NASA/TM—2011–215877

Laboratory for Atmospheres

2010 Technical Highlights

July 2011

Cover Photo Captions:

Top Left: Scott Janz with the ACAM Instrument prior to the GloPac mission. ACAM is one of 11 science instruments that were carried by the remotely operated high-altitude aircraft during the 2010 NASA GloPac mission.

Top Center: Matt McGill and Robert Rivera prepare the CPL Instrument for the GloPac mission. CPL is one of 11 science instruments that were carried by the remotely operated high-altitude aircraft during the 2010 NASA GloPac mission.

Top Right: Gerry Heymsfield with Matt McLinden and Lihua Li installing the HIWRAP instrument for the GRIP mission. HIWRAP is one of four science instruments that were carried by the remotely operated high-altitude aircraft during the 2010 NASA GRIP hurricane study.

Background: NASA's AV-6 Global Hawk cruises over the NASA Dryden Flight Research Center. The AV-6 carried the GloPac mission payload.

Bottom Left: Forecaster Leslie Lait (foreground) and Lenny Pfister (background) supported the GloPac mission using products supplied by the GMAO to plan Global Hawk flights.

Bottom Center: Time Warner Cable SoCal News" Cody Urban and Keli Moore interview NASA atmospheric physicist Paul Newman, co-mission scientist for the GloPac environmental science mission, beside a NASA Global Hawk aircraft at NASA's Dryden Flight Research Center. NASA Photo / Tom Tschida

Bottom Right: Lihua Li prepares to install the HIWRAP, on the underside of a NASA Global Hawk.

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Laboratory for Atmospheres
2010 Technical Highlights

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2011

The NASA STI Program Office … in Profile

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Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Reader:

Welcome to the Laboratory for Atmospheres' 2010 Technical Highlights report. I thank you for your interest. We publish this report each year to describe our research and to summarize our accomplishments.

This document 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 our organization and facilities, our major activities, our science highlights, and our education and outreach accomplishments for calendar year 2010.

The Laboratory's approximately 250 scientists, technologists, and administrative personnel are part of the Earth Sciences Division in the Sciences and Exploration Directorate of NASA's Goddard Space Flight Center. The Mission of the Laboratory for Atmospheres is to advance knowledge and understanding of the Earth's atmosphere.

Satellite missions, retrieval algorithm development, field campaigns, and related modeling and data analyses, as well as long-term dataset development are important components of the Lab's science activities. These activities are helping us to better understand our home planet's environment, and are increasing our knowledge of the complex physics and chemistry of the atmosphere.

The following are some noteworthy events that took place during 2010:

Congratulations to the GSFC Global Hawk Pacific—GloPac team! This was the first NASA science demonstration of the Global Hawk unmanned aircraft system (UAS) for NASA and NOAA Earth Science research and applications. This first mission was for exploration of trace gases, aerosols and dynamics of remote upper troposphere and lower stratosphere regions. Images and captions produced by the Earth Observatory Group (Sigma Space) of the eruption of the Eyjafjallajökull volcano in Iceland and the oil spill in the Gulf of Mexico have been featured heavily in the public media.

Equally impressive was the support provided by Laboratory scientists during the Genesis and Rapid Intensification Processes (GRIP) hurricane field campaign. The project led to the first-ever flights of the Global Hawk over hurricanes and demonstrated the utility of the Global Hawk for hurricane studies for the future Goddard-led Venture Class mission called the Hurricane and Severe Storm Sentinel (HS3). Drs. Scott Braun and Gerald Heymsfield were Mission Scientists and flew the new High-altitude Imaging Wind and Rain Airborne Profiler on the Global Hawk. GRIP was highly successful, obtaining measurements of the genesis of Hurricane Karl and Tropical Storm Mathew and the rapid intensification of hurricanes Earl and Karl, among other flights.

Laboratory scientists provided science and logistic support to the Global Precipitation Measurement (GPM) mission Light Precipitation Validation Experiment (LPVEx) in the Gulf of Finland to detect light rainfall and rainfall intensity in high latitudes affected by shallow freezing levels.

Laboratory scientists played a critical role in a pilot interdisciplinary sciences project named the 7 South East Asian Studies (or 7-SEAS). The primary goal of the project is to understand the impact of aerosol particles on weather and climate in Southeast Asia based on research topics in 7 focus areas. The project will continue until 2012 with a goal to develop a wide-ranging Southeast Asian scientific data network.

In July the ALVICE Raman lidar system was fully accepted by the Network for the Detection of Atmospheric Composition Change (NDACC) as a mobile intercomparison instrument for water vapor profiling. The first deployment will be in Canada in July 2011.

As in previous years, Laboratory scientists received many top professional honors and appointments. Notable among these was the election of Paul Newman as a Fellow of the American Geophysical Union. Jay Herman received the NASA Exceptional Service Medal (ESM) and Bryan Duncan was awarded a RHG Science Award. James Gleason was appointed as the Senior Project Scientist in the Program Office for the Joint Polar Satellite System (JPSS) Project, and Lazaros Oraiopoulos was appointed as Aqua Deputy Project Scientist following Dr. Platnick's appointment as the EOS Project Scientist. Alexander Marshak was appointed Deputy Project Scientist for Deep Space Climate Observatory (DSCOVR). Dr. W. Lau received an Honorary Professorship Award from the School of Environment and Energy, City University of Hong Kong.

The year 2010 was also a time to bid farewell to Rich Stolarski, who retired after 36 years of service. He will continue research under the Emeritus program. I wish to thank Kathy White for her 19 years of high-quality service to the Laboratory; Kathy accepted a civil service position as a contract specialist. Eric Wilcox accepted a position at the Desert Research Institute in Reno, Nevada.

I am pleased to welcome research scientists Bill Cook and Nickolay Krotkov to the Laboratory. Bill will be performing fundamental research in the development of new instrument concepts and technology and will also serve as Deputy Instrument Scientist for the ICESat II mission. Nickolay will work on improving OMI NO_2 and SO_2 data, and maintain long-term volcanic SO_2 datasets from TOMS, Aura/OMI, and future UV instruments. We also welcome Omega Williams, Jan Angevine, and Kelly Gillis to our administration staff. Omega is co-located from the Division Office and serves as the Laboratory Administrative Officer. Jan serves as the Administrative Assistant for the Laboratory Chief, and Kelly supports the travel office functions. The scientific and administrative expertise of 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 Laboratory for Atmospheres Web 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,

Chief, Laboratory for Atmospheres, Code 613

May 2011

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PREFACE

The 2010 Report is the 16th issue of the Laboratory Annual Technical Highlights and it continues an ongoing record of scientific accomplishments in Atmospheric Science at Goddard. Due to a pending reorganization, this may be the last issue under the Laboratory's current title. Over the years, the Laboratory highlights grew from a five to ten page informal brochure into formal reports with more than 100 pages. The issues from 1996 to 2009 are filed on the Laboratory Web site (http://atmospheres.gsfc.nasa.gov/) and are the product of the efforts of all the members of the Laboratory throughout the years. Their dedication to advancing Earth Science through scientific investigations involving research, developing and running models, designing instruments, managing projects, running field campaigns, publishing results, and performing numerous other activities has produced many significant findings which are highlighted in the reports.

This year's report was similarly the product of the efforts of all the members of the Laboratory. Production has been guided by William K.M. Lau, Chief of the Laboratory for Atmospheres who, along with Associate Chief Jim Irons, checked the report for accuracy and made suggestions regarding its content. Erin Lee, Lynn Shupp, Cathy Newman, Pat Luber, and Mariellen Pemberton, all members of the administrative staff, are recognized for helping to gather material for the report and for soliciting the contributions of Lab members. Judith Clark of the Technical Information and Management Services Branch (Code 271), performed the final editing, formatting, and typesetting to turn this report into a polished product in a timely manner. Her efforts, as well as those mentioned above, are gratefully acknowledged. An electronic version of this document and the other issues are available online at http://atmospheres.gsfc.nasa.gov/ thanks to the efforts of Brent Stees our Laboratory Web Master.

We hope that you will find this document informative and useful.

—Charles E. Cote

—Omega V. Williams

1. INTRODUCTION

The Laboratory for Atmospheres (Code 613) is part of the Earth Sciences Division (Code 610) under the Sciences and Exploration Directorate (Code 600) based at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The Laboratory executes comprehensive research and a technology development program dedicated to advancing knowledge and understanding of the atmospheres of Earth and other planets. The research program is aimed at understanding the influence of solar variability on the Earth's climate; understanding the structure, dynamics, and radiative properties of precipitation, clouds, and aerosols; understanding atmospheric chemistry, especially the role of natural and anthropogenic trace species on the ozone balance in the stratosphere and the troposphere; and advancing our understanding of physical properties of Earth's atmosphere. The research program identifies problems and requirements for atmospheric observations via satellite missions. Laboratory scientists conceive, design, develop, and implement ultraviolet, infrared, optical, radar, laser, and lidar technology for remote sensing of the atmosphere. Laboratory members 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 development of next-generation Earth system models. 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.

The Laboratory for Atmospheres is a vital participant in NASA's research agenda. Our Laboratory often has relatively large programs, sizable satellite missions, and observational campaigns that require the cooperative and collaborative efforts of many scientists. We ensure an appropriate balance between our scientists' responsibility for these large collaborative projects and their need for an active individual research agenda. This balance allows members of the Laboratory to improve their scientific credentials continuously. Members of the Laboratory interact with the general public to support a wide range of interests in the atmospheric sciences. Among other activities, the Laboratory raises 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 Laboratory makes substantial efforts to attract 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, gives a broad description of our research, and summarizes our scientists' major accomplishments during calendar year 2010. The report also contains useful information on human resources, scientific interactions, and outreach activities. This report is published in a printed version, and an electronic version on our Laboratory for Atmospheres Web site, http://atmospheres.gsfc.nasa.gov/.

2. STAFF, ORGANIZATION, AND FACILITIES

2.1. Staff

The diverse staff of the Laboratory for Atmospheres is made up of scientists, engineers, technicians, administrative assistants, and collocated resource analysts, with a total staff of 266 members. The civil service composition of the laboratory consists of 50 members—49 scientists and 1 administrative assistant.

An integral part of the Laboratory staff is composed of onsite and near offsite research associates and contractors. The research associates are primarily members of joint centers involving the Earth Sciences Division and nearby university associations, e.g., the Joint Center for Earth Systems Technology (JCET), the Goddard Earth Sciences and Technology Center (GEST), and the Earth System Science Interdisciplinary Center (ESSIC), or are employed by universities with which the Laboratory has a collaborative relationship such as George Mason University, the University of Arizona, and the Georgia Institute of Technology. Of the 87 research associates, 90 percent hold PhDs. Contractors are a very important component of the staffing of the Laboratory. Out of the total of 106 contractors, 24 percent hold PhDs. In addition to these members, the Laboratory currently hosts 10 research fellows and 5 emeritus scientists. All hold PhDs. There are also 5 intern students. The makeup of our Laboratory, therefore, is 19 percent civil servants, 33 percent research associates, 40 percent contractors, and 4 percent research fellows. Emeritus scientists and interns account for 4 percent.

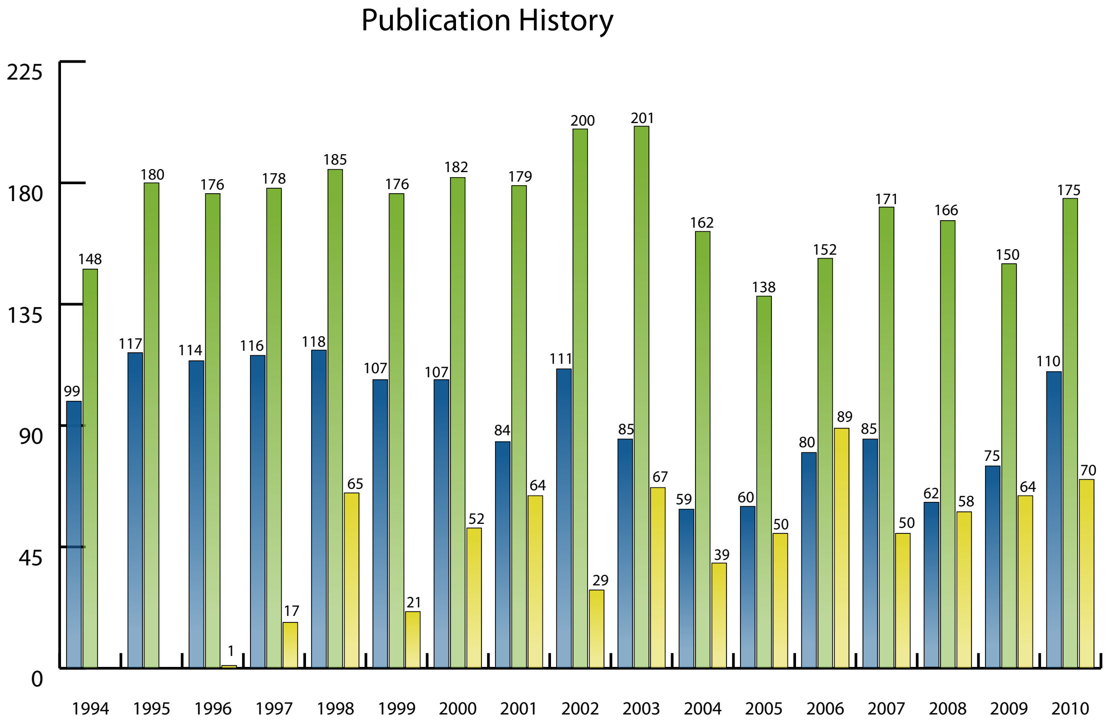


Figure 2.1: Number of proposals and refereed publications by Laboratory for Atmospheres members over the years. The green bar is the total number of publications and the blue bar is the number of publications where a Laboratory member is first author. Proposals submitted are shown in yellow.

2.2. Organization

The management and branch structure for the Laboratory for Atmospheres at the end of 2009 is shown in Figure 2.2.

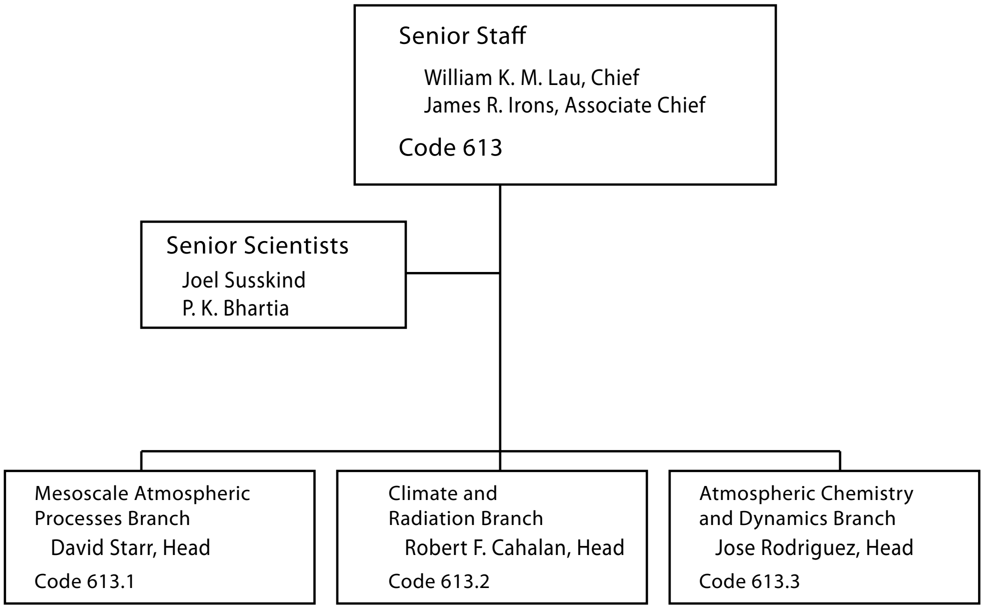


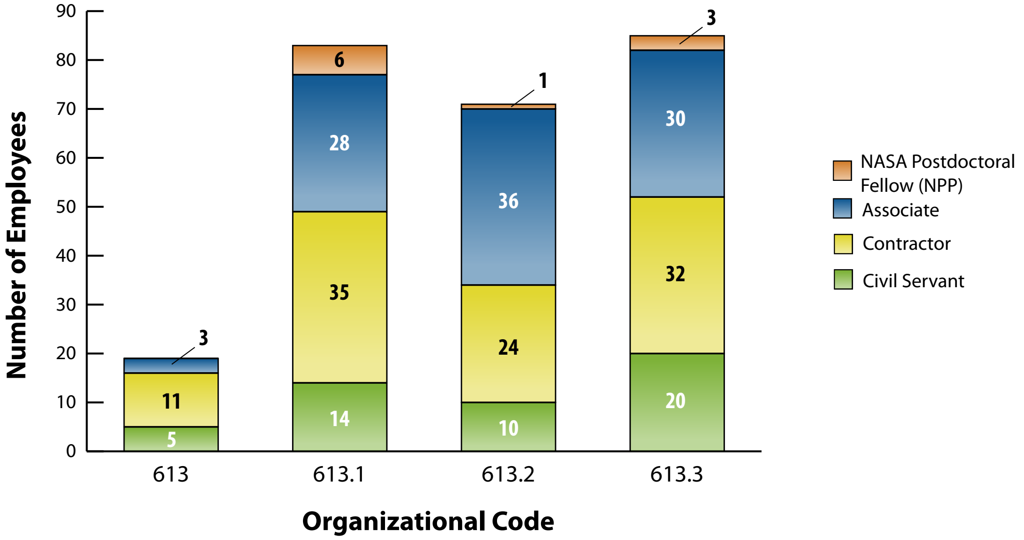
Figure 2.2: Laboratory for Atmospheres management and branch structure.

Branch Descriptions

The Laboratory has traditionally been organized into branches; however, we work on science projects that are becoming more and more cross-disciplinary. Branch members collaborate with each other within their Branch, across branches and Laboratories, and across Divisions within the Directorate. Some of the recent cross-disciplinary research themes of interest in the Laboratory are the Global Water and Energy Cycle, Carbon Cycle, Weather and Short-Term Climate Forecasting, Long-Term Climate Change, Atmospheric Chemistry, and Aerosols. The Senior Staff Office (613) and the three Branches is each composed of civil servant, associate, and contractor employment as shown in Figure 2.3.

A mission description and Web site address is given below for each of the Laboratory's three Branches. Branch Web sites may also be found by clicking on the Branch icons at the Laboratory's home page of http://atmospheres.gsfc.nasa.gov/.

Later, in Section 5, the Branch Heads summarize the science goals and achievements of their Branches. The Branch summaries are supplemented by a selection of news items, publication lists, and samples of highlighted journal articles given in Appendices I through III, respectively.



Employment Mix

Figure 2.3: Employment composition of the members of the Laboratory for Atmospheres.

Mesoscale Atmospheric Processes Branch, Code 613.1

The mission of the Mesoscale Atmospheric Processes Branch is to understand the physics and dynamics of atmospheric processes through the use of satellite, airborne, and surface-based remote sensing observations and model simulations. Further information about Branch activities may be found on the Web at http://atmospheres.gsfc.nasa.gov/meso/.

Climate and Radiation Branch, Code 613.2

The Climate and Radiation Branch has a threefold mission:

- To understand, assess, and predict climate variability and change, including the impact of natural forcing and human activities on climate now and in the future;
- To assess the impacts of climate variability and change on society; and
- To consider strategies for adapting to, and mitigating climate variability and change.

