively paltry 18 hours and 55 minutes."

One of two Global Hawks NASA is using to investigate tropical weather systems (NASA) The drone that gazed down on Nadine is one of two Global Hawks NASA will dispatch from Wallops Island, Va. to collect data on tropical systems through early October and again in 2013 and 2014.

The planes are operated from ground control stations at Wallops and Dryden Flight Research Center at Edwards Air Force Base, Calif. The mission is formally known as the Hurricane and Severe Storm Sentinel (HS3).

NASA video overview of HS3

Reaching altitudes as high as 60,000 feet, the Hawks can fly above the highest-penetrating storms, while its suite of cutting-edge instruments can sense the air all the way down to the ocean surface.

Link: An interactive view of the Hawk aircraft

The two Hawks contain several sensors to take measurements - one focusing on the storm environment, the other - the "over storm Hawk" - which hones in on storm attributes like wind and rain rates.

The Environmental Global Hawk

“The primary objective of the environmental Global Hawk is to describe the interaction of tropical disturbances and cyclones with the hot, dry and dusty air that moves westward off the Saharan desert and appears to affect the ability of storms to form and intensify,” said Scott Braun, a NASA research meteorologist.

The suite of instruments includes:

* A Cloud Physics Lidar (CPL), which measures clouds structure and aerosols (dust, sea salt and smoke particles)

* A scanning high-resolution interferometer sounder (S-HIS), which can sense temperatures and water vapor from the surface through the atmosphere

* The Advanced Vertical Atmospheric Profiling System (AVAPS), which ejects small sensors tied to parachutes (cool!) to measure winds, temperature and humidity

The Over Storm Hawk

“Instruments on the ‘over-storm’ Global Hawk will examine the role of deep thunderstorm systems in hurricane intensity change, particularly to detect changes in low-level wind fields in the vicinity of these thunderstorms,” said Braun.

The suite of instruments includes:

* The High Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP), which measures cloud structure and winds in three dimensions

* The High-Altitude MMIC Sounding Radiometer (HAMSR), which uses microwave wavelengths to measure temperature, water vapor, and precipitation from the top of the storm to the surface

* A Hurricane Imaging Radiometer (HIRAD) which measures surface winds and rain rates

It’s too soon to evaluate how much valuable information this mission is collecting compared to manned aircraft such as Hurricane Hunters. But Climate Central’s Freedman says if the mission proves successful, the Hawks “might one day replace some of those conventional planes as a mainstay of hurricane recon work.”

By Jason Samenow | 11:38 AM ET, 09/12/2012

e! Science News

Discovering the Ozone Hole: Q&A with Pawan Bhartia

09.17.12

On Sept. 16, 1987, representatives from nations around the world drafted a landmark treaty known as the Montreal Protocol. This step marked the beginning of the international agreement to phase out substances that deplete Earth's protective ozone layer. Now, 25 years later, NASA satellites continue to provide clear snapshots of a generally stabilized Antarctic ozone hole as it cycles toward its annual maximum depth by late September or early October.

The protocol is hailed as an international policy success story. That success, however, rests on the ingenuity of numerous scientists involved with the initial discovery and analysis of the then-mysterious atmospheric phenomenon.

In 1977, Pawan Bhartia – known by colleagues as P.K. – had finished a Ph.D in physics and entered a bleak job market. The only somewhat-related opportunity listed in the newspaper's classifieds section was for the position of atmospheric scientist with a NASA contractor, Systems and Applied Sciences in Maryland. He applied, got the job, and had no way to foresee that he was about to play a role in what he and many others now call an "unparalleled environmental success story" – the discovery and stabilization of the Antarctic ozone hole.

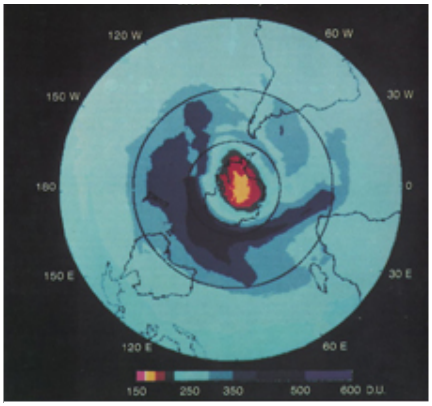
Up to, during and after the discovery, Bhartia worked as part of the Ozone Processing Team to process and produce ozone data from satellites in NASA's Nimbus Program. Kathryn Hansen of NASA's Earth Science News Team talked with Bhartia, now in his 21st year as an atmospheric scientist at NASA's Goddard Space Flight Center in Greenbelt, Md., for the behind-the-scenes story.

What was your motivation for studying ozone?

When I started working on ozone in 1977, there was not a known issue with the ozone layer and we weren't worried about it thinning out. Instruments I was working on weren't designed for observing that. Starting with Nimbus-4 in 1970, we simply wanted to measure the atmosphere. It was curiosity-driven research.

One of those instruments was an ozone sensor. Since then about a dozen instruments on different satellites – improved versions of that original instrument – have flown, giving us a nearly continuous measurement. They measure the ozone very high,

Pawan Bhartia is an atmospheric scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. **Credit:** NASA



Ozone was a hot topic among scientists an August 1985 meeting in Salzburg, Austria, a few days after Pawan Bhartia presented the first satellite image of the ozone hole. In attendance were Donald Heath, who initiated the ozone measurement program at Goddard in the late 1960s, and the late Sherry Rowland, who later received the Noble Prize for ozone layer research. **Credit:** Courtesy of Mary Beth Cullen

At an August 1985 meeting in Prague, Pawan Bhartia presented this satellite-based image that revealed for the first time the size and magnitude of the ozone hole. **Credit:** NASA

primarily around 16 miles (25 kilometers) up. That's the ozone
important for essentially soaking up the UV light from the sun that can cause skin cancer. The layer is critical for the survival of all species, and without it life on land would not have evolved. But because it's so high up, nobody prior to the late 1970s worried about depleting it.

Why did people start to worry about depleting the ozone?

By the time Nimbus-7 was launched in October 1978, the ozone layer was getting to be a hot topic. Two scientists in California had discovered a new mechanism by which CFCs, the gas used in everything from spray cans to air conditioners, can destroy ozone. It was a very common, non-toxic gas that isn't readily destroyed by nature like most pollutants. Because of its long life it can slowly seep up high into atmosphere and start destroying the ozone layer.

That discovery happened right around time of launch of the Nimbus-7 satellite in October 1978. There was a lot of pressure on us from the science community and from Congress to show what was happening to the ozone. The problem was that the satellite was designed to last one year – it ended up lasting 14 – and it was not designed for tracking small changes in the ozone layer that the scientists were predicting at that time. So we were under lot of pressure to come up with a good measurements to verify what scientists were predicting based on their models.

When did the so-called ozone hole appear over Antarctica?

Something happened in 1984 that was pretty remarkable. The ozone hole appeared out of nowhere. It just showed up in the data. It happened very quickly. In 1981 there were hints, and not until 1983 or so could you see it clearly.

Based on the analysis of long-term datasets of ozone from two ground-based stations in Antarctica, British Antarctic Survey scientists first discovered the ozone depletion and reported their observations in May 1985 in the journal Nature. But the problem was that people didn't know what to make of it. No one had any idea of the area that this phenomenon covered. People were wondering why there was no corroborating evidence from NASA satellites.

What was the reason for the wait?

We were still trying to figure it out. We thought maybe it's an instrumental effect, or maybe it's something else. We tried to take our time and make sure the hole was real. By December 1984, we had high degree of confidence that the hole was a real effect. We submitted a paper to a conference in Prague that was held in August 1985. My presentation showing the size and magnitude of the event, later called the "ozone hole," was the first time everyone knew it was such a huge event. All hell broke loose, particularly in the media.

People were scared and thought this could be a real disaster that could kill us, give us cancer. But the significant ozone loss was not happening in areas where people were living. It was occurring mostly over Antarctica. There are penguins there, but no human beings, and it happens for only two months a year. Regardless, it had a huge impact on people.

Is this what led to the Montreal Protocol?

Yes, the discovery ultimately led to the 1987 Montreal Protocol. That was remarkable. People only had to look at a picture to physically see atmospheric chemistry. It didn't take much persuasion to convince the policy makers to take action.

Still, at that time we didn't know the exact mechanism. The British scientists speculated it was CFCs, and they turned out to be partly right. That's also where NASA played a large role, through later work toward figuring out the cause. NASA conducted several field experiments in Antarctica with ground-based instruments, balloons, and aircraft instruments provided by scientists all around the world. The first field mission was the National Ozone Expedition (NOZE) in 1986. These experiments and laboratory work in many institutions helped explain how the CFCs were involved in the formation of ozone hole.

Surface chemistry on ice particles plays a critical role. Though this field had grown rapidly in recent years, in the 1980s this was a new thing. Some reactions that don't take place in the gas phase happen faster and more readily on a surface. This was the case for ozone depletion. The chemical reaction between ozone and certain types of human-produced gases was taking place on the surface of ice particles in clouds. That's not an easy thing to study, and the 1995 Nobel Prize was given to the scientists who had figured that out.

Could that chemistry have happened here in the U.S.?

The type of ice cloud chemistry that creates the ozone hole occurs primarily in the polar regions. But it has now been found that given a sufficient amount of CFCs, a similar thing can happen anywhere. In fact if CFCs had not been regulated, NASA simulations show that we would have had more than 50 percent ozone depletion here. In 1985 we didn't know enough to make predictions for the mid latitudes, but in the last five years new measurements tell us we could have destroyed ozone elsewhere. It's scary to think what would have happened.

That's what would have happened – what did happen?

The Antarctic hole is stabilizing now and maybe slowly recovering. Polar regions vary from month to month and can have ozone decrease by 40 percent in springtime and by about 10 percent other times of the year. The maximum change from 1970 to 1990 here in the mid-latitudes was an ozone layer decrease of about 5 percent. That causes about a 5 percent increase in UVB, the type that causes skin cancer. That is very small. Most people who study health effects study it at a 50 percent increase in UVB exposure. Skin cancer has increased but no link can be attributed to ozone loss, it's most likely because of lifestyle changes. Tropical regions have had essentially no change in the ozone layer.