Further information about Branch activities may be found at http://climate.gsfc.nasa.gov/.

Atmospheric Chemistry and Dynamics Branch, Code 613.3

The principal mission of the Atmospheric Chemistry and Dynamics Branch is to understand the behavior of stratospheric ozone and trace gases that influence ozone. Ozone and trace gases such as methane, nitrous oxide, and the chlorofluorocarbons—profoundly influence the habitability of the Earth even though together they comprise less than one percent of the Earth's atmosphere. Ozone itself absorbs nearly all the biologically damaging solar ultraviolet radiation before it reaches the Earth's surface. The Clean Air Act of 1977 assigns the responsibility for studying the ozone layer to NASA. The Atmospheric

Chemistry and Dynamics Branch is the center for ozone and related atmospheric research at the Goddard Space Flight Center. Further information on Branch activities may be found on the Web at http://atmospheres.gsfc.nasa.gov/acd/.

2.3. Facilities

Computing Capabilities

Computing capabilities used by the Laboratory range from high-performance supercomputers to scientific workstations to desktop personal computers. Each Branch maintains its own system of computers, which are a combination of Windows, Linux, and Mac OS X computers. A major portion of scientific data analysis and manipulation, and image viewing is still done on UNIX cluster machines, with increasing amounts of data analysis and imaging done on single-user personal computers.

Lidar

The Laboratory has well-equipped facilities to develop lidar systems for airborne and ground-based measurements of clouds, aerosols, methane, ozone, water vapor, pressure, temperature, and winds. Lasers capable of generating radiation from 266 nm to beyond 1,000 nm are available, as is a range of sensitive photon detectors for use throughout this wavelength region. Details may be found in the *Laboratory for Atmospheres Instrument Systems Report, NASA/TP-2011-215875*, which is also available on the Laboratory's home page.

Radiometric Calibration and Development Facility

The Radiometric Calibration and Development Facility (RCDF) supports the calibration and development of ground, airborne, and space-based instruments designed to observe trace gases and aerosols important for understanding atmospheric composition. As part of the Earth Observatory System (EOS) calibration program, the RCDF collaborates with many national and international programs in the area of ultraviolet and visible (UV/VIS) spaceborne solar backscatter instruments. For further information, please contact Scott Janz, (scott.j.janz@nasa.gov).

3. OUR RESEARCH AND ITS PLACE IN NASA'S MISSION

The Laboratory for Atmospheres has a long history (more than 40 years) in Earth Science and Space Science missions studying the atmospheres of both the Earth and the planets. The wide array of our work reflects this dual history of atmospheric research from:

(1) The early days of the TIROS and Nimbus satellites with emphasis on ozone, Earth radiation, and weather forecasting; and

(2) The thermosphere and ionosphere satellites, the Orbiting Geophysical Observatory (OGO), the Explorer missions, and the Pioneer Venus Orbiter, to the more recent Galileo and Cassini missions and the current Earth Observing System (EOS) missions.

The Laboratory for Atmospheres conducts basic and applied research in the cross-disciplinary research areas outlined in Table 3.1, and Laboratory scientists focus their efforts on satellite mission planning, instrument development, data analysis, and modeling. In addition, the Laboratory is also conducting feasibility studies, improving remote sensing measurement design and technology in preparation for the planned decadal mission recommendations made in the *Decadal Survey: "Earth Science and Applications from Space: Imperatives for the Next Decade and Beyond,"* published by the National Academy of Sciences in 2007 (http://www.nap.edu/catalog/11820.html).

Table 3.1: Science Themes and our Major Research Areas.

Science Themes	Major Research Areas
Aerosol Atmospheric Chemistry Carbon Cycle Climate Change Global Water and Energy Cycle Weather and Short-term Climate Forecasting	Aerosol Atmospheric Chemistry and Ozone Atmospheric Hydrologic Cycle Carbon Cycle Clouds and Radiation Climate Variability and Prediction Mesoscale Processes Precipitation Systems Severe Weather Chemistry-Climate Modeling Global and Regional Climate Modeling Data Assimilation Tropospheric Winds Solar Variability

Our Research and Its Place in NASA's Mission

Our work can be classified into four primary activities or products: measurements, data sets, data analysis, and modeling. Table 3.2 depicts these activities and some of the topics they address.

Table 3.2: Laboratory for Atmospheres Science Activities.

Measurements	Global Data Sets	Data Analysis	Modeling
Aircraft Balloon Field campaigns Ground Space	Assimilated products Global precipitation MODIS[a] cloud and aerosol OMI[b] aerosol OMI surface UV OMI total ozone OMI Trace Species Column Measurements TOVS[c] Pathfinder TRMM[d] global precipitation products TRMM validation products	Aerosol-cloud-climate interaction Aerosol Atmospheric hydrologic cycle Climate variability and climate change Clouds and precipitation Global temperature trends Ozone and trace gases Radiation UV-B[e] measurements Validation studies	Atmospheric chemistry Clouds, cloud systems and mesoscale Coupled climate–ocean Data assimilation Data retrievals General circulation Radiative transfer Transport models Weather and climate

[a] *Moderate Resolution Imaging Spectroradiometer*
[b] *Ozone Monitoring Instrument*
[c] *TIROS Operational Vertical Sounder*
[d] *Tropical Rainfall Measuring Mission*
[e] *Ultraviolet-B*

The four major classification areas—measurements, datasets, data analysis, and modeling—are somewhat artificial because the activities are strongly interlinked, and cut across science priorities and the organizational structure of the Laboratory. The grouping corresponds to the natural processes of carrying out scientific research: ask the scientific question, identify the variable needed to answer it, conceive the best instrument to measure the variable, generate datasets, analyze the data, model the data, and ask the next question.

4. MAJOR ACTIVITIES

4.1. NASA Missions

4.1.1. Decadal Study Missions

4.1.1.1 ACE

The Aerosols, Clouds, and Ecology (ACE) mission is a mission recommended by the *National Research Council (NRC) Decadal Survey for Earth Sciences.* ACE is a Tier-2 mission. Aerosols and clouds are major factors in modulating global climate change. The IPCC (2007) has noted that uncertainties about clouds and aerosols represent the predominant source of uncertainty that limit present climate prediction capabilities. ACE seeks to provide the necessary measurement capabilities to enable robust investigation of these factors in global change during the 2020s, especially with regard to characterizing 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 (ocean color). In particular, the mission is to 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, and to observe key properties of marine ecosystems and ocean carbon pools not presently available from existing sensors. The mission plans to take strong advantage of the potential synergy between advanced aerosol measurements and next-generation ocean color measurements where atmospheric correction, mostly for aerosol effects, is critically important to the quality of the ecosystem measurements. The current nominal plan is for a 2021 launch into low Earth orbit at an altitude of 400–450 km. With respect to aerosol and cloud measurements, it is the successor to the aging A-Train satellite constellation, specifically CloudSat, CALIPSO, MODIS and POLDER. An intermediate mission is EarthCare, a three-year ESA mission that may launch in the 2015 timeframe and includes a three-channel, high-spectral-resolution lidar (HSRL) and a w-band radar, both nadir pointing. The ACE payload includes an advanced broad-swath ocean ecosystems radiometer, a nadir-pointing, 7-channel HSRL ($3\beta+2\alpha+2\delta$), a dual w- and ka-band radar with limited scanning capability, as well as an advanced polarimeter for aerosol and cloud measurements. Broad-swath radiometers sensing in the infrared, microwave, and sub-millimeter spectral regions are also included in the optimal mission concept.

The GSFC Laboratory for Atmosphere plays a preeminent leadership role in developing this mission. The ACE Science Working Group is charged and funded to develop the focused scientific questions and measurement requirements for this mission, the corresponding mission, and instrument concepts. David Starr is the ACE Study Science Lead. Lorraine Remer leads the ACE Aerosols Study Group (SG), and Ralph Kahn, Peter Colarco, Santiago Gasso (GEST) and Robert Levy (SSAI) participate in the Aerosol SG. Judd Welton and Matt McGill participate in the Lidar SG as well as the Aerosol SG. Vanderlei Martins (JCET) contributes in the Polarimeter SG as well as the Aerosol SG. Gerry Heymsfield, Lihua Li (Code 555) and Paul Racette (Code 555) are engaged in the Radar SG. Steve Platnick, EOS Project Scientist, and David Starr participate in the Cloud SG. The Lab is developing a number of airborne instruments (ACE simulators) to aid in mission definition and algorithm development including a polarimeter, the Passive Aerosol and Cloud Suite (PACS); a new lidar system, the Cloud-Aerosol Transport System (CATS); a rebuilt w-band radar (CRS); an updated submillimeter scanning radiometer (CoSSIR), and an updated microwave scanning radiometer (CoSMIR). The Lab is also active in ka-band radar development.

An extended briefing report (November 2010) on the ACE mission is available at http://dsm.gsfc.nasa.gov/ace/documents.html. For further information, please contact David Starr (david.starr@nasa.gov).

4.1.1.2 GEO-CAPE

The Geostationary Coastal and Air Pollution Events (GEO-CAPE) is one of the missions recommended by the NRC Decadal Survey. This mission is to 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 and allow a better understanding of the processes involved in pollution transformation and transport. The mission is a Tier-2 mission, with expected deployment after 2020.

NASA Headquarters has provided funding to different centers in the United States to start exploring the scientific questions and measurement requirements for this mission. Scientists in the Atmospheric Chemistry and Dynamics Branch are playing a leading role in several of the study subgroups. S. Randall Kawa is one of the two science coleads for this mission. Kenneth Pickering and Bryan Duncan participate in the Atmospheric Variability Study Group, analyzing global and regional model results to understand the scales of variability for the intended measured species, and thus the required resolution for the measurements. Joanna Joiner participates in the Detectability subteam, which examines the measurements that can be carried out in different wavelength ranges, the expected vertical resolution, and the interference of clouds and aerosols in the retrieval of gas species. Mian Chin has spearheaded the “Aerosol Science” subgroup, which is defining science questions and measurement requirements for aerosols. Jose Rodriguez and S. Randall Kawa participate in the Science Traceability Matrix subgroup. Rodriguez also coordinates GEO-CAPE efforts at Goddard.

Details on the GEO-CAPE mission can be found at http://geo-cape.larc.nasa.gov/. For information on Goddard efforts, please contact Jose M. Rodriguez (jose.m.rodriguez@nasa.gov).

4.1.1.3 ASCENDS

The NASA Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) mission, recommended by the 2007 NRC Earth Science Decadal Survey, is considered the technological next step 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 2013). 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 are to enable investigations of the climate-sensitive southern ocean and permafrost regions, produce insight into the diurnal cycle and plant respiration processes, and provide useful new constraints to global carbon cycle models. NASA’s current plan is for launch in 2019–2020.

The Laboratory for Atmospheres supports ASCENDS through technology development, instrument definition studies, and carbon cycle modeling and analysis. Bill Heaps (Code 613.3) is the Principal Investigator for an Instrument Incubator Program (IIP) project to develop 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 Branch, which target instrument and mission development for ASCENDS. They play a key role in radiative transfer modeling, retrieval algorithm development, test instrument field deployment, and data analysis on Jim Abshire’s IIP project. 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 visit the ASCENDS workshop Web site at http://cce.nasa.gov/ascends/index.htm.

4.1.1.4 Global 3D-Winds Decadal Survey Mission

The wind field plays an important role in specifying the global initial conditions for numerical weather forecasting. In addition to improving numerical weather prediction, there is also a need to improve accuracy of wind fields to assess long-term sensitivity of the general circulation to climate change and to improve horizontal and vertical transport estimates of atmospheric constituents including water vapor, CO_2 and aerosols for climate applications. In spite of its significance, the three-dimensional (3D) structure of the wind field remains largely unobserved on a global scale. A new satellite mission using Doppler lidar technology to measure the global wind field accurately is needed to fill this important gap in the global observing system. The 2007 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 Decadal Survey panel recommended a two-phase approach to achieving an operational global wind measurement capability. For the first phase, the panel recommends that NASA develop the technology and fly a pre-operational mission to demonstrate the technology and measurement concept and establish the performance standards for an operational wind mission. The second phase would develop and fly an operational wind system in the 2025 time frame.

In 2010, Laboratory for Atmosphere's scientists continued to make strides in preparation for the Global 3-D Wind mission in several areas. In the area of technology readiness, a major milestone was met in October, 2009 with the successful operation of the Tropospheric Wind Lidar Technology Experiment (TWiLiTE) airborne Doppler lidar on the NASA ER–2 high altitude research aircraft. Also in 2010 significant progress was made in the development of an advanced Observing System Simulation Experiment (OSSE) capability in the GSFC Global Modeling and Assimilation Office. This advanced OSSE capability enabled improved understanding of the impact of the Global 3-D Wind mission observations on future global circulation models and provides insights into mission requirements and measurement objectives. Finally, new Observing System Experiment (OSE) techniques were developed to provide simulated wind observation datasets for assimilation in the OSSEs. The new OSE techniques were based on validated lidar instrument models and improved representations of the global distribution of aerosols and clouds as observed by the GLAS and CALIPSO space-based lidar instruments.

For additional information, please contact Bruce Gentry (bruce.m.gentry@nasa.gov).

4.1.2. NASA Planned Missions

4.1.2.1 GPM Mission

Global Precipitation Measurement (GPM) is an international satellite mission designed to provide next-generation precipitation observations every two to four hours anywhere in the world. The GPM concept centers on the deployment of a Core Observatory that will carry an advanced radar-radiometer system consisting of a Dual-frequency Precipitation Radar (DPR) and the GPM Microwave Imager (GMI). Together, these instruments are to establish a new reference standard for precipitation remote sensing that can be used to unify and refine precipitation estimates from a constellation of research and operational satellites.

GPM is currently a joint venture between NASA and the Japan Aerospace and Exploration Agency (JAXA). The GPM Core Observatory is scheduled to launch in mid-2013. Domestic and international space agencies are to provide additional satellites in the GPM constellation in partnership with NASA and JAXA. NASA also plans to provide a second GMI on a partner-provided GPM Low-Inclination Observatory that will launch in late 2014.

Figure 4:1 The GPM *constellation of satellites with the* GPM *Core Observatory shown on the upper right.*

GPM is a science discovery mission with integrated application goals. GPM measurements is to provide new insights into precipitation microphysics and advance understanding of global water cycle variability. Also, by providing data in near real time, GPM benefits society directly by extending current capabilities in numerical weather prediction, as well as the monitoring and forecasting of natural hazard events such as hurricanes, floods, and landslides.

Scientists in the Laboratory for Atmospheres have played a crucial role in GPM. In 2010, more than 40 Laboratory scientists participated in GPM activities. Contributions included developing definitions of the science and instrument requirements of the mission, developing algorithms to retrieve precipitation information from active and passive microwave sensor measurements, conducting targeted field campaigns to support pre-launch algorithm development, and employing satellite precipitation data in scientific research and societal applications.

For more information on GPM, please visit the Precipitation Measurement Missions (PMM) Web site at http://pmm.gsfc.nasa.gov/ or contact GPM Project Scientist Arthur Hou (arthur.y.hou@nasa.gov) or GPM Deputy Project Scientist Gail Skofronick Jackson (gail.s.jackson@nasa.gov).

4.1.2.2 NPP

The NPOESS Preparatory Project (NPP) has had an excellent year in 2010. All of the instruments are now integrated on the spacecraft and observatory environmental testing has begun. NPP's advanced visible, infrared, and microwave imagers and sounders are 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 NPP launch readiness date is October 25, 2011. The NPP Science Team re-competed in the ROSES 2010 call and 11 proposals from 610 and GEST have been selected.

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

4.1.2.3 Glory

As this report was being finalized, the Glory Mission failed to achieve orbit and was lost.

An accurate description of Earth's energy budget is important for scientists in order to anticipate changes to our climate. Shifts in the global climate and the associated weather patterns impact life by altering landscapes and changing the availability of natural resources. Scientists are working to better understand exactly how and why this energy budget changes. The Glory mission will provide significant contributions toward this critical endeavor.

The science objectives of the Glory mission include: (a) the determination of the global distribution, microphysical properties, and chemical composition of natural and anthropogenic aerosols and clouds with accuracy and coverage sufficient for a reliable quantification of the aerosol direct and indirect effects on climate; and (b) the continued measurement of the total solar irradiance to determine the Sun's direct and indirect effect on the Earth's climate.

These goals are accomplished with two instruments: the Aerosol Polarimetry Sensor (APS) and the Total Irradiance Monitor (TIM). APS is a continuous scanning sensor that has the capability to collect visible, near-infrared, and short-wave infrared data scattered from aerosols and clouds. It is designed to make extremely accurate multi-angle observations of Earth, and atmospheric scene spectral polarization and radiance. APS provides observations of aerosol and cloud optical thickness, aerosol and cloud particle size, aerosol refractive index, aerosol single-scattering albedo, and aerosol particle shape. These observations will contribute new information on aerosol composition and shape that are critical for determining the direct impact of aerosols on the radiation budget of Earth and the effects of aerosols on clouds. TIM is an active cavity radiometer that monitors changes in incident sunlight to Earth's atmosphere with high accuracy and precision. TIM will maintain the continuous record of total irradiance required to determine the Sun's effect on Earth's climate. Judd Welton (613.1) is the Deputy Project Scientist.

For more information, please contact Judd Welton (judd.welton@nasa.gov), (301) 614-6279.

4.1.2.4 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 objective is to extend the ability to detect and characterize changes quantitatively on the global land surface at a scale where natural and man-made causes of change can be detected and differentiated.

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 Goddard Space Flight Center (GSFC) is responsible for the development of the overall mission. USGS is responsible for ground-system development and is to operate LDCM after launch. The LDCM satellite is being developed by General Dynamics Advanced Information Systems and accommodates two instruments: the Operational Land Imager (OLI) built by

Ball Aerospace and Technologies Corporation (BATC), and the Thermal InfraRed Sensor (TIRS) built by NASA GSFC. NASA's Kennedy Space Center is responsible for the Atlas V launch vehicle. The USGS Earth Resources Observation and Science (EROS) Center is to receive, archive, and distribute LDCM data.

The Landsat Program has been declared a National Asset by the Office of Science and Technology Policy (OSTP). 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 vital 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, and national security applications. The LDCM is to expand and improve upon the Landsat data record when launched in December 2012.

A great deal of technical progress was achieved in 2010. The LDCM Project completed a successful critical design review (CDR) in May with all major subsystems proceeding to the integration and test phase. Testing of the OLI engineering design unit (EDU) was completed, leading to the integration of the flight model. The flight model completed radiometric and spatial performance testing in a thermal and vacuum chamber at Ball Aerospace before the end of the year. Similarly, testing of the TIRS functional performance model (FPM) was completed and integration of the TIRS flight model began. The focus of the TIRS optics was being adjusted and tested in a thermal and vacuum chamber at GSFC as the year ended. In both cases, tested performance had, so far, exceeded requirements with healthy margins. The LDCM spacecraft contract was originally awarded to General Dynamics Advanced Information Systems. The division of General Dynamics responsible for the LDCM spacecraft was acquired by Orbital Sciences Corporation during 2010, along with the Gilbert, Arizona facility housing the spacecraft in development. Orbital thus assumed responsibility and began spacecraft assemble in Gilbert this year. The ground system also began initial testing in 2010 in concert with our USGS partners. This progress kept the Project on schedule for the December 2012 launch.

More information can be found on the internet at http://landsat.gsfc.nasa.gov/ or http://ldcm.gsfc.nasa.gov/, or by contacting James R. Irons, LDCM Project Scientist (james.r.irons@nasa.gov).

4.1.2.5 NPOESS/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 NPOESS program experienced several challenges, including schedule delays and cost increases. OSTP issued a fact sheet outlining a restructuring of the NPOESS program in FY2011. Following are excerpts from the fact sheet:

> The President's FY2011 budget contains a major restructuring of NPOESS in order to put the critical program on a more sustainable pathway toward success. The satellite system is a national priority—essential to meeting both civil and military weather-forecasting, storm-tracking, and climate-monitoring requirements. The major challenge of NPOESS was jointly executing the program between three agencies of different size with divergent objectives and different acquisition procedures. The new system will resolve this challenge by splitting the procurements. NOAA and NASA will take primary responsibility for the afternoon orbit, and DOD will take primary responsibility for the morning orbit. The agencies will continue to partner in those areas that have been successful in the past, such as a shared ground system. NOAA's portion will notionally be named the "Joint Polar Satellite System" (JPSS).

> NASA's role in the restructured program will be modeled after the procurement structure of the successful POES and GOES programs, where NASA and NOAA have a long and effective partnership. Work is proceeding rapidly with NOAA to establish a JPSS program at the Goddard Space Flight Center (GSFC). The NASA-developed and operating Earth Observing System (EOS) Aqua satellite and ground system are very similar in scope and magnitude to the proposed JPSS program. NOAA and NASA will strive to ensure that all current NPOESS requirements are met on the most rapid practicable schedule without reducing system capabilities. NASA program and project management practices have been refined over decades of experience developing and acquiring space systems, and NASA anticipates applying its current practices to JPSS. NASA program and project management processes will include thorough and ongoing review and oversight of project progress. Cost-estimates will be produced at or close to the 80% confidence level.

The JPSS program has been established and is in program formulation. JPSS is moving forward by supporting the launch of the NPP mission, it is in development with the Common Ground System and the J1 mission, now scheduled for a 2016 launch. The J2 mission, LRD 2018, is in formulation. Laboratory support to the JPSS program will consist of providing the Senior Project Scientist, the JPSS Instrument Scientists, and recruiting new hires especially instrument scientists.

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

4.1.2.6 DSCOVR

The instruments onboard the Deep Space Climate Observatory (DSCOVR) spacecraft are currently undergoing refurbishment at three locations: Lockheed Martin (EPIC), the National Institute of Standards (NISTAR), and GSFC (the magnetometer, Faraday cup, and electron analyzer). The goal of the mission is to supply space weather information for NOAA and the Air Force for protection of satellite assets and for the power grid. In addition to the space weather objective, NASA has been requested to provide a level of Earth science support equivalent to the mission's original goals.

These goals are measurements of global ozone levels, aerosol optical depth, cloud height, vegetation and leaf area indices (EPIC), and the Earth's radiation balance (NISTAR). The recalibration and refurbishment program, now underway, will correct previously known deficiencies (such as stray light for EPIC) and improve measurements. By replacing the older 393, 645, 870, and 905 nm channels with four new 680, 688, 763, and 780 nm wavelength channels, scientists will be able to measure cloud height using the Oxygen-A and -B bands using new algorithms developed at GSFC. After instrument refurbishment, the instruments will be returned to GSFC for integration with the spacecraft. Algorithm development, spacecraft management software, satellite bus refurbishment, ground systems, and data reception and transmission are awaiting future direction from NASA.

For further information please contact Alexander Marshak (alexander.marshak@nasa.gov), or Jay R. Herman (jay.r.herman@nasa.gov).

4.1.3. NASA Missions of National Interest

4.1.3.1 CASS

The Chemical and Aerosol Sounding Satellite (CASS) is being developed by scientists in Code 613.3 (Jose M. Rodriguez, Charles Jackman, Anne Douglass, and Luke Oman) to address the future gap in measurements of ozone, aerosol, and trace constituents in the stratosphere and upper troposphere. Measurements of these species are currently being carried out by different instruments, primarily aboard the Aura satellite and the Canadian EnviSat Mission, as well as other European missions. However, these missions are already beyond their five-year estimated duration, and realistically, they are not expected to last beyond 2014. Limb profiles of ozone have not been incorporated in the NPOESS series as of now, and no trace gases measurements are being planned. The next Decadal Survey Mission that would carry out these measurements is GACM, a Tier-3 mission that probably would not be launched until late 2020s. This presents a potential gap of more than 10 years in important stratospheric measurements.

The original CASS concept proposed two instruments: the SAGE-III instrument—already in storage at NASA LaRC, which measures profiles of O_3, NO_2, and aerosols by solar and lunar occultation; and a copy of the ACE-FTS instrument, which has been very successful in carrying out measurements of a suite of trace gases in the upper troposphere and stratosphere. These instruments would be incorporated in a dedicated satellite at 57° inclination orbit, allowing for monthly sampling from high latitudes to the tropics. An ideal launch date would be 2014–2015, to minimize the data gap.

The proposed budget for FY 2011 included integration of the SAGE III instrument aboard the International Space Station, with a target date of 2014. This platform has an orbit inclination of about 52°, thus decreasing the high-latitude coverage. Accommodation studies by Canada have determined that the ACE instrument should not be incorporated in the Space Station due to the lack of high-latitude coverage. However, the CASS group is still exploring potential opportunities in other platforms.

For further information, please contact Jose Rodriguez (jose.m.rodriguez@nasa.gov).

4.1.4. NASA Active Flight Missions

4.1.4.1 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 U.S. science team leader at JPL) provides a unique benefit to Terra's mission as a stereoscopic and high-resolution instrument required to measure and verify processes at fine spatial scales; 2) CERES (LaRC) investigates the critical role 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 ten pressure levels and its gas correlation approach that still produces the best data for studies of horizontal and vertical transport of this important trace gas.

For more than 10 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. Terra's basic mission currently produces 72 core data products with the primary goals of enabling the science community to address fundamental questions in Earth Science as articulated in NASA's Science Plan for 2007–2016, under the overarching question, "How is the Earth changing and what are the consequences for life on Earth?" Terra spacecraft and instruments have performed and continue to perform extremely well and only experienced the expected normal on-orbit degradation of some subsystems or components. Propulsive maneuvers of Terra spacecraft to maintain orbital science requirements are projected to function for approximately eight more years. Scientists in the Laboratory for Atmospheres play important roles in algorithm developments, product generations, and conduct vital research on Earth system sciences.

For general information about Terra science team publications, see the following Web sites:

ASTER: http://asterweb.jpl.nasa.gov/bibliography.asp

CERES: http://asd-www.larc.nasa.gov/ceres/pubs.html

MISR: http://www-misr.jpl.nasa.gov/mission/pub.html

MODIS: http://modis.gsfc.nasa.gov/sci_team/pubs/

MOPITT: http://www.acd.ucar.edu/mopitt/publications.shtml

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

4.1.4.2 Aqua

The Aqua spacecraft, launched on May 4, 2002, carries six Earth-observing instruments: AIRS, AMSR-E, AMSU, CERES (two copies), HSB (no longer operating), and MODIS (also flying on Terra). The spacecraft is to begin its third Extended Mission period pending a Senior Review process that will be completed in the summer of 2011. Aqua data products have been recognized as continuing to provide highly valuable Earth science data in the previous two Senior Reviews. In addition to collecting data regarding Earth's water—as highlighted in the name "Aqua"—mission instruments also provide radiative energy fluxes, atmospheric temperature and composition, dust and aerosols, cloud properties, land vegetation, phytoplankton and dissolved organic matter in the oceans, and surface albedo, temperature, and emissivity. These measurements are helping scientists to quantify the state of the Earth system, validate climate models, address key science questions, and serve the applications community.

A number of Laboratory personnel are involved in Aqua or project science efforts. For MODIS, algorithm development is being performed by Lorraine Remer (aerosol dark target algorithm), Christina Hsu (aerosol Deep Blue algorithm), and Steven Platnick (cloud optical properties, Atmosphere Team Level-3 gridded products). For AIRS, Joel Susskind is responsible for the temperature-moisture profile algorithm. Laboratory scientists were awarded funding in 2010 via NASA's ROSES 2009 to conduct investigations with Aqua (and other) satellite data in such diverse areas as clouds, aerosols, biomass burning pollution, Saharan dust, atmospheric sounding, and precipitation. These include Robert Cahalan, Christina Hsu, George Huffman, William Lau, Alexander Marshak, Steven Platnick, Oreste Reale, Lorraine Remer, Joel Susskind, Hongbin Yu, and Zhibo Zhang. Numerous publications authored or coauthored by Laboratory scientists making use of Aqua data can be found in the publications section of this report. In early 2010, Steven Platnick stepped down from his position as Aqua Deputy Project Scientist and was replaced by Lazaros Oreopoulos. Platnick became the EOS Senior Project Scientist and the A-train Project Scientist.

Further information on the Aqua mission can be found at http://aqua.nasa.gov/ or by contacting Lazaros Oreopoulos (lazaros.oreopoulos@nasa.gov).

4.1.4.3 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 addresses questions concerning the stratospheric ozone layer, air quality, and climate.

It has now been more than six years since launch. The end-of-prime mission review, organized by NASA Headquarters, focused on the lessons learned from the pre-launch phase through the six years of successful operation of the Aura platform. In 2011 the scientific results and health of the platform and the instruments is to be evaluated by the Senior Review panel to decide if the Aura mission will be extended for two more years (2012–2013). Aura scientific contributions during the time since senior review 2009 are significant and expected to continue, but the instruments are aging.

Additional information about Aura instruments, spacecraft, and science, along with a list of publications are available on the Web site http://aura.gsfc.nasa.gov/. For further information, please contact Anne Douglass (anne.r.douglass@nasa.gov).

4.1.4.4 GOES

NOAA's Geostationary Operational Environmental Satellites (GOES) have been built, launched, and initialized by GSFC'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 Laboratory for Atmospheres provides a project scientist to assure 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 operates a GOES ground station that offers real-time, full-resolution, calibrated GOES images to support scientific field experiments and to supply Internet users with high-quality data during severe weather events.

In 2010, the project scientist supported the launch of GOES-P (renamed GOES-15 in orbit) and helped debug the new image broadcast format adopted by NOAA. Also in 2010, the five scientific instruments for the next generation of GOES satellites, GOES-R and beyond (2015 launch and beyond), began construction and ground testing for the next three years. A HDTV-quality video was created to illustrate the 2009 hurricane season. The real-time Web site downloaded an average of 200 GB/day of enhanced GOES imagery (http://goes.gsfc.nasa.gov).

For further information, please contact Dennis Chesters, GOES Project Scientist, (dennis.f.chesters@nasa.gov).

4.1.4.5 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 0.1–27 nm and 115–2400 nm wavelength ranges with unprecedented accuracy and precision. SORCE has successfully completed its five-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 forces 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

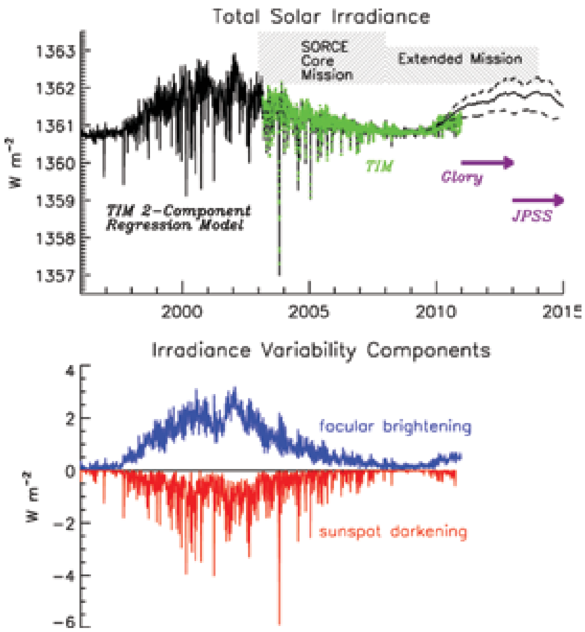


Figure 4.2: Total Solar Irradiance Measurements. SORCE *has tracked the decline of solar irradiance in solar cycle 23, through the solar cycle minimum in 2008. The irradiance is now into the rising phase of solar cycle 24, as shown in the upper panel by the* TIM *measurements of total irradiance (indicated by the green symbols). From these observations, the sunspot and facular sources of irradiance variations have been identified and shown in the lower panel. Estimates of the total irradiance before the* SORCE *launch in 2003 are computed from sunspot and faculae data and are shown as the solid black line in the upper panel. Provided that* SORCE *continues for four more years,* SORCE *will track the rise and maximum of solar cycle 24, permitting significant overlap with* NASA*'s Glory mission, and its* TIM *instrument. Potential overlap with* JPSS TSIS*, with its* TIM *and* SIM *instruments, will require additional extensions. The dashed curves correspond to solar activity predictions that are 40 percent higher and lower than in cycle 23. more years,* SORCE *will track the rise and maximum of solar cycle 24. Potential overlap with* JPSS TSIS *with its* TIM *and* SIM *instruments will require additional extensions. The dashed curves correspond to solar activity predictions that are 40 percent higher and lower than in cycle 23.*

Science program [e.g. NASA Science Plan, 2010]. Current TSI and SSI measurements by NASA SORCE and planned TSI and SSI measurements by NOAA/NASA JPSS TSIS are essential measurements for our national climate program as discussed in the NRC Earth Science and Applications from Space report of 2007.

Major accomplishments of the SORCE mission during the past two years are:

- The most accurate value of total solar irradiance during the 2008 solar minimum period is 1360.8±0.5 W m-2 according to measurements from the SORCE TIM and a series of new radiometric laboratory tests. This value is significantly lower than the canonical value of 1365.4±1.3 W m-2 established in the 1990s, which energy balance calculations and climate models currently use [Kopp and Lean, 2010].
- Fundamental discovery that the solar spectral irradiance in the visible does not vary in phase with the TSI over the solar cycle, necessitating new studies in solar heating in Earth's atmosphere and at the surface [Harder, et al., 2009; Cahalan, et al.; 2010, Haigh, et al., 2010].
- Establishment of reference spectra for the 2008 solar cycle minimum using simultaneous observations throughout the X-ray, UV, visible, and IR regions and with the total irradiance [Woods, et al., 2009].

- Commencement of a new and unique database of near UV, visible, and near infrared solar spectral irradiance [http://lasp.colorado.edu/sorce/].
- Continuation with the UV irradiance database implemented thus far by SBUV, SME, and UARS [http://lasp.colorado.edu/lisird/].
- New, improved models of solar irradiance variations, including forecast capabilities, for investigating physical sources of solar variability for use in studying past and future climate change [Fontenla, et al., 2009].

As this report was being finalized, the Glory Mission failed to achieve orbit and was lost.

The Glory mission will carry a new TIM that uses the same basic design as the SORCE TIM, but with even more precise characterization. Glory will not include the SSI observation, which means that SORCE SIM must continue to provide this required measurement through the launch of the follow-on Total and Spectral Solar Irradiance Sensor (TSIS), planned for launch in 2014. TSIS sensors will continue key climate measurements of total and spectral solar irradiance that contribute to determining the Earth's energy balance and understanding how Earth's climate responds to solar variability. NASA is developing the TSIS flight model under a reimbursable agreement with NOAA.

For further information, please contact Robert Cahalan (robert.f.cahalan@nasa.gov).

4.1.4.6 ICESat

NASA's Ice, Cloud, and land Elevation satellite (ICESat) ended its science mission in February 2010 with the failure of the last of its three lasers. In June, NASA's Science Mission Directorate approved a plan to lower the spacecraft's orbit so that it would re-enter the atmosphere by August–September 2010. A series of thruster burns on the spacecraft conducted June 23–July 14 slowly lowered ICESat's orbit, minimizing the time until it re-entered Earth's atmosphere and broke up. Some pieces of the spacecraft, weighing collectively about 200 pounds, survived re-entry. ICESat finally re-entered the earth's atmosphere in October and came to rest in the Barents Sea north of Norway.

Find out more about ICESat at the Web site: http://icesat.gsfc.nasa.gov/. For further information, please contact Stephen Palm (stephen.p.palm@nasa.gov), or Alexander Marshak (alexander.marshak@nasa.gov).

4.1.4.7 TRMM

The Tropical Rainfall Measuring Mission (TRMM), launched in late 1997, is 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 (35°) have made TRMM the world's foremost satellite for the study of precipitation and associated storms and climate processes in the tropics. TRMM instruments include the first and only precipitation radar (PR) in space, the TRMM microwave imager (TMI), a visible and infrared scanner (VIRS), and a lightning imaging sensor (LIS). TRMM's original 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 now continued into its 14th year, the science objectives have extended beyond just determining the mean precipitation distribution but 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. Significant scientific accomplishments have already come from TRMM data, including reducing the uncertainty of mean tropical oceanic rainfall; a documentation of regional, diurnal, and inter-annual variations in precipitation characteristics; the first estimated profiles of latent heating from satellite data; improved climate simulations; increased knowledge of characteristics of convective systems and tropical cyclones; and new insight into the impact of humans on rainfall distributions. The availability of real-time TRMM data has led to significant applications and fulfillment of national operational objectives through use of TRMM data, primarily in the monitoring of tropical cyclones, in hydrological applications, and in assimilation of precipitation information into forecast models. The TRMM satellite and its instruments are in excellent shape and there is sufficient station-keeping fuel onboard to maintain science operations potentially until 2014 or later.

4.2. Measurements

Studies of the atmosphere of Earth require a comprehensive set of observations, relying on instruments borne on spacecraft, aircraft, balloons, or those that are ground-based. Our instrument systems 1) provide information leading to basic understanding of atmospheric processes, and 2) serve as calibration references for satellite instrument validation. Many of the Laboratory's activities involve developing concepts and designs for instrument systems for spaceflight missions, and for balloon-, aircraft-, and ground-based observations. Airborne instruments provide critical in situ and remote measurements of atmospheric trace gases, aerosol, ozone, and cloud properties. Airborne instruments also serve as stepping-stones in the development of spaceborne instruments, and serve an important role in validating spacecraft instruments. Details concerning the laboratory instruments are presented in a separate Laboratory technical publication, the *Instrument Systems Report*, NASA/TP-2011-215875 which is also available on the Laboratory's home page, http://atmospheres.gsfc.nasa.gov/.

4.3. 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 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 2010, Laboratory personnel supported activities as scientific investigators, or as mission participants, in the planning and coordination phases.

4.3.1. 7-SEAS/Dongsha 2010 Deployment in Northern South China Sea

Biomass burning has been a regular practice for land clearing and land conversion in many countries, especially those in Africa, South America, and Southeast Asia. However, the unique climatology of Southeast Asia is very different than that of Africa and South America such that large-scale biomass burning causes smoke to interact extensively with clouds during the peak-burning season. Significant global sources of greenhouse gases (e.g., CO_2, CH_4), chemically active gases (e.g., NO, CO, HC, CH_3Br), and atmospheric light-absorbing aerosols are produced by the biomass burning processes. These trace gases and aerosols influence the Earth-atmosphere system, impacting both global climate and atmospheric composition. An interdisciplinary atmospheric sciences project with in situ, remote sensing and modeling components, named as the 7 South East Asian Studies (or 7-SEAS, http://7-seas.gsfc.nasa.gov/), initiated in 2008 and continuing until 2012, works closely with in-region scientists to develop a wide-ranging Southeast Asian scientific data network. The primary goal of the 7-SEAS project is to understand the impact of aerosol particles on Southeast Asian weather and climate. Such a goal requires a highly interdisciplinary science team. Research topics include seven focus areas from which the program derives its name: (1) predicting the environment on the immediate, medium-range, and long-term climate time scales; (2) clouds and precipitation; (3) anthropogenic and biomass burning emissions and transport; (4) natural background atmospheric chemistry; (5) radiative transfer; (6) tropical-subtropical meteorology; and (7) satellite and model calibration/validation.