Are we still tracking the hole and learning anything new?

The ozone layer is now on its way to full recovery. Our focus now is to make sure that it is healing as expected. The recently launched Suomi-NPP satellite has a new generation ozone-monitoring instrument called OMPS. Copies of this instrument are planned for future satellites.

Changes in the ozone hole now are not significantly driven by changes in CFCs, but instead driven by year-to-year changes in weather in the stratosphere. While the hole is no longer an issue from an environmental perspective, people continue to be drawn to the quality of the satellite pictures that come out each year at the time it reaches its maximum depth. Like two snowflakes, two ozone holes are never alike. It's not a scary event anymore, but a beautiful event.

Kathryn Hansen
NASA's Earth Science News Team

e! Science News

Cutting-edge technology makes NASA's hurricane mission a reality

Published: Tuesday, September 25, 2012 - 17:02 in Astronomy & Space

NASA

Cutting-edge NASA technology has made this year's NASA Hurricane mission a reality. NASA and other scientists are currently flying a suite of state-of-the-art, autonomously operated instruments that are gathering difficult-to-obtain measurements of wind speeds, precipitation, and cloud structures in and around tropical storms. "Making these measurements possible is the platform on which the instruments are flying," said Paul Newman, the deputy principal investigator of NASA's Hurricane and Severe Storm Sentinel (HS3), managed by NASA's Goddard Space Flight Center in Greenbelt, Md. HS3 will use NASA's unmanned Global Hawks, which are capable of flying at altitudes greater than 60,000 feet with flight durations of up to 28 hours -- capabilities that increase the amount of data scientists can collect. "It's a brand-new way to do science," Newman said.

The month-long HS3 mission, which began in early September, is actually a more robust follow-on to NASA's Genesis and Rapid Intensification Processes (GRIP) experiment that scientists executed in 2010. Often referred to as "GRIP on steroids," HS3 is currently deploying one instrument-laden Global Hawk from the NASA Wallops Flight Facility on Virginia's Eastern Shore to look at the environment of tropical storms. In 2013 and 2014, a second Global Hawk will be added that will focus on getting detailed measurements of the inner core of hurricanes.

Without this new aircraft, developed originally for the U.S. Air Force to gather intelligence and surveillance data, the team says the mission wouldn't be possible.

The Global Hawk's ability to fly for a much longer period of time than manned aircraft will allow it to obtain previously difficult-to-get data. Scientists hope to use that data to gain new insights into how tropical storms form, and more importantly, how they intensify into major Atlantic hurricanes -- information that forecasters need to make better storm predictions, save lives, and ultimately prevent costly coastal evacuations if a storm doesn't warrant them.

"Because you can get to Africa from Wallops, we'll be able to study developing systems way out into the Atlantic," Newman explained. "Normal planes, which can fly for no more than about 10 hours, often miss the points where storms intensify," added Gerry Heymsfield, a Goddard scientist who used NASA Research and Development funding to create one of the mission's six instruments, the High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP). "With the Global Hawks, we have a much higher chance of capturing these events. Furthermore, we can sit on targets for a long time."

Just as important as the aircraft are the new or enhanced instruments designed to gather critical wind, temperature, humidity, and aerosol measurements in the environment surrounding the storm and the rain and wind patterns occurring inside their inner cores, they added. "The instruments bring it all together," Newman said. "We didn't have these instruments 10 years ago."

The Global Hawk currently on deployment at Wallops is known as the "environmental" aircraft because it samples the environment in which hurricanes are embedded. It carries three instruments.

A Goddard-provided laser system called the Cloud Physics Lidar (CPL) is located in the nose. CPL measures cloud structures and aerosols, such as dust, sea salt particles, and smoke particles, by bouncing laser light off these elements. An infrared instrument called the Scanning High-resolution Interferometer Sounder (S-HIS), provided by the University of Wisconsin in Madison, sits in the belly of the aircraft. It measures the vertical profile of temperature and water vapor.

At the tail end is a dropsonde system provided by the National Center for Atmospheric Research and the National Oceanic and Atmospheric Administration. This system consists of 88 paper-towel-roll-sized tubes that are ejected much like a soda can in a vending machine. As the sensor drops, a parachute slows its descent, allowing the sensor to drift down through the storm while measuring winds, temperature, pressure, and humidity.

In 2013 and 2014, working in tandem with its environmental counterpart, will be a second Global Hawk, known as the "over-storm" aircraft. It will sample the internal structure of hurricanes. It, too, will carry three instruments.

Heymsfield's HIWRAP, for example, will be situated in the belly of the Global Hawk and will be responsible for sampling the cores of hurricanes. Similar to a ground radar system, but pointed downward, HIWRAP measures rain structure and winds, providing a three-dimensional view of these conditions.

Also onboard this craft will be a microwave system called the High-Altitude MMIC Sounding Radiometer (HAMSR), created by NASA's Jet Propulsion Laboratory in Pasadena, Calif. Located in the aircraft's nose, this instrument uses microwave wavelengths to measure temperature, water vapor, and precipitation from the top of the storm to the surface.

At the other end of the aircraft in the tail section will be the Hurricane Imaging Radiometer (HIRAD) provided by NASA's Marshall Space Flight Center in Huntsville, Ala. This microwave instrument measures surface wind speeds and rain rates in an unusual way. It collects this data by measuring the amount of "foaminess" in ocean waters. According to Newman, the amount of foaminess is proportional to wind speeds at the surface.

Although all six instruments measure different conditions, they share one important characteristic: all operate autonomously and deliver data to scientists in real-time -- another scientific advance. In the past, aircraft instruments, which often required the presence of a scientist to operate them, would record captured data. Only after the aircraft landed could scientists begin evaluating what they had collected.

With the Global Hawk, however, the data are transmitted to the ground in real-time. Should conditions warrant, the science team can direct the pilot, who flies the aircraft from a computer console on the ground, to change course or tweak the pre-programmed flight path in some way to maximize or improve the data they are gathering. "With the Global Hawk and these instruments, we can make better decisions," Heymsfield added.

The five-year mission will continue through 2014, at which time the team hopes to have dramatically improved their understanding of how storms intensify. "The insights we get will benefit forecasters," Newman said. "What we hope to do is take this technique and make it part of the operational forecast infrastructure."

The HS3 mission is supported by several NASA facilities including Wallops, Goddard, NASA's Dryden Flight Research Center at Edwards Air Force Base, Calif., Ames Research Center, Moffett Field, Calif.; Marshall Space Flight Center, Huntsville, Ala.; and the Jet Propulsion Laboratory, Pasadena, Calif. In addition, the mission also involves collaborations with various partners from government agencies and academia.

HS3 is an Earth Venture mission funded by NASA's Science Mission Directorate in Washington. Earth Venture missions are managed by NASA's Earth System Science Pathfinder Program at NASA's Langley Research Center, Hampton, Va. The HS3 Project itself is managed by the Earth Science Project Office at NASA's Ames Research Center.

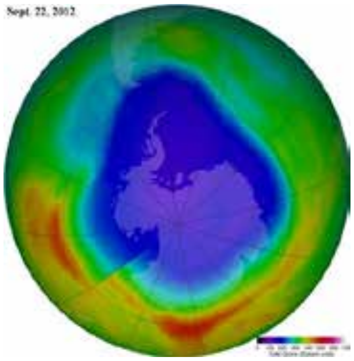
For more information about the NASA GRIP mission, visit: www.nasa.gov/grip

Source: NASA/Goddard Space Flight Center

e! Science News

2012 Antarctic ozone hole second smallest in 20 years

Published: Wednesday, October 24, 2012 - 16:39 in Earth & Climate



NASA/Goddard Space Flight Center

The average area covered by the Antarctic ozone hole this year was the second smallest in the last 20 years, according to data from NASA and National Oceanic and Atmospheric Administration (NOAA) satellites. Scientists attribute the change to warmer temperatures in the Antarctic lower stratosphere. The ozone hole reached its maximum size Sept. 22, covering 8.2 million square miles (21.2 million square kilometers), or the area of the United States, Canada and Mexico combined. The average size of the 2012 ozone hole was 6.9 million square miles (17.9 million square kilometers). The Sept. 6, 2000 ozone hole was the largest on record at 11.5 million square miles (29.9 million square kilometers).

"The ozone hole mainly is caused by chlorine from human-produced chemicals, and these chlorine levels are still sizable in the Antarctic stratosphere," said NASA atmospheric scientist Paul Newman of NASA's Goddard Space Flight Center in Greenbelt, Md. "Natural fluctuations in weather patterns resulted in warmer stratospheric temperatures this year. These temperatures led to a smaller ozone hole."

Observing Earth's Ozone Layer

Atmospheric ozone is no longer declining because concentrations of ozone-depleting chemicals stopped increasing and are now declining.

The ozone layer acts as Earth's natural shield against ultraviolet radiation, which can cause skin cancer. The ozone hole phenomenon began making a yearly appearance in the early 1980s. The Antarctic ozone layer likely will not return to its early 1980s state until about 2065, Newman said. The lengthy recovery is because of the long lifetimes of ozone-depleting substances in the atmosphere. Overall atmospheric ozone no longer is declining as concentrations of ozone-depleting substances decrease. The decrease is the result of an international agreement regulating the production of certain chemicals.

This year also marked a change in the concentration of ozone over the Antarctic. The minimum value of total ozone in the ozone hole was the second highest level in two decades. Total ozone, measured in

Dobson units (DU) reached 124 DU on Oct. 1. NOAA ground-based measurements at the South Pole recorded 136 DU on Oct. 5. When the ozone hole is not present, total ozone typically ranges from 240-500 DU.

This is the first year growth of the ozone hole has been observed by an ozone-monitoring instrument on the Suomi National Polar-orbiting Partnership (NPP) satellite. The instrument, called the Ozone Mapping Profiler Suite (OMPS), is based on previous instruments, such as the Total Ozone Mapping Spectrometer (TOMS) and the Solar Backscatter Ultraviolet instrument (SBUV/2). OMPS continues a satellite record dating back to the early 1970s.