The Dongsha Experiment carried out in March–June 2010 on Dongsha Island (20.70 N, 116.73 E) serves as a pilot study for the 7-SEAS project. Dongsha Island is located in the northern part of the South China Sea, 400 km southwest of the southern tip of Taiwan and 340 km southeast of Hong Kong. This small island features a sub-tropical maritime climate and sees mostly maritime aerosols. Under seasonal prevailing winds, it is influenced by aerosols of continental origins (e.g., dust, anthropogenic, and biomass-burning aerosols). NASA SMART Labs (http://smartlabs.gsfc.nasa.gov/), AERONET (http://aeronet.gsfc.nasa.gov/), MPLNET (http://mplnet.gsfc.nasa.gov/), and Deep-Blue (http://disc.sci.gsfc.nasa.gov/dust/) teams participated in this experiment. Several long-range transport of biomass-burning aerosols over Dongsha were identified by a vertical pointing lidar (at 355nm wavelength); however, an intense Asian dust storm (21 March 2010) was observed surprisingly during the observational period. The dust storm migrated from the great Gobi deserts to the West Pacific in three days, and its spatiotemporal evolution was evident (cf. Fig. 4.3) in the MODIS aerosol retrievals. For the first time, the characterization of Asian dust storm transported to the northern South China Sea was explored by such a comprehensive suite of in situ measurements. Figure 4.4 depicts a dramatic increase of PM2.5 concentration, dust mass fraction, lidar depolarization ratio, decrease of aerosol humidification factor, and a change of aerosol optical properties due to the dust intrusion. The results also suggest that the dust particles were mixed with anthropogenic and marine aerosols and transported near the surface. An important implication of these results is that the Asian dust transported to northern South China Sea may have influence on marine ecosystems.

For further information, please contact Si-Chee Tsay (si-chee.tsay-1@nasa.gov), or http://smartlabs.gsfc.nasa.gov.

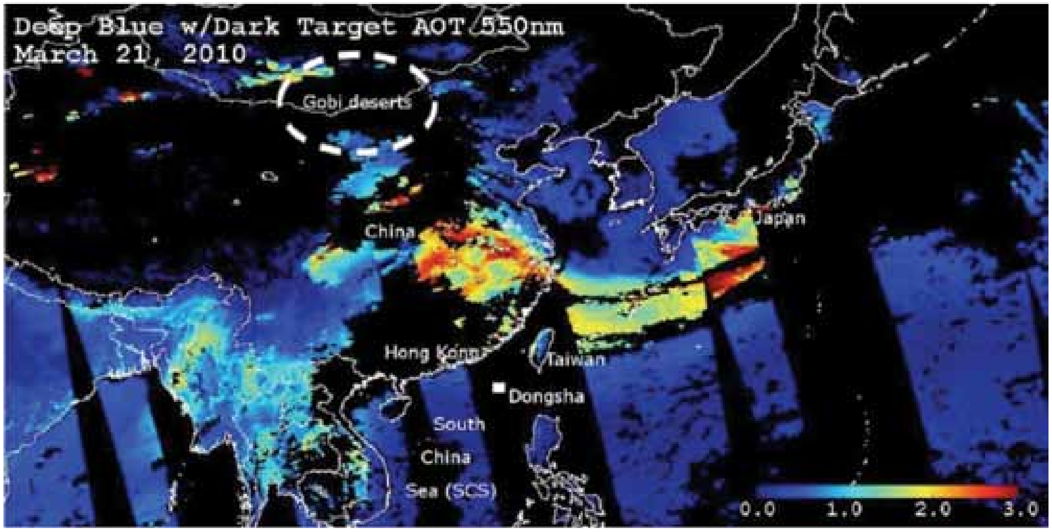


Figure 4.3: Composite Aqua/MODIS Deep-Blue and Dark-Target retrievals of aerosol optical thickness at 0530 UTC overpass.

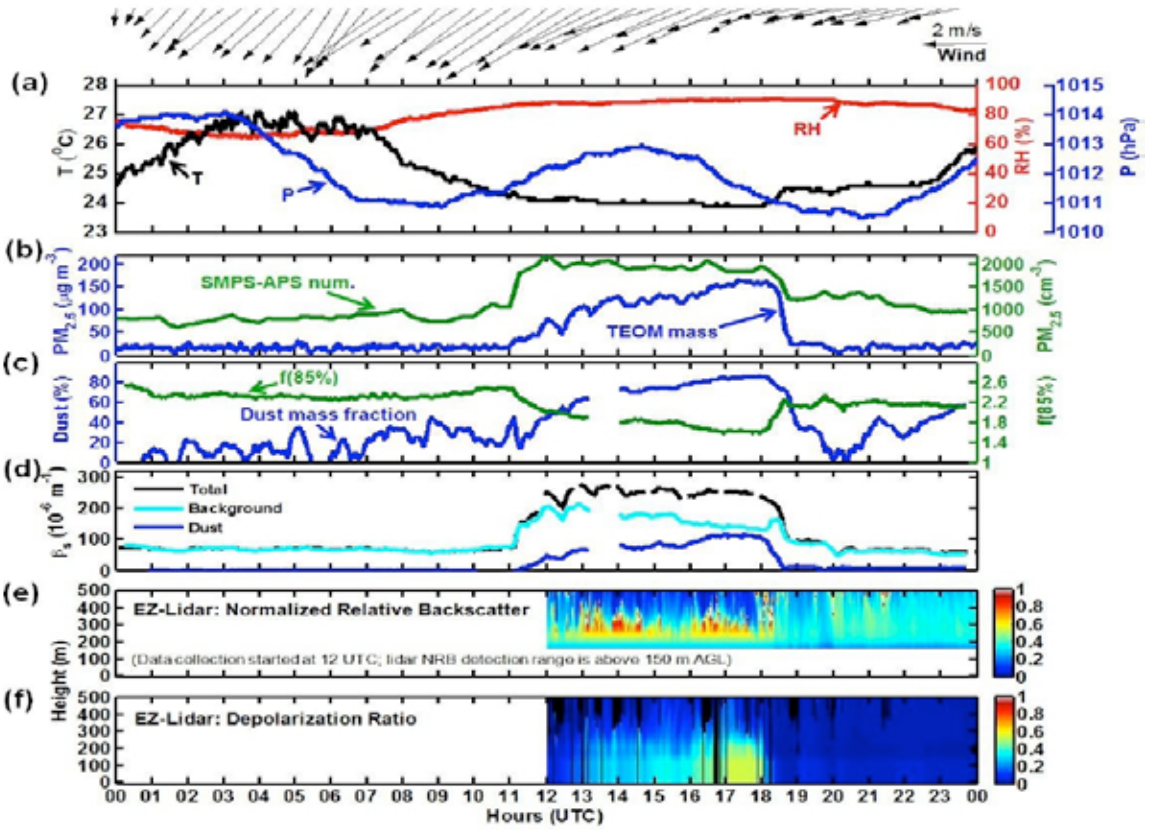


Figure 4.4: Time series of (a) wind speed/direction, temperature, pressure, and relative humidity, (b) mass and number concentrations of particulate matter (PM2.5, diameter less than 2.5µm) (c) dust mass fraction and aerosol humidification factor, (d) total, dust, and background particle scattering coefficients, (e) normalized lidar relative backscatter (150–500 m above ground is shown), and (f) the corresponding lidar depolarization ratio at Dongsha on March 21, 2010.

4.3.2. GloPac

The Global Hawk Pacific Mission (GloPac) was the first demonstration of the Global Hawk (GH) unmanned aircraft system (UAS) for Earth science. A principal GloPac goal was to demonstrate that the Global Hawk could be operated routinely to obtain science-quality data over remote atmospheric regions. A payload of 11 instruments was integrated onto the Global Hawk in March 2010. Initial test flights were conducted on April 2 and 7, followed by full science flights on April 13, 22, and 30. The science flights ranged in duration from 14 to 28 hours, reached cruise altitudes up to 65,000 ft (19.8 km) and covered distances between 4,600 nmi (8520 km) and 9,700 nmi (17,960 km). The GH reached the remote Pacific between 12°N and the Gulf of Alaska and explored the remote Arctic up to 85°N above Alaska. No Global Hawk had previously operated north of 70°N.

Highlights of the Global Hawk flights include sampling a large fragment of the Arctic polar vortex in the Gulf of Alaska, sampling aerosol dust plumes from Asia extending from the surface to 10-km altitude over the Pacific, and extensive flight legs along the ground track of the A-train satellites coinciding with satellite overpass times. The success of the GloPac has provided a wealth of information and experience for science and operation teams that will increase the likelihood of success in future Global Hawk missions.

Paul A. Newman was the co-project scientist of GloPac. GSFC flew two instruments on the Global Hawk for GloPac: the Airborne Compact Atmospheric Mapper (ACAM, PI: Scott Janz) and the Cloud Physics Lidar (CPL, PI: Matt McGill). Randy Kawa, Peter Colarco, Huisheng Bian, and Leslie Lait provided in-field flight planning support, while GMAO personnel (Arlindo DaSilva, Steven Pawson) provided forecasts products for the mission.

For more information, please contact Paul A. Newman (paul.a.newman@nasa.gov), or use the Web site at http://acdb-ext.gsfc.nasa.gov/People/Newman/.

4.3.3. Application of New Spectrometer Instruments (Pandora and Cleo) for measuring Trace Gas Amounts and Aerosol Properties

Recent development of a new class of low-cost, ground-based spectrometer systems (Pandora and Cleo) allow the measurements of aerosol properties (extinction, optical depth, and absorption) and trace gas amounts (NO_2, HCHO, BrO, H_2O, O_3, and SO_2) both for column content. The Pandora instrument is fully described in a recent paper validating the measured quantities against a reference instrument at two different sites (GSFC and Table Mountain, California) [Herman, et al., 2009] along with a comparison to satellite data from OMI. It was found that the OMI NO_2 column amounts are frequently less than the accurate ground-based, direct-sun measurements in highly polluted areas such as those made at GSFC and Thessaloniki. Recent improvements in the satellite retrieval algorithms have reduced this difference. The instruments have been used in a recent inter-comparison campaign in Cabauw, Holland to test the calibration and algorithms used for the Pandora spectrometer system. The result showed excel¬lent agreement between the various groups from the United States and Europe. Additional campaigns have been conducted in Maryland (SO_2 measurements) using four Pandoras and Fairbanks, Alaska (BrO measurements) using two Pandoras operated remotely from Goddard in preparation for a much larger campaign in Maryland the summer of 2011 employing 14 Pandora instruments and coordinated aircraft measurements. The Pandora system consists of a 2048 by 16 pixel CCD detector in a miniature, cooled spectrometer connected to a weather-sealed optical head with two filter wheels that is mounted on a miniature sun tracker. The sun tracker was used to make both direct sun measurements of total column amounts and sky measurements that can be used for profile retrievals. The results from Pandora measurement of NO_2 are now being applied to correct the analysis of water-leaving radiances used for retrieval of chlorophyll and CDOM from satellite data. In particular, the results have been used to show that lack of NO_2 information from the future geostationary satellite, GEOCAPE, would lead to false measurements of diurnal variations of coastal ocean pigment concentrations. Data from the field campaigns and the continuous measurements at three permanent sites are stored on the Code 613.3 cluster and on the AVDC system.

For further information, please contact Jay Herman (jay.r.herman@nasa.gov).

4.3.4. GRIP

The Genesis and Rapid Intensification Processes (GRIP) was the fifth NASA airborne field campaign dedicated to improving our understanding of tropical storms in the Caribbean and western Atlantic Ocean. GRIP was specifically aimed at understanding the formation of hurricanes (genesis) and their transition to intense storms, sometimes in a matter of 6–12 hours (rapid intensification). Three NASA aircraft instrumented were used: the DC–8, the WB–57, and for the first time the NASA Global Hawk with a 26-hour flight endurance. The DC–8 payload had seven remote sensing or in situ instruments, whereas the primary focus was on remote sensing with the WB–57 (microwave radiometer), and the Global Hawk (radar, radiometer, and lightning sensor). The aircraft and payloads were designed for studying both the precipitation regions associated with developing storms and the larger scale storm environment. GRIP was closely coordinated with two partner field programs: the NOAA Hurricane Research Division Intensity Forecasting Experiment (IFEX), and the NSF's Pre-Depression Investigation of Cloud-systems in the Tropics (PREDICT).

There were a number of scientific and technical accomplishments in GRIP. GRIP was successful in capturing the genesis of two storms (Tropical Storm Gaston and Hurricane Earl) with aircraft flights, and also achieved capturing both the rapid intensification of Hurricane Earl to Category 5 and Hurricane Karl from storm stage to Category 3 to landfall. Early on during GRIP, the Global Hawk conducted the first flights ever of an unmanned aircraft over a dissipating tropical storm (Frank) and then a hurricane (Earl). The plane then went on to make 20 crossings of Hurricane Karl, as well as an additional high number of crossings of Hurricane Matthew. During these flights, there was often close coordination between the NOAA, NSF, and NASA aircraft.

Scott Braun and Gerald Heymsfield were Mission Scientists in GRIP. GSFC flew the new High-altitude Imaging Wind and Rain Airborne Profiler (HIWRAP, PI: Gerald Heymsfield) on the Global Hawk. A number of other Code 613.1 personnel supported GRIP forecasting and DC–8 flights (Amber Reynolds and Jason Pippitt) and the HIWRAP deployment (Lin Tian and Steven Guimond). For further information, please contact Gerald Heymsfield (gerald.heymsfield@nasa.gov).

4.3.5. LPVEx

A significant fraction of high-latitude precipitation falls at rates lower than 1 mm per hour in storm systems possessing shallow freezing levels. These light precipitation events pose a significant challenge to satellite-based global precipitation radar, radiometer retrieval algorithms, or both, such as those being used by CloudSat, as well as in the development for use by the Global Precipitation Measurement (GPM) mission. Improving the algorithm capabilities for reliable measurement of light rainfall is a priority; however, a relative dearth of ground validation data makes it difficult to provide a physical framework algorithm enhancement. Accordingly, the NASA CloudSat and GPM missions teamed with the Finnish Meteorological Institute, the University of Helsinki, and Environment Canada to conduct the Light Precipitation Validation Experiment (LPVEx) over the Gulf of Finland and surrounding Helsinki region in September and October. During LPVEx, the University of Wyoming's King Air flew microphysics missions within the coverage of several dual-polarimetric radars and intensive observation sites with each site equipped with multiple disdrometers, micro rain radars, and weighing precipitation gauges. The objectives of this field experiment were to document precipitation physics within an atmospheric column, including information on water contents, particle sizes, shapes, and habits and to couple those properties across the melting layer. The collective operations of flight missions and ground-based instrumentation over the field experiment resulted in three well-sampled precipitation events targeted as priorities for analysis. These events cover a variety of rain-layer depths ranging from near-surface mixed phase precipitation, to a deeper light rain case with a melting layer near 2000 m. A preliminary result based on the disdrometer measurements suggests that drop-size distributions in the light rain events that were sampled exhibited gamma-distribution shape parameters that were roughly twice as large as those values currently assumed in prototype GPM dual-frequency radar retrieval algorithms. A significant fraction of the dataset is now available for access via the GPM GV data archive at the GHRC DAAC (http://gpm.nsstc.nasa.gov) and by sftp at the CloudSat GV data archive at the Colorado State University/CIRA. The formal release of the complete dataset is scheduled for December 2011. For further information, please contact Walt Petersen (walt.petersen@nasa.gov).

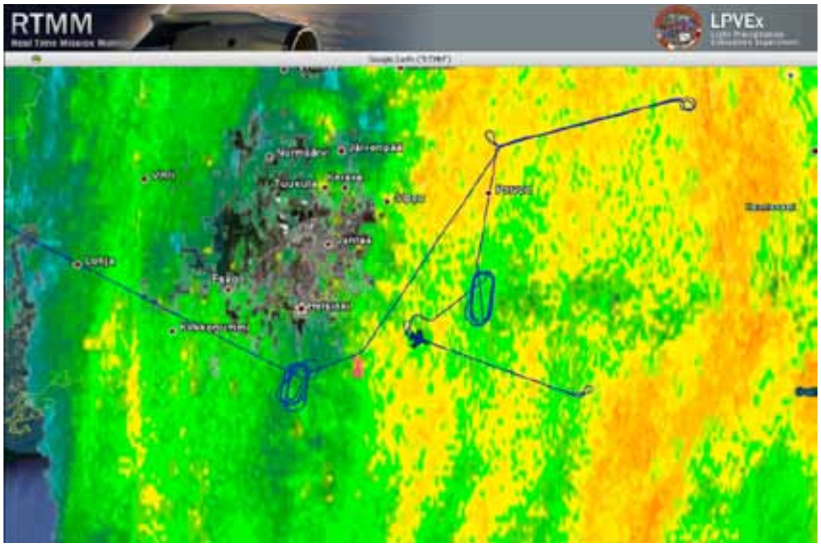


Figure 4.5: Flight operations at 09:55 UTC for the October 20 storm system as depicted in Real Time Mission Monitor (RTMM) software. The University of Wyoming's King Air flight track is overlaid on Helsinki Vantaa radar reflectivity for the region of light precipitation sampled this day.

4.3.6. HS3

The Hurricane and Severe Storm Sentinel (HS3) Earth Venture-1 project is designed to examine the processes that control hurricane formation and intensification. Using two of NASA's Global Hawk unmanned airborne systems, HS3 will carry a payload of seven instruments, four on one Global Hawk in order to sample the storm environment, and three on the other Global Hawk in order to study processes within the inner-core region of storms. The project is led by Scott Braun (Code 613.1) and Paul Newman (Code 613.4) and includes instruments by 613.1 scientists Gerald Heymsfield (HIWRAP), Matt McGill (CPL), and Bruce Gentry (TWiLiTE). HS3 held its first science team meeting in Greenbelt on October 19–20, during which participants discussed instrument and aircraft (NASA's Global Hawk aircraft) status, science objectives, operational strategies, and integration plans, among other things. HS3 is a $30 million, five-year project involving Goddard, Marshall, Ames, and Dryden as well as NOAA, JPL, the several universities. For further information, please contact Scott Braun, (scott.a.braun@nasa.gov).

4.3.7. Pre-Chuva

Scientist from the National Institute for Space Research (INPE) of Brazil and the NASA Precipitation Measurement Missions (PMM) Program conducted a joint field campaign known as Pre-Chuva at the Alcântara Launching Center in Brazil on March 2–24. (Chuva means "rain" in Portuguese.) The campaign targeted warm-rain processes over land in support of GPM prelaunch algorithm development. NASA funded the deployment of the ADMIRARI (ADvanced MIcrowave Radiometer for Rain Identification) instrument from the University of Bonn, as well as Parsivels, disdrometers, and rain gauges from GSFC. The campaign collected a unique set of data for understanding rain structure in three dimensions and the transition between cloud and rainwater. For further information, please contact Arthur Hou (arthur.y.hou@nasa.gov).