In addition to observing the annual formation and extent of the ozone hole, scientists hope OMPS will help them better understand ozone destruction in the middle and upper stratosphere with its Nadir Profiler. Ozone variations in the lower stratosphere will be measured with its Limb Profiler.

"OMPS Limb looks sideways, and it can measure ozone as a function of height," said Pawan K. Bhartia, a NASA atmospheric physicist and OMPS Limb instrument lead. "This OMPS instrument allows us to more closely see the vertical development of Antarctic ozone depletion in the lower stratosphere where the ozone hole occurs."

NASA and NOAA have been monitoring the ozone layer on the ground and with a variety of instruments on satellites and balloons since the 1970s. Long-term ozone monitoring instruments have included TOMS, SBUV/2, Stratospheric Aerosol and Gas Experiment series of instruments, the Microwave Limb Sounder, the Ozone Monitoring Instrument, and the OMPS instrument on Suomi NPP. Suomi NPP is a bridging mission leading to the next-generation polar-orbiting environmental satellites called the Joint Polar Satellite System, will extend ozone monitoring into the 2030s.

NASA and NOAA have a mandate under the Clean Air Act to monitor ozone-depleting gases and stratospheric depletion of ozone. NOAA complies with this mandate by monitoring ozone via ground and satellite measurements. The NOAA Earth System Research Laboratory in Boulder, Colo., performs the ground-based monitoring. The Climate Prediction Center performs the satellite monitoring.

Source: NASA/Goddard Space Flight Center

e! Science News

High-Flying aircraft helps develop new science instruments

Tuesday, September 18, 2012 – 11:03 in Earth & Climate

Sep. 17, 2012 — Over the next few weeks, an ER-2 high altitude research aircraft operating out of NASA's Wallops Flight Facility in Wallops Island, Va., will take part in the development of two future satellite instruments. The aircraft will fly test models of these instruments at altitudes greater than 60,000 feet to gather information researchers can use to develop ways to handle data future spaceborne versions will collect.

ER-2's arrival at NASA's Wallops Flight Facility, Wallops Is., Va. (Credit: NASA/Brea Reeves)

NASA Wallops will be the temporary home of one of NASA's ER-2 research aircraft. The ER-2 from NASA's Dryden Aircraft Operations Facility in Palmdale, Calif., will carry two instruments, the Cloud-Aerosol Transport System (CATS) and the Multiple Altimeter Beam Experimental Lidar (MABEL). CATS and MABEL are test beds for instruments to be carried by future satellite missions, and because they are both high-altitude laser instruments they will share space on the ER-2 in part as a way to lower costs for both teams. The ER-2's deployment began on Sept. 7 and will end no later than Sept. 27.

CATS is a high spectral resolution lidar that uses a laser to gather data about clouds and aerosols. Aerosols are tiny particles in the atmosphere such as dust, smoke or pollution. Similar instruments on existing satellites, such as CALIPSO, can detect aerosol plumes, but cannot determine what they are made of.

"You have to make some assumptions," said atmospheric scientist Matt McGill at NASA's Goddard Space Flight Center in Greenbelt, Md. CATS can better detect aerosol particle properties, allowing researchers to better determine what kind of aerosols the plumes are made of and improve studies of aerosol transport and cloud motion. CATS was designed as a test instrument for the future Aerosol-Cloud Ecosystems (ACE) satellite mission, which is still in its planning stages, and a version of CATS will be installed on the International Space Station in mid-2013.

MABEL is a laser altimeter built to simulate the primary instrument on ICESat-2, scheduled for launch in 2016. ICESat-2 will study land and sea ice and vegetation. In April, a NASA ER-2 carrying MABEL flew surveys of land and sea ice out of Keflavik, Iceland, which yielded large amounts of data that researchers are using to develop algorithms for ICESat-2.

This time around, MABEL will measure vegetation along the U.S. East Coast, which will provide data useful for developing methods for determining the amount and thickness of vegetation coverage. This involves measuring both the tops of tree canopies and ground level at the same time, which Kelly Brunt, a cryospheric scientist at NASA Goddard, said is a challenging task. The ICESat-2 team's need to measure deciduous forest canopies is in part of why these flights will operate out of Wallops. "We can't get the type of vegetation canopy we need flying out of Dryden," Brunt said. The ER-2 will be surveying forests and grasslands from Maine to the Florida Everglades.

In addition to CATS and MABEL, the ER-2 will carry a Cloud Physics Lidar (CPL) instrument that will be used to detect clouds and aerosols that could hinder MABEL's performance. "We need to know what's between MABEL and the surface," said McGill.

These flights will coincide with NASA's Hurricane and Severe Storms Sentinel, or HS3, campaign. HS3 is an airborne mission where a NASA Global Hawk unpiloted aircraft will overfly hurricanes and severe storms to measure properties such as wind, temperature, precipitation, humidity and aerosol profiles. One of the instruments it carries is a CPL identical in design to the one on board the ER-2. The Global Hawk is capable of flying at altitudes greater than 60,000 feet for more than 28 hours at a time and will be operated by pilots back on the ground.

The flights are sponsored by the Earth Science Division of NASA's Science Mission Directorate in Washington.

Source: NASA/Goddard Space Flight Center

e! Science News

Eighth Landsat satellite arrives at launch site

Published: Friday, December 21, 2012 - 12:07 in Astronomy & Space

NASA/Jerry Nagy

An oversized semi-trailer truck carrying NASA's Landsat Data Continuity Mission (LDCM) has arrived at its launch site at Vandenberg Air Force Base in California in preparation for launch. This NASA and U.S. Geological Survey mission will continue a 40-year record of measuring change on the planet from space. LDCM is the eighth satellite in the Landsat series, which began in 1972. It will extend and expand global land observations that are critical in many sectors, including energy and water management, forest monitoring, human and environmental health, urban planning, disaster recovery and agriculture.

Following final tests, the LDCM satellite will be attached to an Atlas V rocket and launched into space February 11, 2013. Built and tested by Orbital Science Corp., LDCM left their Gilbert, Ariz. facility on Dec. 17.

"LDCM builds on and strengthens a key American resource: a decades-long, unbroken Landsat-gathered record of our planet's natural resources, particularly its food, water and forests," said Jim Irons, Landsat project scientist at NASA's Goddard Space Flight Center in Greenbelt, Md.

LDCM carries two instruments, the Operational Land Imager (OLI) built by Ball Aerospace & Technologies Corp. in Boulder, Colo., and the Thermal Infrared Sensor (TIRS) built by NASA Goddard "Both of these instruments have evolutionary advances that make them the most advanced Landsat instruments to date and are designed to improve performance and reliability to improve observations of the global land surface," said Ken Schwer, LDCM project manager at NASA Goddard.

OLI will continue observations in the visible, near infrared, and shortwave infrared portions of the electromagnetic spectrum and includes two new spectral bands, one of which is designed to support monitoring of coastal waters and the other to detect previously hard to see cirrus clouds that can otherwise unknowingly impact the signal from the Earth surface in the other spectral bands. TIRS will collect data in two thermal bands and will thus be able to measure the temperature of the Earth's surface, a measurement that's vital to monitoring water consumption, especially in the arid western United States.

NASA and the U.S. Department of the Interior through the U.S. Geological Survey (USGS) jointly manage the Landsat program. After launch and the initial check out phase, USGS will take operational control of the satellite, will collect, archive, and distribute the data from OLI and TIRS, and will rename the satellite as Landsat 8. The LDCM data will be freely and openly available through the USGS data system.

NASA's Launch Services Program at Kennedy is responsible for launch management. United Launch Alliance is the provider of the Atlas V launch service.

Source: NASA/Goddard Space Flight Center

ACRONYMS

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

3D	Three Dimensional
7-SEAS	Seven SouthEast Asian Studies
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 CO_2 Emissions over Nights, Days, and Seasons
ASIF	Air Sea Interaction Facility
ASR	Atmospheric System Research
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
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

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

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

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APPENDIX 2. HIGHLIGHTED ARTICLES PUBLISHED IN 2012

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The Impact of Dry Midlevel Air on Hurricane Intensity in Idealized Simulations with No Mean Flow

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ABSTRACT

This study examines the potential negative influences of dry midlevel air on the development of tropical cyclones (specifically, its role in enhancing cold downdraft activity and suppressing storm development). The Weather Research and Forecasting model is used to construct two sets of idealized simulations of hurricane development in environments with different configurations of dry air. The first set of simulations begins with dry air located north of the vortex center by distances ranging from 0 to 270 km, whereas the second set of simulations begins with dry air completely surrounding the vortex, but with moist envelopes in the vortex core ranging in size from 0 to 150 km in radius.

No impact of the dry air is seen for dry layers located more than 270 km north of the initial vortex center (~3 times the initial radius of maximum wind). When the dry air is initially closer to the vortex center, it suppresses convective development where it entrains into the storm circulation, leading to increasingly asymmetric convection and slower storm development. The presence of dry air throughout the domain, including the vortex center, substantially slows storm development. However, the presence of a moist envelope around the vortex center eliminates the deleterious impact on storm intensity. Instead, storm size is significantly reduced. The simulations suggest that dry air slows intensification only when it is located very close to the vortex core at early times. When it does slow storm development, it does so primarily by inducing outward-moving convective asymmetries that temporarily shift latent heating radially outward away from the high-vorticity inner core.

1. Introduction

High relative humidity (RH) in the middle troposphere has long been recognized as an important factor in determining where tropical cyclones form (Gray 1975, 1979, 1998; McBride 1981). Its favorable role was viewed more in terms of being a necessary climatological condition rather than being a determining factor in whether or not individual cloud clusters went on to develop into tropical cyclones (McBride 1981; McBride and Zehr 1981). However, DeMaria et al. (2001) showed that their formulation of a genesis parameter, of which midlevel moisture is a part, can provide some useful information as to the probability of tropical storm formation. Kaplan and DeMaria (2003) showed that high values of 850–700-hPa relative humidity generally favor rapid intensification of tropical cyclones.