4.3.8. EcoDOM

Located at the interface between aquatic and terrestrial environments, coastal margin ecosystems are hot spots of biogeochemical transformation and exchange. The main objective of the EcoDOM field campaign was to study how hydrologic processes (floods and associated river discharges, groundwater fluxes, and hydrologic discontinuities), coastal urbanization, industrialization, and agricultural activities affect the sources and cycling of carbon and nutrients along the continuum of river, wetland, and coastal ecosystems, and how these, in turn, affect biogeochemical and optical variability in coastal Mediterranean waters. This information is critical for improving remote sensing satellite retrievals of biogeochemical variables in the coastal zone. Measurements were performed during March–April and July. Study sites included: (i) the Evros trans-boundary river and delta area, a Ramsar protected wetland and the most important river, in terms of freshwater discharge, flowing into the Aegean Sea in Eastern Mediterranean; (ii) Amvrakikos wetlands, a Ramsar site and a Special Protection Area under EC Directive 79/409, on the east coast of the Ionian Sea; and (iii) the Sperchios river and wetlands along the western shore of the Aegean Sea, a system that is strongly affected by anthropogenic, agricultural, and industrial activities.

A comprehensive and detailed data set of hydrological, physicochemical, biological, biogeochemical, and optical parameters has been collected as part of the EcoDOM field campaign program, which fills critical gaps in current knowledge related to the sources, transformation and fate of organic compounds, nutrients and pollutants in coastal Eastern Mediterranean.

Maria Tzortziou (UMD/GSFC) was the Project Scientist of the EcoDOM Campaign. Participants included collaborators from the University of Connecticut (Professor Emmanouil Anagnostou), the University of Athens (Christina Zeri and Eli Pitta), the Hellenic Center for Marine Research (Elias Dimitriou), the Smithsonian Environmental Research Center (Patrick Neale), and the Florida International University (Rudolf Jaffé, Youhei Yamashita, and Yan Ding). For further information, please contact Maria Tzortziou, (maria.a.tzortziou@nasa.gov).

4.3.9. Chesapeake Bay Tidal Marshes

A large uncertainty in carbon budgets is associated with processes occurring in tidal marshes, estuaries, and river mouths, where land-derived materials are processed and organic matter is produced, re-mineralized, deposited locally or exported to the ocean. The magnitude and time-space scales of biogeochemical transformation and exchanges at the land-ocean interface are poorly constrained and need more definition for NASA's future satellite missions. Targeted, high-frequency (hourly), high-resolution (25–100 m) field observations of water optical properties were conducted as part of this campaign to characterize the time and space scales of biological, biogeochemical, and optical variability related to land-ocean exchanges, carbon fluxes and cycling in eastern U.S. wetlands, estuaries, and coastal waters. Measurements were performed at various tidal marsh-estuarine systems of the Chesapeake Bay, including systems in the Patuxent, York, Choptank, Nanticoke, Wicomico rivers, during July, August and November. Detailed measurements were conducted along transects from freshwater and salt wetlands to the Chesapeake Bay estuary to evaluate spatial patterns in measured parameters, including particulate and dissolved organic carbon concentrations, optical properties, and chemical composition of exported terrestrial organic matter.

Among the main objectives of these field observations was to demonstrate how high-frequency data from a geostationary satellite sensor (NASA's Decadal Survey Mission GEO CAPE-Geostationary Coastal and Air Pollution Events) can contribute to understanding small scale and short-term variability in coastal ocean biology and biogeochemistry. Maria Tzortziou (UMD/GSFC) was the Project Scientist of this campaign.

Drs. Antonio Mannino (GSFC), Patrick Neale and Patrick Megonigal (Smithsonian Environmental Research Center) were co-investigators in this project. For further information, please contact Maria Tzortziou, (maria.a.tzortziou@nasa.gov).

4.3.10. Frostburg campaign

Aura/OMI SO_2 (sulfur dioxide) observations allow for detection of strong point pollution sources (e.g., coal-burning power plants, smelters) in addition to global tracking of the transient volcanic clouds. However, low sensitivity of satellite measurements to SO_2 in the planetary boundary layer, uncertainties associated with aerosol loading, cloud cover, etc. require vigorous validation of tropospheric measurements. The main focus of the Frostburg campaign was validation of OMI measured SO_2 downwind of Ohio and Pennsylvania coal power plants using ground based and airborne observations. The campaign was held November 1–15 at Frostburg State University. GSFC participated with four ground-based Pandora spectrometer systems (Pandora, PI: Jay Herman). The Pandora spectrometer systems provide simultaneous measurements of aerosol optical properties and aerosol and trace gas amounts (NO_2, O_3, SO_2, H_2O, HCHO, BrO). Additional observations included ground-based measurements of trace gases and aerosols with an MFDOAS and aerosol lidar from Washington State University and aircraft measurements of trace gas and aerosol vertical distributions from University of Maryland. GSFC contribution included satellite data analysis from OMI (SO_2 and NO_2, PI: Nickolay Krotkov).

Jose Rodriguez (GSFC), Nickolay Krotkov (GSFC), Jay Herman (UMBC/GSFC), and George Mount (Washington State University) were co-project scientists of the Frostburg campaign. Alexander Cede (UMBC /GSFC), Nader Abuhassan and Maria Tzortziou contributed with measurements and data analysis from the GSFC Pandora spectrometers. Elena Spinei (WSU) participated with MFDOAS measurements of column SO_2, NO_2, O_3. Kostya Vinnikov (UMD/MDE) contributed with analysis of diurnal and seasonal variations of SO_2 and other atmospheric pollutants. Russell Dickerson and Jeff Stehr participated with aircraft measurements of trace gases. Ken Pickering (GSFC), Arlindo daSilva (GSFC/GMAO) and Virginie Buchard-Marchant (UMBC/GSFC/GMAO) contributed detailed model forecasts and comparisons using CMAQ and the GEOS–5 models.

4.4. Data Sets

In the previous discussion, we mentioned the array of instruments and described the field campaigns that produce the atmospheric data used in our research. The raw and processed data from these instruments and campaigns are used directly in scientific studies. Some of this data, plus informatoin from additional sources, is arranged into datasets useful for studying various atmospheric phenomena. This section highlights some of the major datasets.

4.4.1. Global Precipitation

An up-to-date, long, continuous record of global precipitation is vital to a wide variety of scientific activities. These activities include initializing and validating numerical weather prediction and climate models, providing input for hydrological and water cycle studies, supporting agricultural productivity studies, and diagnosing climatic fluctuations and trends on regional and global scales. The Global Precipitation Climatology Project (GPCP) was established as part of the Global Water and Energy Cycle Experiment to develop such global datasets by merging data from both low-Earth-orbit and geosynchronous-orbit satellites, and ground-based rain gauges to produce research-quality estimates of global precipitation. The GPCP dataset provides global, monthly precipitation estimates for the period January 1979 to the present, and presently is considered the international standard for such data. A companion daily precipitation product is also produced, running from October 1996 to the (delayed) present. Updates to both datasets are being produced in the Laboratory on a monthly basis with a delay of about two months.

For more details, see the Global Precipitation Analysis Web site http://precip.gsfc.nasa.gov, or contact George Huffman (george.j.huffman@nasa.gov).

4.4.2. Merged TOMS/SBUV Dataset

A merged satellite total ozone dataset exists through December of 2009. Intercalibration includes the SBUV/2 instruments on NOAA–16, NOAA–17, and NOAA–18 and the OMI instrument on the Aura satellite. It is expected that these data will be useful for trend analyses, for ozone assessments, and for scientific studies in general.

For more details, see: http://acdb-ext.gsfc.nasa.gov/Data_services/merged/; or contact Richard McPeters (richard.d.mcpeters@nasa.gov), or Stacey Frith (stacey.m.frith@.nasa.gov).

4.4.3. MODIS

Laboratory personnel in Code 613.2 are responsible for the Moderate Resolution Imaging Spectrometer (MODIS) Level-2 (pixel-level) cloud optical properties and aerosol algorithms, and all Level-3 1° gridded MODIS Atmosphere Team statistical products (daily, eight-day, and monthly). The algorithm teams are currently working on refinements and enhancements that are to be part of the Collection 6 processing stream, planned to be ready for production in early 2011.

The MODIS Level-2 and Level-3 algorithm efforts mentioned above were successfully re-competed through the ROSES 2009 A.41 solicitation, and the Terra and Aqua missions were approved in Fall 2009 for extended mission operations via the 2009 Senior Review process. Information is being compiled for another Senior Review in 2011. The Senior Review budget provides for MODIS data production and archiving.

All MODIS products are available online from the Level-1B and Atmosphere Archive and Distribution System (http://ladsweb.nascom.nasa.gov/, also located at Goddard (Code 614). Further information, including documentation and browse imagery, is available from the MODIS Atmosphere Team Web site (http://modis-atmos.gsfc.nasa.gov/), or contact the following people: Steven Platnick (cloud optical properties, Level-3 products, MODIS Atmosphere Team Lead) at steven.e.platnick@nasa.gov; Lorraine Remer (aerosol dark target algorithm) at lorraine.a.remer@nasa.gov; and Christina Hsu (deep blue aerosol algorithm) at christina.hsu@nasa.gov.

4.4.4. MPLNET Datasets

The NASA Micro Pulse Lidar Network (MPLNET) is a federated network of Micro Pulse Lidar (MPL) systems designed to measure aerosol and cloud vertical structure continuously, day and night, over long time periods. The measurements are required to contribute to climate change studies and to provide ground validation for models and satellite sensors in the NASA Earth Observing System (EOS). Most MPLNET sites are collocated with sites in the NASA Aerosol Robotic Network (AERONET) to provide both column and vertically resolved aerosol and cloud data.

Further information on the MPLNET project, and access to data, may be obtained online at http://mplnet.gsfc.nasa.gov/. For questions on the MPLNET project, contact Judd Welton (ellsworth.j.welton@nasa.gov).

4.4.5. TOVS Pathfinder and AIRS Climate Sets

The Pathfinder Projects are joint NOAA/NASA efforts to produce multiyear climate datasets using measurements from instruments on operational satellites. One such satellite-based instrument suite is TIROS Operational Vertical Sounder, TOVS. TOVS is composed of three atmospheric sounding instruments: the High Resolution Infrared Sounder-2 (HIRS-2), the Microwave Sounding Unit (MSU), and the Spectral Sensor Unit (SSU). These instruments have flown on the NOAA Operational Polar Orbiting Satellite since 1979. The Laboratory has reprocessed TOVS data from 1979 until April 2005, when NOAA-14 stopped transmitting data. The team has used an algorithm developed in the Laboratory to infer temperature and other surface and atmospheric parameters from TOVS observations.

The TOVS Pathfinder Path A dataset covers the period 1979–2004 and consists of twice daily, five-day mean, and monthly mean global fields of surface skin and atmospheric temperatures, atmospheric water vapor, cloud amount, cloud height, Outgoing Longwave Radiation (OLR), clear sky OLR, and precipitation estimates. The dataset includes data from TIROS-N, and NOAA–6, –7, –8, –9, –10, –11, –12, and –14.

The team has demonstrated with the 25-year TOVS Pathfinder Path A dataset that TOVS data can be used to study interannual variability, trends of surface and atmospheric temperatures, humidity, cloudiness, OLR, and precipitation. The TOVS precipitation data have been incorporated in the monthly and daily GPCP precipitation datasets. We have also developed the methodology used by the AIRS science team to generate products from AIRS for weather and climate studies, and continue to improve the AIRS science team retrieval algorithm. The AIRS Science Team algorithm Version 5.0 is now operational at the Goddard DISC. The AIRS Version-5.0 retrieval algorithm not only produces soundings of greater accuracy then those generated previously, but also contains a significantly improved methodology for Quality Control. The Goddard DISC has generated spot-by-spot AIRS Level-2 soundings, beginning September 2002, using Version-5.0 of the AIRS science team retrieval algorithm; and it continues to generate these products on a near real-time basis. Version-5.0 daily mean, eight-day mean, and monthly mean Level-3 gridded products are also produced and are up to date. All products obtained in the TOVS Pathfinder dataset are also produced from AIRS. These products are readily available for use in climate studies by the scientific community. The AIRS products are of higher quality than those of TOVS, but have been shown to be compatible in the anomaly sense. AIRS products, now covering the period September 2002 –February 2011, can be used to extend the TOVS 25-year climate dataset for longer term climate studies. Spatial and temporal anomalies and trends of monthly mean AIRS Version-5.0 OLR have been shown to be in almost perfect agreement with those of CERES Edition 2.5 OLR over the common time period September 2002 through February 2010.

AIRS products also can play a role in improving operational forecast skill. In joint work with Oreste Reale, Version-5.0 AIRS quality-controlled temperature profiles have been assimilated using the GMAO GEOS-5 forecast analysis system. Forecast results assimilating quality-controlled AIRS temperature soundings were shown to be superior compared to those obtained assimilating AIRS radiances, as done operationally at NCEP and ECMWF. The team is currently installing and testing the NCEP operational data assimilation system at the Laboratory for Atmospheres in order to see whether assimilation of AIRS quality-controlled temperature profiles, if done operationally by NCEP, will improve operational forecast skill.

For further information, please contact Joel Susskind (joel.susskind-1@nasa.gov).

4.4.6. TOMS and OMI Datasets

The Atmospheric Chemistry and Dynamics Branch makes periodic ozone assessments. This work has resulted in a number of ozone and related datasets based on the OMI and TOMS instruments. OMI data are given as daily files of total column ozone, reflectivity, aerosol index, and erythemal UV flux at the ground. The Nimbus-7, Meteor-3, and Earth Probe TOMS datasets were all processed using the Version 8 algorithm.

These datasets are described on the Atmospheric Chemistry and Dynamics Branch Web site, which is available through the Laboratory Web site, http://atmospheres.gsfc.nasa.gov/. Select "Atmospheric Chemistry and Dynamics Research (Code 613.3)," then "For our Colleagues," then "Data Services". The TOMS spacecraft and datasets are then found by clicking on "TOMS Total Ozone" data. Alternatively, TOMS data can be accessed directly from http://toms.gsfc.nasa.gov. For further information, please contact Stacey Frith (stacey.m.frith@nasa.gov).

4.4.7. Sulfur Dioxide, SO_2

Sulfur dioxide (SO_2) is a short-lived atmospheric pollutant that is produced primarily by volcanoes, thermal power plants, smelters and refinery emissions and the burning of fossil fuels. Where SO_2 remains near the Earth's surface, it has detrimental health and acidifying effects. Volcanic SO_2 emitted directly into stratosphere is soon converted to sulfate aerosol that reflects solar radiation and cools the climate.

Since October 2004 Ozone Monitoring Instrument (OMI) on NASA Aura produces global daily column SO_2 data archived at Goddard Earth Sciences (GES) Data and Information Services Center (DISC). http://disc.sci.gsfc.nasa.gov/Aura/data-oldings/OMI/omso2g_v003.shtml OMI near-real-time SO_2 images, within three hours of the Aura overpass, can be seen at NOAA Web site: http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/index.html and FMI direct broadcast Web site: http://omivfd.fmi.fi/. Archived daily OMI SO_2 images are available from UMBC site: http://so2.umbc.edu/omi/. With advances in retrieval techniques, current UV measurements have improved sensitivity to volcanic clouds and provide "top-down" constraints on anthropogenic SO_2 emissions. For further information, please contact Nickolay Krotkov (nickolay.a.krotkov@nasa.gov), (301) 614-5553.

2010 publications on OMI operational SO_2 data and algorithms:

Krotkov N.A., M. Schoeberl, G. Morris, S. Carn, and Kai Yang. "Dispersion and Lifetime of the SO_2 Cloud from the August 2008 Kasatochi Eruption," *J. Geophys. Research*, 115 (2010): D00L20. doi:10.1029/2010JD013984.

Li, C., N. A. Krotkov, R. R. Dickerson, Z. Li, K. Yang, and M. Chin. "Transport and Evolution of a Pollution Plume from Northern China: A Satellite-based Case Study," *J. Geophys. Res.*, 115 (2010): D00K03, doi:10.1029/2009JD012245.

Li, C., Q. Zhang, N. A. Krotkov, D. G. Streets, K. He, Si-Chee Tsay, and J. Gleason. "Recent Large Reduction in Sulfur Dioxide Emissions from Chinese Power Plants Observed by the Ozone Monitoring Instrument," *Geophysical Research Letters*, 37 (2010): L08807, doi:10.1029/2010GL042594.

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Yang, K., Xiong Liu , P.K. Bhartia, Nickolay Krotkov, Simon Carn, Eric Hughes, Arlin Krueger, Robert Spurr, Samuel Trahan. "Direct Retrieval of Sulfur Dioxide Amount and Altitude from Spaceborne Hyper-spectral UV Measurements: Theory and Application," *J. Geophys. Res*., 115 (2010): D00L09, doi:10.1029/2010JD013982.

4.4.8. SHADOZ

The Southern Hemisphere Additional OZonesondes (SHADOZ) is a project to augment and archive balloon-borne ozonesonde launches from tropical and subtropical operational sites. The project was initiated in 1998 by NASA's Goddard Space Flight Center and involves United States and international co-investigators. The collective dataset provides the first profile climatology of tropical ozone in the equatorial region, enhances validation studies aimed at improving satellite remote sensing techniques for tropical ozone estimations, and serves as an educational tool for students, especially in the participating countries. As a flexible archive, SHADOZ has grown and evolved as scientific needs and research questioned change.

Data are collected and available publicly at the SHADOZ official Web site: http://croc.gsfc.nasa.gov/shadoz. For more information, contact the Principal Investigator: Anne M. Thompson (anne@met.psu.edu) or Jacquelyn Witte (jacquelyn.c.witte@nasa.gov).

Publications:

Thompson, A.M., J.C. Witte, R.D. McPeters, S.J. Oltmans, F.J. Schmidlin, J.A. Logan, M.Fujiwara, V.W.J.H. Kirchhoff, F. Posny, G.J.R. Coetzee, B. Hoegger, S. Kawakami, T. Ogawa, B.J. Johnson, H. Vömel, and G. Labow. "Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998–2000 Tropical Ozone Climatology 1. Comparison with Total Ozone Mapping Spectrometer (TOMS) and Ground-based Measurements," *J. Geophys. Res.*, 108, no. D2 (2003): 8238. doi:10.1029/2001JD000967.

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4.4.9. Tropospheric O_3 Data

Measurements of tropospheric and stratospheric ozone are available from the Code 613.3 tropospheric ozone Web page (via a direct link from the TOMS homepage http://toms.gsfc.nasa.gov). These measurements involve two different algorithms: one is from the cloud-slicing method for long data records (1979–2005 from TOMS), and the other is an OMI/MLS residual method for the Aura time period (2004–present) to derive global maps of tropospheric and stratospheric ozone. Both monthly means and daily data (at the present, daily along orbital track data from OMI/MLS) can be downloaded. The tropospheric ozone data products include both column ozone abundance in Dobson units and tropospheric ozone mean volume mixing ratio in units ppbv. In year 2010, there were several new science highlights derived from these data products. One was the establishment of a new tropospheric "ozone ENSO index" [Ziemke, et al., 2010], which is important for long-term monitoring of ENSO-related changes in ozone and related trace gases, and also important as a diagnostic test for evaluating new developing chemistry and transport climate models of the troposphere. This ozone ENSO index is made available from the tropospheric ozone Web page. A second highlight was to use the OMI/MLS tropospheric ozone product to measure urban ozone pollution in the vicinity of cities including related downwind transport [Kar, et al., 2010]. Another highlight was to use the OMI/MLS measurements under post-mission analysis to evaluate aircraft ozone measurements during the TC4 campaign of year 2007 [Avery, et al., 2010].

For information regarding the data products, please contact Jerry Ziemke (jerald.r.ziemke@nasa.gov).

References:

Avery, M., et al. "Convective Distribution of Tropospheric Ozone and Tracers in the Central American ITCZ Region: Evidence from Observations During TC4," *J. Geophys. Res.*,115 (2010). doi:10.1029/2009JD013450.

Kar, J., J. Fishman, J. K. Creilson, A. Richter, J. R. Ziemke, and S. Chandra. "Are There Urban Signatures in the Tropospheric Ozone Column Products Derived from Satellite Measurements?," *Atmos. Chem. Phys.*, 10 (2010): 5213-5222. doi:10.5194/acp-10-5213-2010.

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4.4.10. Composite Solar Spectral Ultraviolet Irradiance Dataset

A composite solar spectral ultraviolet irradiance dataset, representing the longest continuous record of solar UV irradiance observations, is now available for general use. This dataset is available at the LASP Interactive Solar Irradiance Datacenter (LISIRD) Web site (http://lasp.colorado.edu/lisird/cssi/cssi.html). A complete discussion of the creation process has been published:

DeLand, M. T., and R. P. Cebula (2008), Creation of a composite solar ultraviolet irradiance dataset, *J. Geophys. Res.*, 113, A11103, doi:10.1029/2008JA013401.

For more information, please contact Matt DeLand (matthew.deland@ssaihq.com).

4.4.11. CRM Merge Product

The CRM (CPL-Radar-MAS) Merge product was developed at GSFC's Lab of Atmosphere to collocate and fuse ER–2 aircraft data from the Cloud Physics Lidar (CPL), the Cloud Radar System (CRS), and the MODIS Airborne Simulator (MAS). The product has been successfully completed for the TC4 field experiment in HDF format. Future plans call for the product to be created for the CLASIC07, CC–VEX, and CRYSTAL–FACE field experiments. An exciting new possibility is to combine the lidar and radar profile products from the UAV–CPL lidar and HIWRAP radar onboard the high-altitude Global Hawk unmanned aircraft during the upcoming HS3 hurricane intensification project. The nadir-pointing lidar profiles complement similar radar reflectivity measurements and together have shown their utility for obtaining accurate vertical cloud and aerosol distribution statistics throughout the troposphere. Cloud radar can penetrate dense convective clouds and detect clouds composed of large ice crystals, both of which fully attenuate the lidar signal. On the other hand, backscatter lidars are highly sensitive to optically thin cirrus and aerosol layers that cloud radar cannot detect.

Furthermore, knowledge of the region where lidar and radar signals overlap plus the passive upwelling radiation retrievals from MAS are important for particle size and cloud microphysical properties calculations. Both fundamental and enhanced parameters of the atmospheric column from each instrument make up the product and are calculated each second (~200 m along track) for the nadir view. Parameters included in the combined data file include: reflectance, brightness temperature, cloud fraction, layer and column optical depth, effective radius, cloud top pressure, cloud top temperature, cloud thermodynamic phase, layer top and bottom heights of all layers (aerosol and cloud), layer type and characterization, attenuated backscatter profile, particulate backscatter profile, extinction profile, radar reflectivity profile, and Doppler velocity profile. Plotting programs have been written to read the HDF data file and plot or image the above parameters.

The data will eventually be archived on the CPL Web site (http://cpl.gsfc.nasa.gov); however, Dennis Hlavka (dennis.l.hlavka@nasa.gov), is currently the point of contact for access to the data files.

4.4.12. EDOP/CRS

Data is archived from the ER–2 Doppler Radar (EDOP) and the Cloud Radar System (CRS) from various hurricane, convection, and atmospheric radiation field campaigns (http://har.gsfc.nasa.gov) ranging back to 1995, with the most recent being TC4 in 2007. The archive contains quick look images from these campaigns, and ASCII datasets containing reflectivity and Doppler velocity measurements. Higher resolution binary datasets of radar reflectivity and Doppler velocity are available on request from G. Heymsfield (gerald.heymsfield@nasa.gov).

4.4.13. HIWRAP

Data archive is in progress for the HIWRAP radar on the Global Hawk that participated in the Genesis and Rapid Intensification Processes (GRIP) field campaign in August/September 2010. For further information, please contact Gerald Heymsfield (gerald.heymsfield@nasa.gov).

4.4.14. Raman Lidar

Raman lidars have been involved in a large number of field campaigns supporting NASA objectives. For access to data, please contact David Whiteman (david.n.whiteman@nasa.gov).

4.4.15. MISR Aerosol Product

Laboratory personnel in Code 613.2 are jointly responsible with JPL for the MISR aerosol products. At GSFC, the Laboratory contributes a leadership role in aerosol product validation, the research aerosol retrieval algorithm, many applications, and outreach to the wider community. The full 11-year MISR aerosol data product record is available with a uniform version of the algorithm (Version 22), and further upgrades are being implemented, including refined aerosol-type retrievals and better optical depth performance at very low and very high aerosol optical depth. Another upgrade under consideration is a regional, higher resolution aerosol product (the standard aerosol product is reported at 17.6 km resolution, whereas the radiance pixel size is between 275 m and 1.1 km). Applications to dust transport, wildfire smoke injection, volcanic ash dispersal, and air quality are being pursued, taking advantage of MISR's strengths at (1) aerosol retrievals over bright surfaces, including desert (though not snow and ice); (2) aerosol type (a combination of particle size, shape, and single-scattering albedo constraints); and (3) ability to retrieve aerosol plume height near sources using stereo imaging.

All MISR products, along with documentation, browser imagery, and data analysis tools, are available online from the Atmospheric Science Data Center (ASDC) at NASA Langley (http://eosweb.larc.nasa.gov). The GSFC contact for MISR aerosol product science-related questions is Ralph Kahn (ralph.kahn@nasa.gov). Questions about data access and handling should be directed to the Langley ASDC User Services group (larc@eos.nasa.gov).

4.4.16. Total Solar Irradiance (TSI)

The Total Solar Irradiance (TSI) dataset consists of daily and six-hourly measurements of top-of-atmosphere TSI based on the Total Irradiance Monitor (TIM) instrument onboard SORCE. These observations indicate a solar constant several W/m^2 smaller than previous measurements. Earlier measurements were less reliable for reasons discussed in the SORCE summary section.

For further information please contact Robert Cahalan (robert.f.calahan@nasa.gov).

4.4.17. Spectral Solar Irradiance (SSI)

The SORCE SOLSTICE, SIM, and XPS instruments together provide measurements of the full-disk Solar Spectral Irradiance (SSI) from 0.1 nm to 2400 nm (excluding 34 to 115 nm, which is not covered by the SORCE instruments). The two SOLSTICE instruments measure spectral irradiance from 115 nm to 310 nm with a resolution of 1 nm, the SIM instrument measures spectral irradiance from 310 nm to 2400 nm with a resolution varying from 1 to 34 nm, and the XPS instrument measures six broadband samples from 0.1 to 34 nm and at Lyman-alpha (121.6 nm). Measurements from these instruments are combined into daily and six-hourly spectra each containing representative irradiances reported on a uniform wavelength scale, which varies from 1 to 34 nm over the entire spectral interval. Irradiances are reported at a mean solar distance of 1 astronomical unit (AU) with units of W/m^2/nm.

For further information please contact Robert Cahalan (robert.f.calahan@nasa.gov).

4.4.18. NO_2

The Laboratory continued data production for the OMI Nitrogen Dioxide (NO_2) Data Product publicly available from GES DISC at http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omno2_v003.shtml.

Analyses of the data and validation studies have brought to light a number of areas in which the product may be expanded and improved. The next generation NO2 algorithm is under development. Major improvements are to include more accurate tropospheric and stratospheric column amounts, along with much improved error estimates and diagnostics. The Laboratory is to use a monthly a priori NO_2 profile shape climatology based on the GMAO GEOS-5 version of the combined stratosphere/troposphere model from the Global Modeling Initiative (GMI). The team is to use cloud screening to improve separation of stratospheric and tropospheric columns. Proposed OMI NO_2 product enhancements are also to make the data significantly easier to use and interpret. An important goal is to enable agile response to changes in OMI's instrumental characteristics while maintaining high-quality data products.

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4.4.19. Earth Surface and Atmospheric Reflectivity ESDR Since 1979 from Multiple Satellites (TOMS, SBUV, SBUV-2, OMI, SeaWiFS, NPP, and NPOESS)

The new climate reflectivity product is based on the production of a continuous ultraviolet reflectivity data record for the surface of the Earth and its atmosphere using multiple satellite data records since 1979. The scene reflectivities of the Earth at blue and ultraviolet (UV) wavelengths (320 nm to 415 nm) are low over most surfaces (except ice and snow), and are almost independent of the seasonal changes in vegetation on land and in the oceans. This makes it ideal for examining changes in radiation reflected back to space from changes in cloud and aerosol amounts, especially as affected by the start of climate change. The ultraviolet reflectivity of the Earth's surface and atmosphere (clouds, aerosols, and Rayleigh scattering) has been accurately measured since the launch of Nimbus-7/TOMS and Nimbus-7/SBUV in October 1978. Gaps in the TOMS data record, most notably the period from 1993 to 1997, and the degrading calibration of Earth-Probe/TOMS (1997–2006) after 1999 have made it necessary to join the data record from multiple satellites to produce a continuous climate quality Earth System Data Record (ESDR) quality dataset.

The method is based on each satellite viewing the same long-term stable scenes for high reflectivity using Hudson Bay in the winter, and low reflectivity in the central Pacific Ocean and, again, Hudson Bay in the summer. The derived radiance calibration corrections and reprocessing need to be applied to the total existing and future reflectivity datasets to produce a unique long-term ESDR data record. We have combined Nimbus-7/TOMS (1978–1993), Earth-Probe/TOMS (1997–2006), Nimbus-7/SBUV (1978–1985), the NOAA series of SBUV-2 (1988–present), SeaWiFS (1997–present), and OMI (2004–present) to produce a continuous record of scene reflectivity after removing atmospheric Rayleigh scattering. In addition, we have used OMI (270 to 500 nm in steps of 0.5 nm) to relate reflectivity in the UV wavelengths to reflectivity in the visible wavelengths. This has permitted us to join the higher spatial resolution (4 km) reflectivity data available from SeaWiFS (1997 to present) to obtain a continuous long-term UV reflectivity ESDR. The Measures reflectivity project has recently completed generating an intercalibrated zonal average dataset from 1979 to 2010 by using TOMS, SBUV, multiple SBUV-2, and OMI data. The reflectivity data have now been adjusted to local noon by accounting for time of day differences. The results have been published in JGR [Labow, et al., 2011]. In addition to the zonal average data, a 1979–2010 latitude by longitude reflectivity dataset is being prepared using techniques similar to those previously published for a single satellite instrument. The current reflectivity data record will be extended to include NPP (proposed launch in October 2011) followed by NPOESS. The resulting data, documentation, and software are freely available on the AVDC NASA data servers.

For further information please contact Jay Herman (jay.r.herman@nasa.gov).

4.4.20. Polar Mesospheric Clouds (PMCs) from OMI

Polar mesospheric clouds (PMCs) are observed at high altitudes (80–85 km) and high latitudes (above 50°) during the summer months in each hemisphere. PMCs are very sensitive to mesospheric temperature and water vapor, which in turn may be affected by climate change. Measurements from the SBUV and SBUV/2 series of instruments on NOAA polar-orbiting satellites have been used to determine long-term trends in PMC brightness and occurrence frequency during the last 30 years. Comparisons of these data with coincident Aura MLS temperature and water vapor measurements illustrate the differences between PMC behavior in the Northern Hemisphere and Southern Hemisphere.

The Ozone Monitoring Instrument (OMI) on the EOS Aura satellite has new and improved capabilities for PMC characterization compared to SBUV/2 instruments. Its smaller pixels and wide cross-track viewing swath provide increased information about PMC spatial structure and short-term evolution. In addition, OMI data are uniquely suited to measure directly PMC local time variations above 65° latitude.

SBUV/2 PMC data products are available at http://sbuv2.gsfc.nasa.gov/pmc/scans_v3/. For access to OMI PMC data or additional information, please contact Matt DeLand (matthew.deland@ssaihq.com).

Publications:

DeLand, M. T., E. P. Shettle, G. E. Thomas, and J. J. Olivero. "Direct Observations of PMC Local Time Variations by Aura OMI," *J. Atmos. Solar-Terr. Phys.* (2010). doi:10.1016/j.jastp.2010.11.019.

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4.4.21. GSSTF2b

A new global (1°×1°) air-sea surface turbulent fluxes dataset—the Goddard Satellite-based Surface Turbulent Fluxes Version 2b (GSSTF2b) dataset—has been produced and released in HDF–EOS5 format by the Goddard Earth Sciences Data and Information Services Center (GES DISC). GSSTF2b, which covers July 1987–December 2008, is part of a NASA Making Earth Science Data Records for Use in Research Environments (MEaSUREs) funded project led by Chung-Lin Shie (UMBC/Code 613.1). The previous GSSTF dataset (GSSTF2, July 1987–December 2000), generated by the late Shu-Hsien Chou (Code 613.1), had been widely used by scientific communities for global energy and water cycle research and regional and short period data analysis since its official release in 2001. All of the GSSTF2b data types (daily, monthly, climatology, and individual SSM/I satellites daily data) in the HDF–EOS5 format are available along with documentation from the GES DISC MEaSUREs portal (http://disc.sci.gsfc.nasa.gov/measures).

For further information, please contact Chung-Lin Shie (chung-lin.shie-1@nasa.gov).

4.5. Data Analysis

A considerable effort by our scientists is spent in analyzing the data from a vast array of instruments and field campaigns. This section details some of the major activities in this endeavor.

4.5.1. Aerosol and Atmospheric Water Cycle Interaction

Aerosol can influence the regional and global water cycles by changing the surface energy balance (direct effect), suppressing convection (semi-direct effect), and modifying cloud microphysics and rainfall (indirect effect). On the other hand, condensation heating from rainfall, and radiative heating from clouds and water vapor associated with fluctuations of the water cycle (feedback processes) drive winds, which determines the residence time and transport of aerosols and their interaction with the water cycle. Understanding the mechanisms and dynamics of aerosol-cloud-precipitation interaction, and eventually implementing realistic aerosol-cloud microphysics in climate models are clearly important pathways to improve the reliability of predictions by climate and Earth system models.

Laboratory scientists are involved in analyses of the interrelationships among satellite-derived quantities such as cloud optical thickness and effective radii, aerosol optical thickness and size mode (CALIPSO, CloudSat, MODIS, MISR, OMI, and SeaWiFS), water vapor, non-precipitable cloud liquid/ice water, and rainfall (AMSR, CloudSat, MODIS, and TRMM) and atmospheric temperatures (MSU and AIRS), in conjunction with analysis of large scale circulation and moisture convergence in different climatic regions of the Earth. This includes the semi-arid regions of the southwestern United States, the Middle East, northern Africa, and central and western Asia. Field campaigns, including ground-based and aircraft missions, that measure properties of aerosols, clouds and precipitation play an important role in this research.

Observations from satellite and field campaigns are being coordinated with numerical studies using global and regional climate models and cloud-resolving models coupled to land surface, vegetation, and ocean models. A major goal of this research activity is to develop a fully interactive Earth system model, including data assimilation, so that atmospheric water-cycle dynamics can be studied in a unified modeling and observational framework. Currently, the use of Multi-Model Framework (MMF), including the embedding of cloud-resolving models in global general circulation models, is being pursued. A recent focus includes the interdisciplinary investigation of the effects of dust and biomass burning aerosols on the Asian monsoon, and accelerated melting of snowpack in the Himalayas-Tibetan Plateau. This research also calls for the organization and coordination of field campaigns for aerosol and water-cycle measurements in conjunction with the Global Energy and Water Cycle Experiment (GEWEX), Climate Variability and Predictability Programme (CLIVAR), and other international World Climate Research Programs (WCRP) on aerosols and water-cycle studies. Laboratory scientists have played key roles in major international research projects such as the Joint Aerosol Monsoon Experiment (JAMEX), a core element of the 2008–2012 Asian Monsoon Years (AMY) under WCRP, involving both field observations, satellite data utilization and modeling effects. The first AMY/JAMEX campaign has been conducted successfully at northwestern China for characterizing the properties of dust-laden aerosols.

For more information, contact William K.-M. Lau (william.k.lau@nasa.gov), N. Christina Hsu (christina.hsu@nasa.gov), Mian Chin (mian.chin@nasa.gov), Si-Chee Tsay (si-chee.tsay-1@nasa.gov), L. Oraiopoulos (lazaros.oraiopoulos-1@nasa.gov), P. Colarco (peter.r.colarco@nasa.gov), A. Da Silva (arlindo.m.dasilva@nasa.gov), Ralph Kahn (ralph.a.kahn@nasa.gov), or Wei-Kuo Tao (wei-kuo.tao-1@nasa.gov).

4.5.2. Rain Estimation Techniques from Satellites

Rainfall information is a key element in studying the hydrologic cycle. A number of techniques have been developed to extract rainfall information from current and future spaceborne sensor data, including the current TRMM satellite and AMSR on EOS Aqua (AMSR–E), as well as the future Global Precipitation Measurement (GPM) mission.

The retrieval techniques include the following:

- A physical, multi-frequency technique that relates the complete set of microwave brightness temperatures to rainfall rate at the surface. This multi-frequency technique also provides information on the vertical structure of hydrometeors and on latent heating through the use of a cloud ensemble model. The approach has recently been extended to make use of spaceborne radar data to compile a precipitation profile database to improve estimations from passive microwave observations.
- A physical, multi-frequency, combined radar-radiometer technique that relates the complete set of microwave brightness temperatures from the microwave imager and dual-frequency radar profiles to rainfall rate at the surface. This multi-instrument, or combined, technique provides improved information on the vertical structure of hydrometeors compared to the microwave-only approach.
- A multi-satellite technique that merges rainfall information from multiple microwave radiometers and geosynchronous infrared sensors to produce near global, high-resolution precipitation analyses.

The satellite-based rainfall information has been used to study the global distribution of atmospheric latent heating; the impact of ENSO on global-scale and regional precipitation patterns; heavy rainfall events, including tropical cyclones and major flooding events; diurnal variation of precipitation over both land and ocean; and the validation of global models.

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

4.5.3. Rain Measurement Validation for TRMM

The objective of the TRMM Ground Validation Program is to provide reliable, instantaneous area- and time-averaged rainfall data from several representative tropical and subtropical sites worldwide for comparison with TRMM satellite measurements. Rainfall measurements are made at Ground Validation (GV) sites equipped with weather radar, rain gauges, and disdrometers. A range of data products derived from measurements obtained at GV sites is available via the Goddard DAAC. With these products, the validity of TRMM measurements is being established with accuracies that meet mission requirements.