Kimball (2006) examined the impact of dry intrusions by perturbing initial moisture in simulations of Hurricane Danny (1997). Kimball varied both the magnitude of the inner-core moisture anomaly (4 g kg^{-1} variations in peak magnitude, maximum in the boundary layer and decreasing with height) and its size (from 250 to 600 km). As might be expected, an initial vortex with higher moisture content (for fixed size) generally led to more intense storms, while more extensive moisture anomalies typically led to increased areal extent of rainbands and a larger area of storm-strength winds (17 m s^{-1}). Kimball claimed that dry air intrusions into systems with smaller moist envelopes contributed to weakening of those cases, although the differences in minimum central sea level pressure were generally less than 5 hPa

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DOI: 10.1175/JAS-D-10-05007.1

IMPACT OF AEROSOLS ON CONVECTIVE CLOUDS AND PRECIPITATION

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Received 14 July 2011; revised 2 December 2011; accepted 18 December 2011; published 17 April 2012.

[1] Aerosols are a critical factor in the atmospheric hydrological cycle and radiation budget. As a major agent for clouds to form and a significant attenuator of solar radiation, aerosols affect climate in several ways. Current research suggests that aerosol effects on clouds could further extend to precipitation, both through the formation of cloud particles and by exerting persistent radiative forcing on the climate system that disturbs dynamics. However, the various mechanisms behind these effects, in particular, the ones connected to precipitation, are not yet well understood. The atmospheric and climate communities have long been working to gain a better grasp of these critical effects and hence to reduce the significant uncertainties in climate prediction resulting from such a lack of adequate knowledge. Here we review past efforts and summarize our current understanding of the effect of aerosols on convective precipitation processes from theoretical analysis of microphysics, observational evidence, and a range of numerical model simulations. In addition, the discrepancies between results simulated by models, as well as those between simulations and observations, are presented. Specifically, this paper addresses the following topics: (1) fundamental theories of aerosol effects on microphysics and precipitation processes, (2) observational evidence of the effect of aerosols on precipitation processes, (3) signatures of the aerosol impact on precipitation from large-scale analyses, (4) results from cloud-resolving model simulations, and (5) results from large-scale numerical model simulations. Finally, several future research directions for gaining a better understanding of aerosol-cloud-precipitation interactions are suggested.

Citation: Tao, W.-K., J.-P. Chen, Z. Li, C. Wang, and C. Zhang (2012), Impact of aerosols on convective clouds and precipitation, *Rev. Geophys.*, *50*, RG2001, doi:10.1029/2011RG000369.

1. INTRODUCTION

[2] Aerosols, and especially their effect on clouds and precipitation, are one of the key components of the climate system and the hydrological cycle. Yet the aerosol effect on clouds and precipitation remains poorly known. A recent report published by the U.S. National Academy of Science states that "The greatest uncertainty about the aerosol climate forcing—indeed, the largest of all the uncertainties about global climate forcing—is probably the indirect effect of aerosols on clouds" [*National Research Council* (*NRC*), 2005]. This "aerosol indirect effect" (AIE) includes the traditional "indirect," or "Twomey," effect on cloud droplet size and thus reflectance for a constant liquid water path [*Twomey*, 1977; *Twomey et al.*, 1984] and the "second indirect" effect on cloud extent and lifetime [*Albrecht*, 1989; *Hansen et al.*, 1997; *Ackerman et al.*, 2000]. Enhanced aerosol concentrations can also suppress warm-rain processes by reducing particle sizes and causing a narrow droplet spectrum that inhibits collision and coalescence processes [e.g., *Squires and Twomey*, 1961; *Warner and Twomey*, 1967; *Warner*, 1968; *Rosenfeld*, 1999]. The aerosol effect on precipitation processes, considered part of the second type of aerosol indirect effect [*Albrecht*, 1989], is even more complex, especially for mixed-phase convective clouds.

[3] Continued advancement of instrumental technology has provided the community with much improved research tools to gain insights concerning aerosol-cloud-precipitation interactions (ACPI). For instance, a combination of cloud top temperature and effective droplet sizes, estimated from the advanced very high resolution radiometer (AVHRR), has been used to infer the suppression of coalescence and precipitation processes by smoke [*Rosenfeld and Lensky*, 1998] and desert dust [*Rosenfeld et al.*, 2001]. Multisensor (passive/active microwave and visible and infrared) satellite

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8755-1209/12/2011RG000369

Paper number 2011RG000369

Environmental Modelling & Software 39 (2013) 103–115

Contents lists available at SciVerse ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

The NASA-Goddard Multi-scale Modeling Framework–Land Information System: Global land/atmosphere interaction with resolved convection[☆]

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ARTICLE INFO

Article history:
Received 5 May 2011
Received in revised form
8 February 2012
Accepted 28 February 2012
Available online 10 May 2012

Keywords:
Land–atmosphere interaction
Earth system modeling
Global modeling
Atmospheric prediction
Hydrologic prediction

ABSTRACT

The present generation of general circulation models (GCM) use parameterized cumulus schemes and run at hydrostatic grid resolutions. To improve the representation of cloud-scale moist processes and land–atmosphere interactions, a global, Multi-scale Modeling Framework (MMF) coupled to the Land Information System (LIS) has been developed at NASA-Goddard Space Flight Center. The MMF–LIS has three components, a finite-volume (fv) GCM (Goddard Earth Observing System Ver. 4, GEOS-4), a 2D cloud-resolving model (Goddard Cumulus Ensemble, GCE), and the LIS, representing the large-scale atmospheric circulation, cloud processes, and land surface processes, respectively. The non-hydrostatic GCE model replaces the single-column cumulus parameterization of fvGCM. The model grid is composed of an array of fvGCM gridcells each with a series of embedded GCE models. A horizontal coupling strategy, GCE ↔ fvGCM ↔ Coupler ↔ LIS, offered significant computational efficiency, with the scalability and I/O capabilities of LIS permitting land–atmosphere interactions at cloud-scale. Global simulations of 2007–2008 and comparisons to observations and reanalysis products were conducted. Using two different versions of the same land surface model but the same initial conditions, divergence in regional, synoptic-scale surface pressure patterns emerged within two weeks. The sensitivity of large-scale circulations to land surface model physics revealed significant functional value to using a scalable, multi-model land surface modeling system in global weather and climate prediction.

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1. Introduction

The land and atmosphere form a highly coupled system. Surface heat and momentum fluxes are linked to the surface net radiation flux, the vegetation state, and the profiles of temperature and water from below the surface up through the atmospheric boundary layer. The fluxes of heat, momentum, and moisture across the land/atmosphere interface are influenced by the heterogeneous character of the land surface layer and vary on spatial scales ranging from meters to thousands of kilometers. Linking the water and energy cycles is precipitation. Feedbacks between the heterogeneous land surface and the boundary layer affect the development of clouds and precipitation (review in Pielke, 2001). The vertical distribution of latent heat released through the formation of clouds and precipitation modulates the large-scale atmospheric dynamics of the low and mid-latitudes, affecting the distribution, intensity, and longevity of waves, jets, and fronts, and thus to future precipitation patterns. Coupling a general circulation model (GCM) to a land surface model (LSM) allows for two-way interaction of atmospheric moist processes with the land surface. By coupling a GCM to a multi-model Land Information System (LIS) rather than to a single LSM, significant additional physical and functional flexibility is achieved (Kumar et al., 2006; Peters-Lidard et al., 2007). This paper describes the NASA-Goddard finite-volume Multi-scale Modeling Framework–Land Information System (MMF–LIS), a global model framework capable of explicitly resolving cumulus convection and simulating cloud-scale land/atmosphere interactions. The MMF–LIS integrates an atmospheric GCM with a 2D cloud-resolving model (CRM) for explicit simulation of cumulus clouds and couples the LIS to the GCM. We describe the development and operation of the current Goddard MMF–LIS, focusing on the model coupling and its initial testing, particularly with respect to surface variables. This paper can be viewed as a third companion to two previous papers on LIS, the first

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[☆] Thematic Issue on the Future of Integrated Modeling Science and Technology.

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1364-8152/$ – see front matter Published by Elsevier Ltd.
doi:10.1016/j.envsoft.2012.02.023

2968 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 50, NO. 8, AUGUST 2012

Assessment of the Performance of a Dual-Frequency Surface Reference Technique Over Ocean

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***Abstract*—The high correlation of the rain-free surface cross sections at two frequencies suggests that the estimate of differential path-integrated attenuation caused by precipitation along the radar beam can be obtained to a higher degree of accuracy than the path attenuation at either frequency. We explore this potential first analytically and then by examining data from the JPL dual-frequency airborne radar using measurements from the Tropical Composition, Cloud, and Climate Coupling experiment obtained during July–August 2007. Despite an improvement in the accuracy of the differential path attenuation, solving for parameters of the particle size distribution often requires not only this quantity but the single-wavelength path attenuation as well. We investigate a simple method of estimating the single-frequency path attenuation from the differential attenuation and compare this estimate with that derived directly from the surface return.**

***Index Terms*—Attenuation, precipitation, radar, surface scattering.**

I. INTRODUCTION

THE SURFACE reference technique (SRT) is based on the idea that a decrease in the surface return power in the presence of precipitation relative to a rain-free reference value provides an estimate of the two-way path attenuation caused by precipitation along the radar beam. The method has been shown to be useful particularly at higher rain rates and under certain combinations of incidence angle and surface type (land/ocean) where the path attenuations are much larger than the inherent fluctuations in the normalized radar cross section (NRCS) of the surface, σ^0. The method has been applied to both airborne and spaceborne radar data [1]–[10].

The primary objective of the paper is to investigate an extension of this method to dual-frequency radar data, specifically to the Ku/Ka-band weather radar that will be flown on the global precipitation measurement (GPM) satellite. Although an analysis of airborne measurements of sea surface cross sections at Ku/Ka-band has been published [11] as well as a theoretical study of the dual-frequency SRT (DSRT) [12], this study is the first to investigate the DSRT using airborne radar data.

The GPM satellite is scheduled to be launched in 2014 where the set of instruments on board will include the first spaceborne dual-frequency precipitation radar (DPR), built jointly by the Japan Aerospace Exploration Agency and the National Institute of Information and Communications Technology. The frequencies of operation are Ku-band (13.6 GHz) and Ka-band (35.5 GHz). Of interest here is the fact that matched-beam, dual-frequency radar data will be acquired over a swath of approximately 120 km, consisting of 25 fields of view, including nadir and extending, to either side of nadir, out to approximately 9°. With dual-frequency radar comes the potential of estimating parameters of the particle size distribution (PSD) for rain and snow along the radar beam [13]–[18]. In many of the methods, the path-integrated attenuations (PIAs) are needed at both frequencies as they are used as constraints in restricting the set of possible solutions.