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

4.5.4. Weekly Cycle

Aerosols (suspended particles in the atmosphere) are known to affect the way the atmosphere is heated and cooled and the way clouds behave as they form. Extensive research is being carried out determining how the climate is changed by aerosols, both natural and man-made. The effect of pollution on rainfall and storm behavior is of particular interest since their impact on living conditions is so direct. Research by T. L. Bell and colleagues [Bell, et al., 2008] found that average rainfall measured by the TRMM satellite changed with the day of the week in the summertime over the southeastern United States and that the changes were extremely unlikely to have happened by chance. The theory for these changes had already been developed by D. Rosenfeld and others: storms in hot, moist environments climb higher and grow bigger in the presence of extra aerosol pollution, but the effect varies in strength depending on the atmospheric environment and the types of aerosols. Since these results were published, a further research confirms the weekly changes in atmospheric behavior, including storm heights, wind patterns, cloud cover and cloud heights, lightning activity [Bell, et al., 2009], and, just recently, tornado and hailstorm activity [submitted].

The figure gives an especially convincing example of how strong the effect is. Data for rainfall from satellite and lightning activity from ground-based equipment were analyzed for each summer, 1998–2009, over the Southeastern United States. The changes in activity with the day of the week were fit to a seven-day sinusoidal curve to estimate the day with maximum activity, and the colored balloons are placed in the sector corresponding to this maximum. (The distance from the origin is an indicator of the strength of the weekly cycle.) The last two digits of each year are given inside each balloon. For 12 summers in a row, maximum activity occurred during the work week, not on the weekends. For more information, contact Tom Bell (thomas.l.bell@nasa.gov).

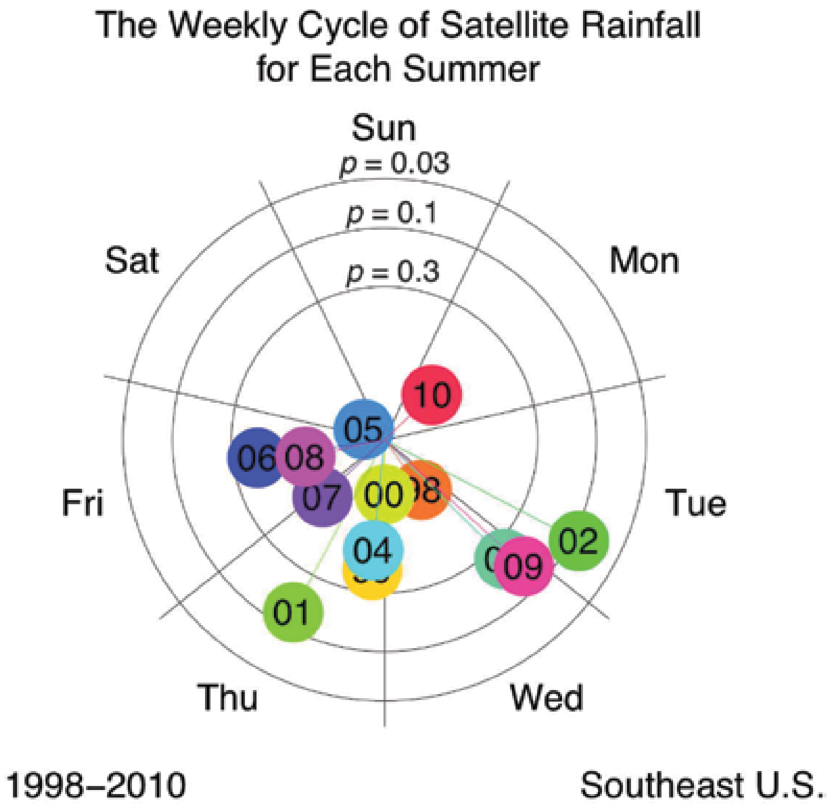

Figure 4.6: The weekly cycle of satellite rainfall for each summer.

Publications:

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Bell, T. L., D. Rosenfeld, and K.-M. Kim. “The Weekly Cycle of Lightning: Evidence of Storm Invigoration by Pollution,” *Geophys. Res. Lett.,* 36 (2009): L23805. doi:10.1029/2009GL040915.

4.6. Modeling

Modeling is an important aspect of our research, and is the path to understanding the physics and chemistry of our environment. Models are intimately connected with the data measured by our instruments: models are used to interpret data, and the data is combined with models in data assimilation. Some of our modeling activities are highlighted below.

4.6.1. Aerosol Modeling

Aerosol climate forcing is one of the largest uncertainties in assessing the global climate change. Aerosol is also a key component determining the surface air quality. Atmospheric models are important tools in incorporating the current knowledge and synthesizing the observed aerosol information in order to project the future change. The aerosol modeling capability at Goddard have branched out from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model and now is a part of the GEOS Global Circulation Model, the NASA Unified Weather Research and Forecast (NU–WRF) model, the NOAA Global Forecast System, and the community regional model Weather Research Forecast-Chemistry (WRF-Chem) model. The modeling activities have always been closely connected to the satellite, ground-based, and aircraft observations. In 2010, research topics involved in aerosol modeling include:

- Help refine the science objectives and measurement requirements of future satellite missions (ACE, GEO–CAPE)
- Forecast and support the NASA UAV field experiment
- Participate in the United Nations' Task Force of Hemispheric Transport of Air Pollution (HTAP) assessment
- Study the long-term trends of aerosols and effects on surface radiation
- Analyze the relationship between aerosol and CO on multiple time- and spatial-scales
- View of aerosol vertical distribution from model and CALIPSO data
- Investigate the aerosol "semi-direct" effects on atmospheric circulation and hydrological cycles
- Develop a simulation capability of ammonium nitrate aerosols
- Develop the coupling between aerosols and radiation in the NU–WRF model

For more information, contact Mian Chin (mian.chin@nasa.gov), Huisheng Bian (huisheng.bian@nasa.gov), Peter Colarco (peter.r.colarco@nasa.gov), Arlindo da Silva (arlindo.dasilva@nasa.gov), Thomas Diehl (thomas.diehl@nasa.gov), Cynthia Randles (cynthia.a.randles@nasa.gov), Qian Tan (qian.tan@nasa.gov), or Hongbin Yu (hongbin.yu@nasa.gov).

Publications:

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Ott, L., B. Duncan, S. Pawson, P. Colarco, M. Chin, C. Randles, T. Diehl, and E. Nielsen. "The Influence of the 2006 Indonesian Biomass Burning Aerosols on Tropical Dynamics Studied with the GEOS–5 AGCM," *J. Geophys. Res.*, 115 (2010): D14121. doi:10.1029/2009JD013181.

Lu, Z., D. G. Streets, Q. Zhang, S. Wang, G. R. Carmichael, Y. F. Cheng, C. Wei, M. Chin, T. Diehl, and Q. Tan. "Sulfur Dioxide Emissions in China and Sulfur Trends in East China Since 2000," *Atmos. Chem. Phys.,* 10 (2010): 6311–6331.

Yu, H., M. Chin, D. M. Winker, A. H. Omar, Z. Liu, C. Kittaka, and T. Diehl. "Global View of Aerosol Vertical Distributions from CALIPSO Lidar Measurements and GOCART Simulations: Regional and Seasonal Variations," *J. Geophys. Res.*, 115 (2010): D00H30. doi:10.1029/2009JD013364.

4.6.2. CCM

The Chemistry-Climate Modeling (CCM) project brings together the atmospheric chemistry and transport modeling of the Atmospheric Chemistry and Dynamics Branch and the General Circulation Model (GCM) development of the GMAO, with the goal of understanding the role of climate change in determining the future composition of the atmosphere. The team has coupled the Goddard Earth Observing System (GEOS) general circulation model with two distinct photochemical mechanisms. The stratospheric chemical mechanism is used to study the past and future coupling of the stratospheric ozone layer with climate. A second mechanism combines stratospheric and tropospheric photochemical schemes, developed through the Global Modeling Initiative (GMI), referred to as the COMBO CCM. Either of these are chemistry climate models (CCMs), the first with applications where only stratospheric constituents are important and the second with applications in the troposphere and especially the upper troposphere and lower stratosphere. The stratospheric and tropospheric chemical mechanism requires far more computing resources than the stratospheric mechanism. For both implementations the Laboratory emphasizes the testing of model processes and simulations using data from satellites and ground-based measurement platforms. The simulations may begin in 1950 and are to extend into the future to the year 2100. The team has completed scenarios and participated in leadership roles in the international Chemistry-Climate Model Validation exercise (CCMVal) that provided input for the 2010 ozone assessment. The model has ranked as one of the best CCMs in almost every CCMVal evaluation. The COMBO CCM has been coupled to an aerosol transport code (GOCART) developed by Mian Chin and colleagues at Goddard. This version of the model is now the team's basic tool for understanding the impact of stratospheric changes on tropospheric chemistry and climate.

The present co-principal investigators are Anne Douglass (Atmospheric Chemistry and Dynamics Branch) and Steven Pawson (Global Modeling and Assimilation Office). The past co-principal investigator is Richard Stolarski (Code 613.3).

For further information, please contact Steven Pawson (steven.pawson-1@nasa.gov), Anne Douglass (anne.r.douglass@nasa.gov), or Richard Stolarski (richard.s.stolarski@nasa.gov).

4.6.3. Cloud and Mesoscale Modeling (Multi-scale Modeling)

Three different coupled modeling systems were again improved (especially the moist, aerosol, and land surface processes) over the last year. These models are used in a wide range of studies, including investigations of the dynamic and thermodynamic processes associated with cyclones, hurricanes, winter storms, cold rainbands, tropical and mid-latitude deep convective systems, surface (i.e., ocean and land, including vegetation and soil) effects on atmospheric convection, cloud-chemistry, cloud-aerosol, and stratospheric-tropospheric interactions. Other important applications include long-term integrations of the models that allow for the study of transport, air-sea, cloud-aerosol, cloud-chemistry, and cloud-radiation interactions and their role in cloud-climate feedback mechanisms. Such simulations provide an integrated system-wide assessment of important factors such as surface energy, precipitation efficiency, radiative exchange processes, and diabatic heating and water budgets associated with tropical, subtropical, and mid-latitude weather systems. The modeling system has been coupled with the Goddard Satellite Simulator Unit. This allows for a physical comparison between the model-simulated and satellite-derived cloud properties. In addition, the improved simulations (cloud properties) have been used to improve TRMM and GPM rainfall and latent heating retrieval.

The scientific output from the modeling activities was again exceptional in 2010 with more than 24 new papers published, in press or accepted. Additional details may be found in Chapter 5.4.3. For more information, contact Wei-Kuo Tao (Wei-Kuo.Tao.1@nasa.gov), (301) 614-6269. The Web address for the Goddard Mesoscale Dynamics and Modeling group and multi-scale modeling system and its associated cloud library is http://portal.nccs.nasa.gov/cloudlibrary/index2.html.

4.6.4. GMI

The Global Modeling Initiative (GMI) was initiated under the auspices of the Atmospheric Effects of Aviation Program in 1995. The goal of GMI is to develop and maintain a state-of-the-art modular 3D chemical transport model (CTM), which can be used for assessment of the impact of various natural and anthropogenic perturbations on atmospheric composition and chemistry, including, but not limited to, the effect of aircraft. The GMI model also serves as a testbed for model improvements. The goals of the GMI effort follow:

- Reduce uncertainties in model results and predictions by understanding the processes that contribute most to the variability of model results, and by evaluating model results against existing observations of atmospheric composition;
- Understand the coupling between atmospheric composition and climate through coordination with climate models; and
- Contribute to the assessment of the anthropogenic perturbations to the Earth system.

The chemistry, wet and dry deposition, and emission components of GMI have been tested by com¬parison to ground-based, aircraft, and satellite data. This testing has given confidence to the use of these components in the chemistry-climate model studies being carried out as a collaboration between the Atmospheric Chemistry and Dynamics Branch and the Global Modeling and Analysis Office. This model is being used for multi-year simulations that would examine the impact of climate change on atmospheric composition and vice versa from the troposphere through the stratosphere. The GMI effort was re-proposed in ROSES 09 and is funded for four more years. This funding has allowed incorporation of new mechanisms in the GMI model for testing and eventual transfer to the Chemistry Climate Model. In addition, the GMI model has recently incorporated complete ammonia and nitrate chemistry, as well full coupling between aerosol and gas-phase chemistry. Model results have been used as input to study the variability in predicted CCN and ICNs due to different meteorological fields; to test algorithms for NO_x production by lightning; and to provide analysis for the ARCTAS campaign.

For more information, contact Jose Rodriguez (Jose.M.Rodriguez@nasa.gov).

4.6.5. Cloud Radiation Parameterization in Atmospheric GCM

Some of the major impediments in the ability of Global Climate Models (GCMs) to simulate realistic climate change relate to parameterizations of cloud, aerosol, and radiative processes, especially when all these elements interact. Our emphasis during the 2010 calendar year has been the implementation In GCMs of cloud microphysical schemes that predict the number and size of (liquid and ice) cloud particles, the parameterizations of aerosol optical properties tailored for specific radiative transfer schemes, the study of the cloud radiative forcing as a function of cloud type, the study of the effect of precipitating hydrometeors on GCM radiation budgets, the study of cloud overlap from ground- and space-based cloud radars, and the introduction of a new radiation package capable of Monte Carlo spectral integration in GMAO's GEOS-5 atmospheric GCM. As part of the process of evaluating current and candidate GCM radiation schemes, laboratory scientist Lazaros Oreopoulos has deployed the Continual Intercomparison of Radiation Codes (CIRC), endorsed by the GEWEX Radiation Panel and the International Radiation Commission. For more information contact Lazaros Oreopoulos (Lazaros.Oreopoulos@nasa.gov). Web sites: http://circ.gsfc.nasa.gov/ and http://climate.gsfc.nasa.gov/research/modeling.php.

Publications:

Oreopoulos, L., and E. Mlawer. "The Continual Intercomparison of Radiation Codes (CIRC): Assessing Anew the Quality of GCM Radiation Algorithms," *Bull. Am. Met. Soc.* (March 2010): 305–310.

Oreopoulos, L., and P. M. Norris. "An Analysis of Cloud Overlap at a Midlatitude Atmospheric Observation Facility," *Atmos. Chem. Phys., Disc.* 11 (2011): 597–625.

Oreopoulos, L., and W. B. Rossow. "The Cloud Radiative Effects of ISCCP Weather States," *J. Geophys. Res.* (in review).

4.6.6. Trace Gas Modeling

The Atmospheric Chemistry and Dynamics Branch has developed two- and three-dimensional (2D and 3D, respectively) models to understand the behavior of ozone and other atmospheric constituents. Present effort centers on development and application of the coupled chemistry and climate model (CCM). This model couples a version of the Goddard Earth Observing System (GEOS) general circulation model (GCM) developed by the Global Modeling and Assimilation Office (GMAO) with a representation of photochemistry and in which changes in radiatively active gases feedback to the circulation through the radiative code.

The GEOS CCM has two versions: the first couples the GEOS GCM with a photochemical mechanism that is appropriate for the stratosphere; the second version couples the GEOS GCM with the GMI combined stratosphere/troposphere chemical mechanism. The GEOS CCM is being used to investigate linkages among tropospheric composition, air quality, and climate.

Simulated constituent fields exhibited many observed features in both the stratosphere and troposphere. The Laboratory participated in the initiative called CCMVal sponsored by Stratospheric Processes and their Role in Climate (SPARC). The diagnostics were based on processes that have been identified using observations; many of the datasets were from instruments on NASA's Upper Atmosphere Research Satellite (UARS) and the Earth Observing Satellite Aura. CCMVal evaluated performance of the CCMs that contributed results for the Scientific Assessment of Ozone Depletion: 2010, sponsored by the World Meteorological Organization. GEOS CCM was among the models with the best rankings for transport and photochemistry.

More information about the CCM, including a list of publications, can be found at the following Web site: http://acdb-ext.gsfc.nasa.gov/Projects/geosccm/output/index.html. For more information, contact Anne Douglass, (Anne.R.Douglass@nasa.gov).

4.6.7. Influence of Solar Protons on the Stratosphere and Mesosphere

Certain large solar eruptive events led to significant fluxes of protons at the Earth, mostly connected with solar maximum time periods. The solar protons associated with these events created hydrogen- and nitrogen-containing compounds, which led to the polar ozone destruction. We have used the National Center for Atmospheric Research (NCAR) Whole Atmosphere Community Climate Model (WACCM) to study the short- to long-term (days to a few years) influence of solar proton events (SPEs) between 1963 and 2005 on ozone. Recently, we used WACCM to study two time periods (October-November 2003 and January 2005), where there were large SPEs causing distinctive observed polar changes in the mesosphere (12-50 km) and upper stratosphere (40–50 km). These SPE-induced perturbations of the atmospheric composition represented an ideal natural laboratory for studying mesospheric and stratospheric chemistry. We participated in a study involving eight other global models and remote sensing experts wherein the model predictions were compared with satellite instrument measurements. This study focused on the influence of the October-November 2003 SPEs [Funke et al., 2010]. Another investigation focused on the influence of the January 2005 SPEs, for which atmospheric impacts were recorded by three composition instruments on separate satellites [Jackman et al., 2010].

Solar proton fluxes are accessible at the NOAA Space Weather Prediction Center Web site: http://www.swpc.noaa.gov/Data/goes.html. The NCAR Whole Atmosphere Community Climate Model is a community model and is described at the Web site: http://waccm.acd.ucar.edu/. For further information please contact Charles Jackman (charles.h.jackman@nasa.gov).

Publications:

B. Funke, A. Baumgaertner, M. Calisto, T. Egorova, C. H. Jackman, J. Kieser, A. Krivolutsky, M. Lopez-Puertas, D. R. Marsh, T. Reddmann, E. Rozanov, S.-M. Salmi, M. Sinnhuber, G. P. Stiller, P T. Verronen, S. Versick, T. von Clarmann, T. Y. Vyushkova, N.Wieters, and J. M. Wissing, Composition changes after the “Halloween” solar proton event: the High-Energy Particle Precipitation in the Atmosphere (HEPPA) model versus MIPAS data intercomparison study, submitted to *Atmos. Chem. Phys.*, 2010.

Jackman, C. H., D. R. Marsh, F. M. Vitt, R. G. Roble, C. E. Randall, P. F. Bernath, B. Funke, M. López-Puertas, S. Versick, G. P. Stiller, A. J. Tylka, and E. L. Fleming, Northern Hemisphere Atmospheric Influence of the Solar Proton Events and Ground Level Enhancement in January 2005, presented at the Committee on Space Research (COSPAR) 38th Assembly in Bremen, Germany, July, 2010.

4.7. Project Scientists

Spaceflight missions at NASA depend on cooperation between two upper level managers, the project scientist and the project manager, who are the principal leaders of the project. The project scientist provides continuous scientific guidance to the project manager while simultaneously leading a science team and acting as the interface between the project and the scientific community at large. Table 4.3 lists the project and deputy project scientists for current missions; Table 4.4 lists the validation and mission scientists and major participants for various campaigns.