Denoting the PIA by A, in dB, then the differential path attenuation, δA, is defined by $\delta A = A(\mathrm{Ka}) - A(\mathrm{Ku})$. If the DSRT provides an estimate of δA, it is necessary, in order to circumvent errors in the single-frequency SRT, to derive from this an estimate of A(Ka) or A(Ku). Thus, the objectives of the paper are first to assess the accuracy of δA and then the accuracy of an estimate of A(Ka) (or A(Ku)) derived from δA, and finally to compare this to the accuracy of A(Ka) (or A(Ku)) obtained from the usual single-frequency SRT.

The paper is organized as follows. In Section II, approximate expressions are derived for the error variance of the differential and single-frequency attenuations obtained from the SRT. It is shown that the error variance of the former quantity is smaller than that of the latter if the correlation between the rain-free normalized surface cross sections is high. The relationship between the single- and dual-frequency applications of the method is illustrated graphically where the differential attenuation can be interpreted as the distance of the measured data point to the regression line obtained from the rain-free surface cross-section data. In Section III, airborne dual-frequency radar measurements are used to investigate the relative accuracies of Ku, Ka, and differential estimates of path attenuation. This is done by comparing the degree of agreement among the various nearly independent ways of deriving path attenuation; this, in turn, amounts to using different types of surface reference data to form the estimates of attenuation.

Even though the DSRT may provide a more accurate estimate of differential attenuation than the attenuation itself, as noted above, many approaches to estimating parameters of the size distribution from the dual-frequency radar data require the

Manuscript received March 31, 2011; revised September 2, 2011; accepted October 23, 2011. Date of publication February 3, 2012; date of current version July 18, 2012. This work was supported by Dr. R. Kakar of NASA Headquarters under NASA's Precipitation Measurement Mission Grant NNH06ZDA001N-PMM.

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Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TGRS.2011.2180727

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D09207, doi:10.1029/2011JD017053, 2012

Airborne validation of cirrus cloud properties derived from CALIPSO lidar measurements: Optical properties

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Received 25 October 2011; revised 26 March 2012; accepted 5 April 2012; published 9 May 2012.

[1] The Cloud-Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) satellite was successfully launched in April 2006 to study cloud and aerosol layers using range-resolved laser remote sensing. Dedicated flights were conducted from July 26 to August 14, 2006 using the airborne Cloud Physics Lidar (CPL) to validate the CALIPSO lidar (CALIOP) data products. This paper presents results from coincident ice cloud measurements of lidar ratio, extinction coefficient, and optical depth. Flight segment case studies are shown as well as statistics for all coincident measurements during this CALIPSO-CloudSat Validation Experiment (CC-VEX). For the penetrated portion of opaque layers, CALIOP estimates of lidar ratio and extinction are substantially lower than the corresponding CPL values. Significant differences were also found for measurements of horizontally aligned ice, where different instrument viewing geometries precluded meaningful comparisons. After filtering the data set to exclude these discrepancies, overall CALIOP lidar ratio and extinction averages compared favorably to within 1% of overall CPL averages. When restricting the data further to exact coincident in-cloud point-pairs, CALIOP lidar ratios remained close to CPL values, averaging 2.1% below CPL, and the retrieved extinction and optical depth averaged 14.7% above CPL values, a result partially of higher average CALIOP attenuated backscatter but still a respectably close match.

Citation: Hlavka, D. L., J. E. Yorks, S. A. Young, M. A. Vaughan, R. E. Kuehn, M. J. McGill, and S. D. Rodier (2012), Airborne validation of cirrus cloud properties derived from CALIPSO lidar measurements: Optical properties, *J. Geophys. Res.*, *117*, D09207, doi:10.1029/2011JD017053.

1. Introduction

[2] Cirrus clouds have an important influence on the earth's climate system and radiation budget, which remains a significant uncertainty in understanding and predicting the climate system [*Stephens et al.*, 1990; *Intergovernmental Panel on Climate Change*, 2007]. A global climatology of ice cloud optical and spatial properties is necessary to improve estimates of cloud radiative processes in Global Climate Models. An important tool for improving the accuracy of cirrus optical and spatial property measurements is space-based atmospheric lidar. Space-based elastic backscatter lidars such as the Geoscience Laser Altimeter System (GLAS) [*Spinhirne et al.*, 2005] and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) [*Hunt et al.*, 2009] provide global statistics of optically thin cirrus cloud properties to the limit of signal attenuation with high temporal and spatial resolution that are not possible using in situ measurements [*Wang and Sassen*, 2001]. CALIOP, a dual wavelength, polarization-sensitive lidar, is the primary payload aboard the Cloud-Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) satellite [*Winker et al.*, 2007]. The CALIOP level 1 and 2 standard data products report spatial and optical properties of both clouds and aerosols [*Winker et al.*, 2010]. CALIOP data has already been used extensively in global studies of cirrus spatial distributions [*Nazaryan et al.*, 2008; *Sassen et al.*, 2008] and the role of atmospheric dynamics in determining cirrus optical properties [*Martins et al.*, 2011]. CALIOP measurements and retrievals are also essential to regional studies that, for example, establish the role of the tropical eastern jet in the formation of cirrus layers during the Asian summer monsoon [*Das et al.*, 2011], investigate cloud formation mechanisms [*Riihimaki and McFarlane*, 2010] and ice nucleation processes [*Jensen et al.*, 2010] in the tropical tropopause, and provide guidance for improved model

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0148-0227/12/2011JD017053

Atmos. Chem. Phys., 12, 8037–8053, 2012
www.atmos-chem-phys.net/12/8037/2012/
doi:10.5194/acp-12-8037-2012

Atmospheric
Chemistry
and Physics

Global and regional trends of aerosol optical depth over land and ocean using SeaWiFS measurements from 1997 to 2010

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Received: 5 March 2012 – Published in Atmos. Chem. Phys. Discuss.: 29 March 2012
Revised: 15 August 2012 – Accepted: 22 August 2012 – Published: 10 September 2012

Abstract. Both sensor calibration and satellite retrieval algorithm play an important role in the ability to determine accurately long-term trends from satellite data. Owing to the unprecedented accuracy and long-term stability of its radiometric calibration, SeaWiFS measurements exhibit minimal uncertainty with respect to sensor calibration. In this study, we take advantage of this well-calibrated set of measurements by applying a newly-developed aerosol optical depth (AOD) retrieval algorithm over land and ocean to investigate the distribution of AOD, and to identify emerging patterns and trends in global and regional aerosol loading during its 13-yr mission. Our correlation analysis between climatic indices (such as ENSO) and AOD suggests strong relationships for Saharan dust export as well as biomass-burning activity in the tropics, associated with large-scale feedbacks. The results also indicate that the averaged AOD trend over global ocean is weakly positive from 1998 to 2010 and comparable to that observed by MODIS but opposite in sign to that observed by AVHRR during overlapping years. On regional scales, distinct tendencies are found for different regions associated with natural and anthropogenic aerosol emission and transport. For example, large upward trends are found over the Arabian Peninsula that indicate a strengthening of the seasonal cycle of dust emission and transport processes over the whole region as well as over downwind oceanic regions. In contrast, a negative-neutral tendency is observed over the desert/arid Saharan region as well as in the associated dust outflow over the north Atlantic. Additionally, we found decreasing trends over the eastern US and Europe, and increasing trends over countries such as China and India that are experiencing rapid economic development. In general, these results are consistent with those derived from ground-based AERONET measurements.

1 Introduction

The impact of natural and anthropogenic sources of air pollution on Earth's weather and climate systems and their long-term tendencies have gained increasing attention from the scientific community in recent years (Mishchenko et al., 2007; Rosenfeld et al., 2008; Zhang and Reid, 2010). Indeed, tropospheric aerosols not only perturb the radiative energy balance by interacting with solar and terrestrial radiation (Ramanathan et al., 2001) but also by changing cloud properties and lifetimes (Rosenfeld et al., 2008). Furthermore, the Intergovernmental Panel on Climate Change (IPCC, 2007) report indicates that the aerosol cooling effect could have partially counteracted warming from greenhouse gas increases over the past few decades. However, there are large uncertainties in the estimation of climate forcing from aerosols due to their complex nature and short lifetime. In order to achieve a better understanding of the spatial and temporal variability of aerosol distributions on both regional and global scales, long-term satellite measurements of high fidelity are required.

Published by Copernicus Publications on behalf of the European Geosciences Union.

Atmos. Chem. Phys., 12, 9459–9477, 2012
www.atmos-chem-phys.net/12/9459/2012/
doi:10.5194/acp-12-9459-2012

Atmospheric Chemistry and Physics

Eyjafjallajökull volcano plume particle-type characterization from space-based multi-angle imaging

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Received: 12 June 2012 – Published in Atmos. Chem. Phys. Discuss.: 19 July 2012
Revised: 28 September 2012 – Accepted: 28 September 2012 – Published: 22 October 2012

Abstract. The Multi-angle Imaging SpectroRadiometer (MISR) Research Aerosol algorithm makes it possible to study individual aerosol plumes in considerable detail. From the MISR data for two optically thick, near-source plumes of the spring 2010 Eyjafjallajökull volcano eruption, we map aerosol optical depth (AOD) gradients and changing aerosol particle types with this algorithm; several days downwind, we identify the occurrence of volcanic ash particles and retrieve AOD, demonstrating the extent and the limits of ash detection and mapping capability with the multi-angle, multi-spectral imaging data. Retrieved volcanic plume AOD and particle microphysical properties are distinct from background values near-source, as well as for over-water cases several days downwind. The results also provide some indication that as they evolve, plume particles brighten, and average particle size decreases. Such detailed mapping offers context for suborbital plume observations having much more limited sampling. The MISR Standard aerosol product identified similar trends in plume properties as the Research algorithm, though with much smaller differences compared to background, and it does not resolve plume structure. Better optical analogs of non-spherical volcanic ash, and coincident suborbital data to validate the satellite retrieval results, are the factors most important for further advancing the remote sensing of volcanic ash plumes from space.

1 Introduction

Satellite observations can play a key role in constraining aerosol transport models used to diagnose the environmental impacts of volcanic eruptions (e.g., Stohl et al., 2011; Heinold et al., 2012). Emitted-aerosol microphysical properties are among the most important volcanic plume characteristics for air traffic safety, and are also significant indicators of eruption style and intensity (e.g., ESA, 2010). And although individual, major eruptions that inject sulfur into the stratosphere and significantly affect climate are rare, it is also advantageous for climate models to parameterize the numerous, smaller eruption plumes accurately. The ability to distinguish non-spherical volcanic ash from spherical water and sulfate particles near-source (e.g., Scollo et al., 2012), to identify ash concentrations downwind, and to constrain particle size, are key contributions multi-angle, multi-spectral remote sensing can make, at least in principle, toward characterizing volcanic eruptions.

This paper explores the ability to retrieve and to map, with data from the NASA Earth Observing System's Multi-angle Imaging SpectroRadiometer (MISR) instrument, particle properties for both near-source and downwind volcanic plumes. MISR flies aboard the Terra satellite, in a sun-synchronous, polar orbit that crosses the equator on the descending node at about 10:30 a.m. LT. The instrument measures upwelling short-wave radiance from Earth in four spectral bands centered at 446, 558, 672, and 866 nm, at each of nine view angles spread out in the forward and aft directions along the flight path, at 70.5°, 60.0°, 45.6°, 26.1°, and nadir (Diner et al., 1998). Over a period of seven minutes, as the spacecraft flies overhead, a 380-km-wide swath of Earth is successively viewed by each of MISR's nine cameras. As a result, the instrument samples a very large range of scattering angles – between about 60° and 160° at mid latitudes, providing constraints on particle size, shape, and single-scattering albedo (SSA), for particles between about

Published by Copernicus Publications on behalf of the European Geosciences Union.

Paper in Press

JOURNAL OF GEOPHYSICAL RESEARCH, doi:10.1029/2011JD016510

Observed recent trends in tropical cyclone rainfall over the North Atlantic and North Pacific

Key Points

- Tropical cyclone carries more rain in the N. Atlantic
- Inverse relationship between TC rainfall in N. Atlantic compared to NE Pacific
- Rainfall data are still too short to determine TC rain trends

Authors:

William K.M. Lau

Yaping Zhou

In this study, we use TRMM and GPCP rainfall data together with historical storm track records to examine the trend of tropical cyclone (TC) rainfall in the North Atlantic, Northeast and Northwest Pacific during recent decades (1988-2007). We find that there is an approximate linear relationship between TC-rain (defined as accumulated total rainfall along storm tracks) and storm intensity as classified by the Saffir-Simpson scheme. During the data period total TC-rain has trended upward at a rate of 23.8{plus minus}23.5% per decade over the North Atlantic, but downward with a rate of 25.1{plus minus}19.7% per decade over the Northeast Pacific. Over the Northwest Pacific, there is a reduction in TC-rain of approximately 20.9{plus minus}13.5 % per decade, possibly associated with a strong inter-decadal scale oscillation. Storm characteristics such as duration and TC-rain energy per storm (EPS) remain unchanged for the North Atlantic and the Northeast Pacific. For the Northwest Pacific, a 28{plus minus}18% reduction in EPS from the previous decade (1988- 1997) to the present decade (1998-2007) is found with the track data from the Joint Typhoon Warning Center. Analyses of the probability distribution function of TC-rain show that there is an overall increase in TC frequency across the entire TC rainfall spectrum over the North Atlantic, but an overall decrease for the Northeast Pacific. In the Northwest Pacific, we find a re-distribution in EPS, with decreased frequency in heavy-rain storms and increased frequency in light-rain storms. Overall, trends in TC-rain in the different ocean basins are consistent with long-term relative changes in the ambient large-scale SST and vertical wind shear, and to a lesser extent, tropical cyclone Maximum Potential Intensity (MPI).

Received 4 July 2011; accepted 27 November 2011.

Citation: Lau, W. K.M. and Y. Zhou (2011), Observed recent trends in tropical cyclone rainfall over the North Atlantic and North Pacific, *J. Geophys. Res.*, doi:10.1029/2011JD016510, in press.

mass ratio on discharge and charge is $2e^-/O_2$, confirming that the reaction is overwhelmingly Li_2O_2 formation/decomposition. We have also shown that such electrodes are particularly effective at promoting the decomposition of Li_2O_2, with all the Li_2O_2 being decomposed below 4 V and ~50% decomposed below 3.3 V, at a rate approximately one order of magnitude higher than on carbon. Although DMSO is not stable with bare Li anodes, it could be used with protected Li anodes. Nanoporous Au electrodes are not suitable for practical cells, but if the same benefits could be obtained with Au-coated carbon, then low-mass electrodes would be obtained, although cost may still be a problem. A cathode reaction overwhelmingly dominated by Li_2O_2 formation on discharge, its complete oxidation on charge and sustainable on cycling, is an essential prerequisite for a rechargeable nonaqueous $Li-O_2$ battery. Hence, the results presented here encourage further study of the rechargeable nonaqueous $Li-O_2$ cell, although many challenges to practical devices remain.

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Acknowledgments: P.G.B. is indebted to the UK Engineering and Physical Sciences Research Council, including the Supergen Programme and Alistore for financial support.

Supplementary Materials
www.sciencemag.org/cgi/content/full/science.1223985/DC1
Materials and Methods
Figs. S1 to S9
References (*34*, *35*)

30 April 2012; accepted 26 June 2012
Published online 19 July 2012;
10.1126/science.1223985

Aerosols from Overseas Rival Domestic Emissions over North America

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Many types of aerosols have lifetimes long enough for their transcontinental transport, making them potentially important contributors to air quality and climate change in remote locations. We estimate that the mass of aerosols arriving at North American shores from overseas is comparable with the total mass of particulates emitted domestically. Curbing domestic emissions of particulates and precursor gases, therefore, is not sufficient to mitigate aerosol impacts in North America. The imported contribution is dominated by dust leaving Asia, not by combustion-generated particles. Thus, even a reduction of industrial emissions of the emerging economies of Asia could be overwhelmed by an increase of dust emissions due to changes in meteorological conditions and potential desertification.

Atmospheric aerosols emitted or produced in one region can be transported thousands of miles downwind to affect other regions on intercontinental or hemispheric scales (*1*–*3*). Because of such intercontinental transport, emission controls over North America may be offset partly by the import of aerosols from remote international sources. Assessing the aerosol intercontinental transport and its impacts on atmospheric composition, air quality, and climate in North America is thus needed from both scientific and policy perspectives. Currently, such assessment for the most part has been based on global model simulations (*4*–*6*) and remains very uncertain (*7*).

Today's constellation of passive and active satellite sensors are providing three-dimensional distributions of aerosol properties on a global scale, with improved accuracy for aerosol optical depth (AOD) and enhanced capability of characterizing aerosol type (*8*). Such advances have made it feasible to elucidate the evolution of aerosol plumes during the cross-ocean transport (*9*, *10*) and generate measurement-based estimates of aerosol intercontinental transport on seasonal and annual time scales (*11*, *12*).

We integrated satellite measurements from the Moderate-resolution Imaging Spectroradiometer (MODIS) (*13*) and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) (*14*) in order to characterize the three-dimensional distributions of trans-Pacific dust transport (*15*). We used MODIS measurements of total AOD and fine-mode fraction over ocean to separate AOD for dust, combustion aerosol, and marine aerosol (*16*). Combustion aerosol refers to aerosol products from the burning of both biomass and fossil fuels, which include sulfates, nitrates, and carbonaceous particles. The partitioning of AOD into these three categories accounts for fine-mode components of marine and dust aerosol (*15*, *16*). The CALIOP measurements are used to characterize seasonal variations of aerosol extinction profiles, with dust being separated from other types of aerosols by the measured depolarization ratio (*15*). The climatology of springtime (March-April-May, or MAM) AOD (2001–2007) and vertical profile of extinction (2006–2010) over the North Pacific basin are shown in Fig. 1. Spring is the most active season for trans-Pacific transport of combustion aerosols and dust because of the combined effect of active extratropical cyclones and the strongest mid-latitude westerlies. However, trans-Pacific transport occurs throughout the year (*12*). Over the period we examined here, interannual variations of AOD are generally small for dust in the outflow and inflow regions (8 and 4%, respectively), but larger (17 and 18%, respectively) for combustion aerosol. The relatively large interannual variations for combustion

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JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D07107, doi:10.1029/2011JD017050, 2012

Arctic low cloud changes as observed by MISR and CALIOP: Implication for the enhanced autumnal warming and sea ice loss

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Received 23 October 2011; revised 15 February 2012; accepted 19 February 2012; published 11 April 2012.

[1] Retreat of Arctic sea ice extent has led to more evaporation over open water in summer and subsequent cloud changes in autumn. Studying recent satellite cloud data over the Arctic Ocean, we find that low (0.5–2 km) cloud cover in October has been increasing significantly during 2000–2010 over the Beaufort and East Siberian Sea (BESS). This change is consistent with the expected boundary layer cloud response to the increasing Arctic evaporation accumulated during summer. Because low clouds have a net warming effect at the surface, October cloud increases may be responsible for the enhanced autumnal warming in surface air temperature, which effectively prolong the melt season and lead to a positive feedback to Arctic sea ice loss. Thus, the new satellite observations provide a critical support for the hypothesized positive feedback involving interactions between boundary layer cloud, water vapor, temperature, and sea ice in the Arctic Ocean.

Citation: Wu, D. L., and J. N. Lee (2012), Arctic low cloud changes as observed by MISR and CALIOP: Implication for the enhanced autumnal warming and sea ice loss, *J. Geophys. Res.*, *117*, D07107, doi:10.1029/2011JD017050.

1. Introduction

[2] Summer sea ice extent in the Arctic is shrinking at a pace faster than most of the climate model predictions [*Stroeve et al.*, 2007]. Arctic warming, nearly twice as large as the global average [*Intergovernmental Panel on Climate Change*, 2007; *Graversen et al.*, 2008; *Gillett et al.*, 2008], has been the fundamental driving force of the rapid sea ice loss. Because perennial ice is increasingly replaced by thinner first-year ice [*Nghiem et al.*, 2007; *Kwok*, 2007], the ice pack becomes more vulnerable to annual warming and wind-driven export, leading to the expectation that the summer Arctic Ocean would be ice-free in 20–30 years [*Serreze et al.*, 2007].

[3] The Arctic warming reported in surface air temperature (SAT) occurs nonuniformly with season with the strongest increase in autumn [*Serreze et al.*, 2009]. Over the Arctic Ocean, the Beaufort and East Siberian Sea (BESS) show the largest SAT increases in September–November, resembling the pattern of sea ice reduction in September. An immediate impact of the rising autumn Arctic temperature is to lengthen the melt season and reduce the possibility of perennial ice pack formation. As illustrated in Figure 1, it was not until 2000–2009 that the autumn temperature starts to increase significantly above the envelope defined by previous decades. Interestingly, the temperature increases are most pronounced during the period of late September to December, but with only moderate in spring and summer. This nonuniform SAT change is puzzling because it cannot be explained by direct solar radiation. Current research has been focused on coupled atmospheric-oceanic-cryospheric processes.

[4] In a quest for the cause of the intensified Arctic warming, several mechanisms have been explored, including oceanic heat transport [*Shimada et al.*, 2006], influence of the upper air [*Graversen et al.*, 2008], ocean-to-atmosphere heat transfer [*Serreze et al.*, 2009], and water vapor feedback [*Curry et al.*, 1995; *Screen and Simmonds*, 2010]. In these proposed mechanisms, clouds are still an enigma of the coupled Arctic climate system, because they are related intimately to regional radiation and dynamics [*Curry et al.*, 1996; *Intrieri et al.*, 2002]. Advanced from the positive ice-albedo feedback concept [*Lindsay and Zhang*, 2005], a cloud-temperature-ice feedback is suggested as an effective mechanism to warm autumnal SAT [e.g., *Kay and Gettelman*, 2009; *Vavrus et al.*, 2010; *Eastman and Warren*, 2010a]. This mechanism is based on increased absorption of solar radiation during summer, since more open water and hence more evaporation occurs over the Arctic Ocean [*Perovich et al.*, 2007]. As a result, more clouds are likely to form in autumn when air temperature drops. In autumn, cloud longwave (LW) radiation, especially from liquid clouds [*Shupe and Intrieri*, 2004], dominates the surface heat budget by trapping LW between the surface and cloud layers. The increased cloudiness prevents or delays the accumulated heat from releasing back to space. Thus, the LW trapped by clouds could effectively increase SAT and lengthen the melt season. As shown by *Belchansky et al.* [2004], the magnitude of the summer melt is closely related to changes in the duration of the melt season, and the longer the season, the less chance of forming perennial ice, and the more thinning of sea ice. Because the cloud warming effect is proportional to low cloud fraction (CF) [*Intrieri et al.*, 2002], it is hypothesized that more

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0148-0227/12/2011JD017050

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D06216, doi:10.1029/2011JD016968, 2012

Dispersion of the volcanic sulfate cloud from a Mount Pinatubo–like eruption

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Received 3 October 2011; revised 25 January 2012; accepted 26 January 2012; published 29 March 2012.

[1] We use the GEOS-5 general circulation model to simulate the transport of the volcanic cloud from an eruption similar to the 1991 eruption of Mount Pinatubo. The simulated aerosol optical thickness and transport of the volcanic cloud are in good agreement with observations of the actual Pinatubo eruption from the Stratospheric Aerosol and Gas Experiment II (SAGE II) and the Advanced Very High Resolution Radiometer (AVHRR) and with vertical profiles of sulfur dioxide observed by the Microwave Limb Sounder (MLS). We tested the importance of initial conditions corresponding to the specific meteorological situation at the time of the eruption by comparing results when GEOS-5 is initialized using Modern Era Retrospective Analyses for Research and Applications (MERRA) reanalysis fields with results when it is initialized from an existing model run. We found no significant difference in the transport of the cloud. We show how the inclusion of the interaction between volcanic sulfate aerosol and radiation is essential for a reliable simulation of the transport of the volcanic cloud. The absorption of longwave radiation by the volcanic sulfate largely induces the rising of the volcanic cloud up to the middle stratosphere and the divergent motion from the latitude of the eruption to the tropics. Our simulations indicate that the cloud is transported to the Northern Hemisphere through a lower stratospheric pathway and to middle and high latitudes of the Southern Hemisphere through a middle stratospheric pathway, centered at about 30 hPa. The direction of the middle stratospheric pathway depends on the season of the eruption.

Citation: Aquila, V., L. D. Oman, R. S. Stolarski, P. R. Colarco, and P. A. Newman (2012), Dispersion of the volcanic sulfate cloud from a Mount Pinatubo–like eruption, *J. Geophys. Res.*, *117*, D06216, doi:10.1029/2011JD016968.

1. Introduction

[2] Volcanic eruptions are a major source of stratospheric aerosol [*Deshler*, 2008]. Sulfur dioxide (SO_2) injected into the stratosphere by large eruptions is oxidized into sulfate aerosol and can increase the background aerosol mass by orders of magnitude. The induced perturbation of the stratospheric aerosol layer can persist for a few years. During such time the aerosol from a tropical eruption can spread over the whole globe, changing the global climate in a significant way [*Robock*, 2000].

[3] Mount Pinatubo is located in the Philippines (15.1°N, 120.4°E). Pinatubo erupted on 15 June 1991, injecting about 20 Tg of SO_2 into the atmosphere [*Bluth et al.*, 1992]. The resulting sulfate cloud was detected at altitudes higher than 30 km [*McCormick and Veiga*, 1992]. After about 1 year, roughly one third of the volcanic aerosol was still present in the atmosphere. The sulfate cloud generated by the eruption of Mount Pinatubo circled the globe and crossed the equator within 3 weeks of the eruption [*Guo et al.*, 2004; *McCormick and Veiga*, 1992] and diffused to middle and high latitudes in both the Northern and the Southern hemispheres.

[4] Such broad meridional spreading is not typical of all tropical eruptions. The volcanic cloud from the April 1982 El Chichón eruption, located 2° north of Mount Pinatubo, was mainly confined to the Northern Hemisphere [*McCormick and Swissler*, 1983]. *Young et al.* [1994] first suggested that the cross-equatorial transport of the Mount Pinatubo cloud was due to local absorption of infrared radiation from the troposphere. *Timmreck et al.* [1999a] showed this hypothesis was plausible with a one-simulation study using the MAECHAM4 Hamburg climate model. *Niemeier et al.* [2009] applied the most recent version of the MAECHAM5 Hamburg climate model, coupled to an aerosol microphysical model, to the study of the Pinatubo eruption, showing that the radiative heating of the aerosol has a strong impact on the behavior of the volcanic cloud. *Stenchikov et al.* [1998] and *Kirchner et al.* [1999] showed that the absorption of near-IR radiation by the volcanic aerosol contributes significantly to the stratospheric heating. *Thomas et al.* [2009] showed by means of simulations with prescribed aerosol distributions that the phase of the quasi-biennial oscillation (QBO) at the moment of the eruption can produce a large stratospheric temperature response.

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0148-0227/12/2011JD016968

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D16306, doi:10.1029/2012JD017483, 2012

Understanding differences in upper stratospheric ozone response to changes in chlorine and temperature as computed using CCMVal-2 models

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Received 13 January 2012; revised 25 June 2012; accepted 3 July 2012; published 18 August 2012.

[1] Projections of future ozone levels are made using models that couple a general circulation model with a representation of atmospheric photochemical processes, allowing interactions among photochemical processes, radiation, and dynamics. Such models are known as coupled chemistry-climate models (CCMs). Although developed from common principles and subject to the same boundary conditions, simulated ozone time series vary among models for scenarios for ozone depleting substances (ODSs) and greenhouse gases. Photochemical processes control the upper stratospheric ozone level, and there is broad agreement among CCMs in that ozone increases as ODSs decrease and temperature decreases due to greenhouse gas increase. There are quantitative differences in the ozone sensitivity to chlorine and temperature. We obtain insight into differences in sensitivity by examining the relationship between the upper stratospheric seasonal cycles of ozone and temperature as produced by fourteen CCMs. All simulations conform to expectation in that ozone is less sensitive to temperature when chlorine levels are highest because chlorine catalyzed loss is nearly independent of temperature. Analysis reveals differences in simulated temperature, ozone and reactive nitrogen that lead to differences in the relative importance of ozone loss processes and are most obvious when chlorine levels are close to background. Differences in the relative importance of loss processes underlie differences in simulated sensitivity of ozone to composition change. This suggests 1) that the multimodel mean is not a best estimate of the sensitivity of upper stratospheric ozone to changes in ODSs and temperature; and 2) that the spread of values is not an appropriate measure of uncertainty.

Citation: Douglass, A. R., R. S. Stolarski, S. E. Strahan, and L. D. Oman (2012), Understanding differences in upper stratospheric ozone response to changes in chlorine and temperature as computed using CCMVal-2 models, *J. Geophys. Res.*, *117*, D16306, doi:10.1029/2012JD017483.

1. Introduction

[2] Atmospheric models are used to interpret constituent observations and to predict the response of ozone to changes in composition, including the changes in stratospheric chlorine that have taken place due to release of man-made ozone depleting substances (ODSs). The Montreal Protocol and its amendments banned the production of many of these compounds beginning in 1996, and surface measurements of chlorofluorcarbons $CFCl_3$ and CF_2Cl_2 show that their atmospheric concentrations leveled off and began to decrease after the late 1990s [*Daniel and Velders et al.*, 2007]. The effects of ODSs are expected to be easiest to quantify in the upper stratosphere where photochemical processes control the ozone level. First efforts to identify the atmospheric response to the Montreal Protocol have focused on the upper stratosphere, and *Newchurch et al.* [2003] reported evidence that the upper stratospheric ozone had ceased to decline. Presently upper stratospheric ozone is expected to increase both because of the decline in ODSs and because greenhouse gases continue to increase, cooling the stratosphere and decreasing the rate of catalytic ozone destruction as noted in the *Scientific Assessment of Ozone Depletion: 2010* [*WMO*, 2011; hereafter referred to as WMO2011]. Attribution of observed changes in ozone to changes in ODSs requires untangling the effects of ODSs from the effects of continuing increases in greenhouse gases [*Douglass and Fioletov et al.*, 2011].

[3] Projections of future ozone levels are now commonly made using models that couple a general circulation model (GCM) with a representation of atmospheric photochemical processes, allowing interactions among photochemical processes, radiation, and dynamics. Such models are known as coupled chemistry-climate models (CCMs) and were evaluated

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0148-0227/12/2012JD017483

Atmos. Meas. Tech., 5, 809–829, 2012
www.atmos-meas-tech.net/5/809/2012/
doi:10.5194/amt-5-809-2012

Atmospheric
Measurement
Techniques

Filling-in of near-infrared solar lines by terrestrial fluorescence and other geophysical effects: simulations and space-based observations from SCIAMACHY and GOSAT

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Received: 8 November 2011 – Published in Atmos. Meas. Tech. Discuss.: 6 January 2012
Revised: 19 March 2012 – Accepted: 11 April 2012 – Published: 24 April 2012

Abstract. Global mapping of terrestrial vegetation fluorescence from space has recently been accomplished with high spectral resolution ($\nu/\Delta\nu > 35\,000$) measurements from the Japanese Greenhouse gases Observing SATellite (GOSAT). These data are of interest because they can potentially provide global information on the functional status of vegetation including light-use efficiency and global primary productivity that can be used for global carbon cycle modeling. Quantifying the impact of fluorescence on the O_2-A band is important as this band is used for photon pathlength characterization in cloud- and aerosol-contaminated pixels for trace-gas retrievals including CO_2. Here, we examine whether fluorescence information can be derived from space using potentially lower-cost hyperspectral instrumentation, i.e., more than an order of magnitude less spectral resolution ($\nu/\Delta\nu \sim 1600$) than GOSAT, with a relatively simple algorithm. We discuss laboratory measurements of fluorescence near one of the few wide and deep solar Fraunhofer lines in the long-wave tail of the fluorescence emission region, the calcium (Ca) II line at 866 nm that is observable with a spectral resolution of $\sim$0.5 nm. The filling-in of the Ca II line due to additive signals from various atmospheric and terrestrial effects, including fluorescence, is simulated. We then examine filling-in of this line using the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) satellite instrument. In order to interpret the satellite measurements, we developed a general approach to correct for various instrumental artifacts that produce false filling-in of solar lines in satellite measurements. The approach is applied to SCIAMACHY at the 866 nm Ca II line and to GOSAT at 758 and 770 nm on the shoulders of the O_2-A feature where there are several strong solar Fraunhofer lines that are filled in primarily by vegetation fluorescence. Finally, we compare temporal and spatial variations of SCIAMACHY additive signals with those of GOSAT and the Enhanced Vegetation Index (EVI) from the MODerate-resolution Imaging Spectroradiometer (MODIS). Although the derived additive signals from SCIAMACHY are extremely weak at 866 nm, their spatial and temporal variations are consistent with chlorophyll *a* fluorescence or another vegetation-related source. We also show that filling-in occurs at 866 nm over some barren areas, possibly originating from luminescent minerals in rock and soil.

Published by Copernicus Publications on behalf of the European Geosciences Union.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D10303, doi:10.1029/2011JD017006, 2012

Climatology 2011: An MLS and sonde derived ozone climatology for satellite retrieval algorithms

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Received 12 October 2011; revised 2 April 2012; accepted 15 April 2012; published 23 May 2012.

[1] The ozone climatology used as the a priori for the version 8 Solar Backscatter Ultraviolet (SBUV) retrieval algorithms has been updated. The climatology was formed by combining data from Aura MLS (2004–2010) with data from balloon sondes (1988–2010). The Microwave Limb Sounder (MLS) instrument on Aura has excellent latitude coverage and measures ozone daily from the upper troposphere to the lower mesosphere. The new climatology consists of monthly average ozone profiles for ten degree latitude zones covering pressure altitudes from 0 to 65 km. Ozone below 8 km (below 12 km at high latitudes) is based on balloons sondes, while ozone above 16 km (21 km at high latitudes) is based on MLS measurements. Sonde and MLS data are blended in the transition region. Ozone accuracy in the upper troposphere is greatly improved because of the near uniform coverage by Aura MLS, while the addition of a large number of balloon sonde measurements improves the accuracy in the lower troposphere, in the tropics and southern hemisphere in particular. The addition of MLS data also improves the accuracy of the climatology in the upper stratosphere and lower mesosphere. The revised climatology has been used for the latest reprocessing of SBUV and TOMS satellite ozone data.

Citation: McPeters, R. D., and G. J. Labow (2012), Climatology 2011: An MLS and sonde derived ozone climatology for satellite retrieval algorithms, *J. Geophys. Res.*, *117*, D10303, doi:10.1029/2011JD017006.

1. Introduction

[2] In 2007, *McPeters et al.* [2007] introduced an ozone climatology designed to be used in satellite retrieval algorithms for backscattered ultraviolet (buv) measurements. We use “buv” to designate the general technique, while a specific instrument such as SBUV is capitalized. This climatology, sometimes designated the LLM climatology, was used in the version 8.0 retrieval of ozone profiles from NASA SBUV and NOAA SBUV/2 instruments. The 2007 climatology was considerably more detailed than the simple climatology that had been used for previous versions of the SBUV and TOMS retrievals [*McPeters et al.*, 1998], which consisted of only 26 profiles with ozone in Umkehr layers (~5 km) covering low, mid, and high latitude zones. While the 1998 climatology accounted quite well for changes in stratospheric ozone profiles, tropospheric ozone information was poor because tropospheric ozone does not correlate well with total column ozone. The 2007 climatology consisted of ozone profiles from the surface to 60 km pressure altitude (1 km steps) as a function of latitude (10° zones) and month. The climatology included an accurate tropospheric ozone variation derived from ozone sondes that was different in the southern hemisphere than in the northern hemisphere. A low vertical resolution version of this same climatology with total ozone dependence added was used for total column ozone retrievals from TOMS and OMI.

[3] The revised climatology presented here was created in support of the upcoming version 8.6 reprocessing. The SBUV team is now engaged in reprocessing data from the entire series of SBUV instruments, from the original Nimbus 4 buv instrument launched in 1970 through the SBUV/2 instruments on NOAA 16, 17, and 18 which are currently operating. For version 8.6 a consistent calibration has been applied so that a long-term multi-instrument time series can be created. New ozone cross sections, those of *Brion et al.* [1993] and *Malicet et al.* [1995] were used, and a new cloud height climatology [*Vasilkov et al.*, 2008] based on OMI retrievals was used. To support this reprocessing the previous climatology needed to be updated.

[4] We have updated the *McPeters et al.* [2007] climatology by using ozone profile data from the Aura MLS instrument, taking advantage of the excellent latitude coverage of MLS and its improved accuracy at low altitudes over the UARS MLS instrument. Also, nearly double the number of sonde profiles has been included in the new climatology, and several new stations have been added, greatly improving the accuracy of the tropospheric climatology. Ozone retrieval algorithms based on the optimal retrieval method [*Rodgers*, 2000] benefit from an accurate climatology in altitude regions where the measurement loses sensitivity, for example in the lowest ten kilometers of the

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Retrieval of Aerosol Optical Depth above Clouds from OMI Observations: Sensitivity Analysis and Case Studies

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(Manuscript received 12 May 2011, in final form 20 September 2011)

ABSTRACT

A large fraction of the atmospheric aerosol load reaching the free troposphere is frequently located above low clouds. Most commonly observed aerosols above clouds are carbonaceous particles generally associated with biomass burning and boreal forest fires, and mineral aerosols originating in arid and semiarid regions and transported across large distances, often above clouds. Because these aerosols absorb solar radiation, their role in the radiative transfer balance of the earth–atmosphere system is especially important. The generally negative (cooling) top-of-the-atmosphere direct effect of absorbing aerosols may turn into warming when the light-absorbing particles are located above clouds. The actual effect depends on the aerosol load and the single scattering albedo, and on the geometric cloud fraction. In spite of its potential significance, the role of aerosols above clouds is not adequately accounted for in the assessment of aerosol radiative forcing effects due to the lack of measurements. This paper discusses the basis of a simple technique that uses near-UV observations to simultaneously derive the optical depth of both the aerosol layer and the underlying cloud for overcast conditions. The two-parameter retrieval method described here makes use of the UV aerosol index and reflectance measurements at 388 nm. A detailed sensitivity analysis indicates that the measured radiances depend mainly on the aerosol absorption exponent and aerosol–cloud separation. The technique was applied to above-cloud aerosol events over the southern Atlantic Ocean, yielding realistic results as indicated by indirect evaluation methods. An error analysis indicates that for typical overcast cloudy conditions and aerosol loads, the aerosol optical depth can be retrieved with an accuracy of approximately 54% whereas the cloud optical depth can be derived within 17% of the true value.

1. Introduction

Because of the nature of the physical processes driving the emission and atmospheric injection of desert dust and carbonaceous aerosols (i.e., the wind's lifting power of soil particles over arid and semiarid areas and the strong convective activity associated with anthropogenic biomass burning and wild fire events), large amounts of these light-absorbing particles reach the free troposphere more often than other aerosol types that generally reside in the boundary layer such as sulfate and sea salt aerosols. Elevated layers of desert dust and carbonaceous particulate are therefore frequently observed above clouds where they are mobilized by the prevailing winds and transported thousands of kilometers away from their original sources. The spring and summer transoceanic transport of desert dust across the Atlantic Ocean and the spring flow of aerosol from Asian sources across the Pacific Ocean to North America and sometimes reaching Northern Europe have been well documented using both satellite observations (Kaufman et al. 2005) and model calculations (Kallos et al. 2006; Johnson et al. 2010). Smoke layers originate from well-known regional sources of agricultural biomass burning mainly in Africa and South

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DOI: 10.1175/JAS-D-11-0130.1