Table 4.3 Laboratory for Atmospheres Project and Deputy Project Scientist

Project Scientists		Deputy Project Scientists	
Name	**Project**	**Name**	**Project**
Charles Jackman	AIM	Lazaros Oraiopoulos	Aqua
Ann Douglass	Aura	Warren Wiscombe	ARM
Steve Platnick	EOS	Bryan Duncan	Aura
Dennis Chesters	GOES	Joanna Joiner	Aura
James Irons	LDCM	Alex Marshak	DSCOVR
James Gleason	JPSS/NPP	Judd Welton	Glory
Pawan K. Bhartia	OMI	Gail Jackson	GPM
Robert Cahalan	SORCE & TSIS	Christina Hsu	NPP
Scott Braun	TRMM	Si-Chee Tsay	Terra

Table 4.4 Laboratory for Atmospheres validation and Mission Scientists, and Major Participants/ Instruments

Validation Scientists		Field/Aircraft Campaigns	
Name	**Mission**	**Name**	**Campaign Leaders**
David Starr	EOS	Judd Welton	MPLNET
Ralph Kahn	EOS/MISR	Si-Chee Tsay	7-SEAS/Dongsha
		Paul Newman	GloPac
		Arthur Hou	LPVEx
		Arthur Hou	Pre-Chuva
		Scott Braun	HS3
		Maria Tzortziou	Chesapeake Bay Tidal Marshes
		Maria Tzortziou	EcoDOM
		Maria Tzortziou	Frostburg
			Campaign/Instrument
		Jay Herman	Trace Gas Measurements/ Pandora and Cleo
		Gerry Heymsfield/Scott Braun	GRIP/HiWRAP
		David Whiteman	WAVES/MOHAVE/ALVICE
		Tom McGee	WAVES/AT Raman Lidar

4.8. Interactions with Scientific Organizations

Laboratory staff, at all levels, interact with other labs, branches, and directorates at GSFC as well as with scientific groups in the United States and worldwide. This section describes some of these interactions.

4.8.1. International Commission on Clouds and Precipitation (ICCP)

The International Commission on Clouds and Precipitation (ICCP) is a Commission of the International Association of Meteorology and Atmospheric Sciences (IAMAS). The IAMAS is one of the associations of the International Union of Geodesy and Geophysics (IUGG). The primary purpose of the ICCP is to stimulate scientific research and facilitate international collaboration in the area of clouds and precipitation. Toward this end, the commission organizes the International Conference on Clouds and Precipitation, which is held every four years. The next conference is planned for Leipzig, Germany in July 2012. Symposia are also organized at IAMAS conferences and for the quadrennial IUGG General Assembly next in Melbourne, Australia in summer 2011. The commission is formed of elected experts from around the world. David Starr is currently the secretary of ICCP.

More information on the ICCP can be found at http://www.iccp-iamas.org/. For further information, please contact David Starr (david.starr@nasa.gov).

4.8.2. International Radiation Commission (IRC)

In December 2008, IRC officers Robert Cahalan (NASA's GSFC), Werner Schmutz (PMOD), and B.J. Sohn (Seoul National University) were elected to serve as president, vice president, and secretary, respectively, of the International Radiation Commission (IRC), the oldest commission of the International Association of Meteorology and Atmospheric Sciences. They serve the IRC for a four-year term from 2008 through 2012. At present, the IRC is composed of 42 members from 18 countries, including 21 new members elected for the new term. These are identified on the new IRC Web site, www.irc-iamas.org. This new Web site allows members to log in and update their personal and working group information and to add news items to share with the community.

At the 2010 annual IRC business meeting, held in conjunction with COSPAR in Bremen, Germany, a vote of the IRC selected Berlin to be the site of the 2012 International Radiation Symposium, IRS–2012. Sessions for IRC–2012 are to be decided at the 2011 IRC business meeting to be held at IUGG-Melbourne in July, 2011. At the IUGG–2011 meeting in Melbourne, IRC is sponsoring sessions on aerosols, clouds, solar variability, and three-dimensional radiative transfer.

"History of the IRC 1896–2008" by H.J. Bolle is available for download at http://irc-iamas.org/resources/. Detailed information on IRC symposia and business meetings are available from the IRC Web site (see above). For further information please contact Robert Cahalan (robert.f.cahalan@nasa.gov).

4.8.3. GLOBE

Global Learning and Observations to Benefit the Environment (GLOBE) is a worldwide, hands-on, primary and secondary school-based science and education program, which was announced in 1994 and began operations on Earth Day 1995 (http://www.globe.gov). GLOBE's Mission Statement is "to promote the teaching and learning of science, enhance environmental literacy and stewardship, and promote scientific discovery," and its vision is to create a "worldwide community of students, teachers, scien¬tists, and citizens working together to better understand, sustain, and improve Earth's environment at local, regional, and global scales." As of the end of 2009, the GLOBE network has grown to include representatives from 111 participating countries and 140 U.S. Partners coordinating GLOBE activities into their local and regional communities. Due to their efforts, there are more than 50,000 GLOBE-trained teachers representing more than 20,000 schools around the world. GLOBE students have contributed more than 20 million measurements to the GLOBE database for use in their "inquiry-based science projects."

Headquartered in Boulder, Colorado, GLOBE has started full scale planning activities for a worldwide Student Climate Research Campaign (SCRC) that will be launched in 2011. This is made possible through the harnessing of support from NASA, the NSF, and GLOBE's own vast network of partners and schools from the United States and around the world. During 2009–2010, NASA provided the funding support to a few of its scientists, who actively provided their expertise to assist in the development of the scientific ideas and data to be used in the campaign. The NASA scientists that coordinated that activity are Charles Ichoku (Code 613.2), Robert Cahalan (Code 613.2), Charles Gatebe (GEST, UMBC, and Code 613.2), and Lin Chambers (LaRC/E302). During the last few years, the NSF provided funding to various research groups to develop cutting-edge research approaches for GLOBE in four main areas of the earth system sciences. GLOBE is integrating these NASA and NSF resources to develop a robust science curriculum for the student campaign, which will be implemented from 2011 to 2013 with the aim of effectively creating a climate-literate society across the world.

For more information, please contact Charles Ichoku (charles.m.ichoku@nasa.gov).

4.8.4. WMO/UNEP Ozone Assessment

The Montreal Protocol is the international agreement that regulates substances that deplete the ozone layer. As part of that agreement, scientists every four years write a report, which documents the science of ozone depletion, and submit it to the parties of the Montreal Protocol. GSFC scientists were heavily involved with writing the 2010 report, Scientific Assessment of Ozone Depletion: 2010. Paul A. Newman is the co-chair the Science Assessment panel to the Montreal Protocol and is one of the four scientists leading the overall assessment. Anne R. Douglass was the coordinating lead author of Chapter 2 of the assessment, "Stratospheric Ozone and Surface Ultraviolet Radiation." There are also a number of GSFC scientists who were authors, contributors, and reviewers of this assessment. For more information, please contact Paul A. Newman (paul.a.newman@nasa.gov), or (http://acdb-ext.gsfc.nasa.gov/People/Newman/).

4.8.5. The Internal Ozone Commission

The International Ozone Commission (IO_3C) was established in 1948 as one of the special commissions of the International Union of Geodesy and Geophysics, who represent the entire community of geophysical scientists around the world. The purpose of the IO_3C is to help organize the study of ozone around the world, including ground-based and satellite measurement programs; and the analyses of the atmospheric chemistry and dynamic processes affecting ozone. The current president of the commission is Christos Zerefos of Greece. The vice-president is Richard Stolarski of the NASA Goddard Space Flight Center and the current secretary is Sophie Godin-Beekman of CNRS in Paris, France. Membership in IO_3C is limited to approximately 30 of the leading scientists in the study of atmospheric processes from around the world. Membership includes Anne Douglass, Paul Newman, and P.K. Bhartia, all part of the Atmospheric Chemistry and Dynamics Branch at Goddard. More information can be found at http://ioc.atmos.uiuc.edu/.

4.8.6. ACCRI

The Aviation Climate Change Research Initiative (ACCRI) was established by the FAA four years ago to address outstanding issues in our understanding of the impact of aviation on climate. Jose Rodriguez from Code 613.3 has been a member of its steering committee since its inception. ACCRI funded a series of white papers to establish priorities for studies that would clarify understanding of aviation impacts. Based on these white papers, ACCRI had a call for proposals in the fall 2009. A proposal submitted by Henry Selkirk and associates in 613.3 was selected for funding; the funded work is using results from the coupled chemistry-climate model and observations to assess our knowledge of water vapor in the upper troposphere, a crucial element in our understanding of the formation of contrails and cirrus clouds due to aviation. Funding is expected for at least one additional year. Jose Rodriguez continues to serve in the ACCRI Advisory Committee, representing NASA.

Information on ACCRI can be obtained from Rangasayi.Halthore@faa.com.

4.8.7. U.S. Navy Fleet Numerical Meteorological and Oceanographic Center

The U.S. Navy Fleet Numerical Meteorological and Oceanographic Center announced the operational assimilation of the NASA MODIS aerosol optical thickness products used in Navy's numerical weather, and aerosol forecasting. The assimilation was done using the Navy Variational Analysis Data Assimilation System-Aerosol Optical Depth (NAVDAS–AOD), which combines corrected/filtered MODIS over-ocean AOD data with the six-hour forecast from the Navy Aerosol Analysis and Prediction System (NAAPS). This is an excellent example of NASA earth-science satellite products are being used by another Federal agency in a very successful research-to-operation transition. The NASA GSFC MODIS was acknowledged for "their extensive efforts developing the underlying Level-2 products." The NASA Radiation Science and the Applied Science Program are co-sponsors of this effort.

4.8.8. NOAA Cooperative Institute for Climate and Satellites

A nationwide consortium led by University of Maryland (UMD) won a competition for a new, NOAA-supported Cooperative Institute for Climate and Satellites (CICS) that will receive up to $93 million in funding over the next five years. Principal Investigators of the cooperative agreement proposal are Phillip Arkin (UMD/CICS), Antonio Busalacchi (UMD/ESSIC) and Otis Brown (UMD/ESSIC). Bo-Wen Shen (Co-PI, UMD/ESSIC, Code 613.1), Wei-Kuo Tao (Code 613.1, Collaborator), and Karen Mohr (Code 613.1, Collaborator) were invited to strengthen the modeling section, which lead the subproject entitled, "Utilize NOAA Satellite Data to Validate and Advance the Regional and Global Forecast in Short-term (weather) and Seasonal (climate)."

4.8.9. WMO GALION

Judd Welton (613.1) and Timothy Berkoff (GEST/613.1) participated in the second workshop on the GAW Aerosol Lidar Observation Network (GALION) from September 20 to 23, 2010 at the WMO in Geneva, Switzerland. The WMO's Global Atmosphere Watch (GAW) aerosol program was developed to determine the spatial and temporal distribution of aerosol properties related to climate forcing and air quality up to multi-decadal time scales. The GALION component of the GAW program began in 2007 at the first workshop held in Hamburg, Germany. The goal of GALION is to provide the vertical component of aerosol distributions through advanced laser remote sensing from a network of ground-based stations. In reality, GALION is a network of networks composed of existing lidar activities worldwide, including MPLNET (NASA), EARLINET (EU), AD–NET (East Asia), CIS-LINET (CIS), CLN (Northeast United States), CORALNET (Canada), ALINE (Central/South America, Caribbean), and NDACC. Welton serves on the GALION steering committee and is co-chair of the model and satellite validation and data assimilation working group. The first workshop focused on formulation of the GALION concept. The second workshop focused on implementation of initial GALION activities including standard operations, data collection, and a data distribution system.

More information on GALION can be found on the project Web site, http://alg.umbc.edu/galion/.

4.8.10. Commercialization and Technology Transfer

The Laboratory for Atmospheres fully supports government-industry partnerships, SBIR projects, and technology transfer activities. Successful technology transfer has occurred on a number of programs in the past and new opportunities are to become available in the future. Past examples include the MPL, holographic optical scanner technology, and circle to point conversion detector. New research proposals involving technology development are to have strong commercial partnerships wherever possible.

5. HIGHLIGHTS OF LABORATORY ACTIVITIES

5.1. Mesoscale Atmospheric Processes Branch, Code 613.1

The Mesoscale Atmospheric Processes Branch (MAPB) seeks to understand the contributions of mesoscale atmospheric processes to the global climate system. The Branch 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 systems 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. Branch members participate in satellite missions and develop advanced remote-sensing technology with strengths in the active remote sensing of clouds, precipitation, aerosols, water vapor, and winds. There are also world-class research activities in cloud system modeling and in the analysis, application, and visualization of a variety of data. As of December 31, the MAPB consisted of 86 personnel. Demographically, there are14 civil service scientists (12 with PhDs and one currently enrolled in a PhD program). Also resident in the Branch are the GPM project scientist (Code 613) and 3 civil servant engineers (5555, 551, 567). The Branch maintains cooperative agreements with four institutions (UMBC/GEST, UMBC/JCET, and UMCP/ESSIC), which collectively comprise 27 scientists (25 PhDs). There are presently 3 postdoctoral fellows (ORAU) in the Branch and 2 external scientists on extended visits. Since 1990, the Branch has had a contractual relationship with SSAI of Lanham, MD for scientific, engineering, computer, and administrative support. Currently, there are 26 SSAI personnel. There are 10 additional support personnel via other mechanisms. The Branch Research Web site is http://atmospheres.gsfc.nasa.gov/meso/, where current information can be found on projects, instruments, field campaigns, publications, and personnel listings.

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 virtually every major hurricane, typhoon, and flood event around the globe with attendant maps of accumulated precipitation can be found at http://trmm.gsfc.nasa.gov/publications_dir/extreme_events.html/.

Another important Branch asset is the GOES Project Science Web site (http://goes.gsfc.nasa.gov/) that displays real-time GOES imagery and provides high-quality data to the scientific community. For example, in a non-hurricane month (May 2006), the site served 50 GB/day to 46 thousand distinct hosts at the average rate of 2 requests per second. During a hurricane, the Web server typically hits its limit of 10 requests per second to 150 simultaneous guests.

The Branch activities are described below in the areas of precipitation (and attendant climate-scale research), mission and instrument concept development, instrument systems development, and numerical modeling. Data analysis is a key aspect in each area.

5.1.1. Precipitation

Branch scientists develop retrieval techniques to estimate precipitation using satellite observations from TRMM and other satellites, such as GOES and the AMSR–E sensor on EOS Aqua. The overall accuracy of the TRMM algorithms continues to improve. Thirteen years of high-quality TRMM data are now available through the Goddard DAAC. TRMM and other precipitation/latent heating data are used within the Branch for a wide spectrum of studies on precipitating cloud systems, the global water and energy cycles, and precipitation variability. These activities are well represented in our publication record (Appendix 2). See also the 2010 highlight articles by the following lead authors: Huffman, Braun, Tao, Li, and Shen.

5.1.2. Mission and Instrument Concepts Development

The Branch provides project scientists to assure the scientific integrity of the mission definition, design, development, testing, operations, and data analysis phases of each mission. Branch scientists play a crucial role in the Global Precipitation Measurement (GPM) mission that is scheduled to launch in 2013. This involves (1) defining the science requirements for advanced instrument capabilities for measuring precipitation rates over both ocean and land from the tropics to high-latitudes, (2) developing algorithms to retrieve precipitation information from active and passive microwave sensors, (3) planning and conducting ground validation field experiments to support pre-launch algorithm development and post-launch product validation, and (4) employing satellite precipitation data in scientific research and practical applications. In 2010, there were more than 40 Laboratory scientists involved in GPM science activities. Dr. Arthur Hou is the GPM Project Scientist, and Dr. Gail Jackson is the GPM Deputy Project Scientist.

Dr. Scott Braun serves as the TRMM Project Scientist and leads the TRMM Science Team in close coordination with GPM. The TRMM Ground Validation Program continued to provide reliable, instantaneous area- and time-averaged rainfall data from several representative tropical and subtropical sites worldwide for comparison with TRMM satellite measurements. The availability of real-time TRMM data has led to significant applications and fulfillment of national operational objectives through use of TRMM data, primarily in the monitoring of tropical cyclones, in hydrological applications, and in assimilation of precipitation information into forecast models.

Dennis Chesters, GOES Project Scientist, supported the launch of GOES–P (renamed GOES-15 in orbit) and helped debug the new image broadcast format adopted by NOAA. The real-time Web site downloaded an average of 200 GB/day of enhanced GOES imagery (http://goes.gsfc.nasa.gov).

Dr. Matt McGill is the Instrument Scientist for the ICESat-2 mission with Dr. William Cook (recently hired) as the deputy Instrument Scientist (Tier-1 Decadal Survey mission) that is presently in formulation, and Dr. Judd Welton serves as Deputy Project Scientist for Glory. David Starr serves as Aerosols, Clouds and Ecology (ACE) Science Study Lead. ACE is a Tier-2 Decadal Survey flagship-class mission nominally planned for late in the current decade. Branch scientists are involved as leaders or participants in four of the study groups supporting the science and payload requirements for the ACE mission. An extended briefing report (November 2010) on the ACE mission is available at http://dsm.gsfc.nasa.gov/ace/documents.html.

In 2010, Laboratory for Atmosphere's scientists made important strides in preparation for the Global 3-D Wind Mission in several areas (Tier-3 Decadal Survey mission). In the area of technology readiness, a major milestone was met in October 2009 with the completion of the Tropospheric Wind Lidar Technology Experiment (TWiLiTE) airborne Doppler lidar instrument incubator project. Significant progress was made in the development of an advanced Observing System Simulation Experiment (OSSE) capability in the GSFC Global Modeling and Assimilation Office. New Observing System Experiment (OSE) techniques have been developed to provide simulated wind observation datasets for assimilation in the OSSEs.

5.1.3. Instrument Systems Development

Development of lidar technology and application of lidar data for atmospheric measurements is a key areas of research in the Branch. Systems have been developed to characterize the vertical structure and optical depth of clouds (CPL), atmospheric aerosols (MPLNET, CPL), water vapor and aerosols (ALVICE, RASL), and winds (GLOW, TWiLiTE) at fine temporal and/or spatial resolution from ground-based (MPLNET, ALVICE, GLOW) or airborne platforms (CPL, RASL, TWiLiTE). Our airborne Cloud Radar System (CRS), a millimeter-wavelength radar for profiling cloud systems, is an instrument simulator for CloudSat; and together with our CALIPSO simulator (CPL), provides a powerful and unique airborne measurement synergy within the Branch. CRS is being refurbished and should again be available for deployment in 2011. See the 2010 highlight articles by Heymsfield and Tian.

UAV–CPL was completed and flown on the first science mission of NASA's Global Hawk GloPac mission in April 2010. UAV–CPL was a critical component of the GloPac campaign in support of Aura validation. The HIWRAP, recently completed, is a conical scanning Doppler radar to provide horizontal winds within precipitation and clouds, and ocean surface winds, in addition to more traditional 3D radar reflectivity and hydrometeor characteristics. HIWRAP is envisioned as a key element of GPM validation. It was integrated on NASA's Global Hawk platform and flown in NASA's Genesis and Rapid Intensification Processes (GRIP) field campaign, a major interagency campaign focused on hurricanes in late summer of 2010.

The NASA Micro Pulse Lidar Network (MPLNET) is a federated network of Micro Pulse Lidar (MPL) systems designed to measure aerosol and cloud vertical structure continuously, day and night, over the long time periods, which are required to contribute to climate-change studies and provide ground validation for models and satellite sensors in the NASA Earth Observing System (EOS). At present, there are eighteen active sites worldwide, and three more in the planning stage. Numerous temporary sites have been deployed in support of various field campaigns and two more are planned in 2010. Most sites are collocated with sites in the NASA Aerosol Robotic Network (AERONET) to provide both column and vertically resolved aerosol and cloud data. Further information on the MPLNET project, and access to data, may be found at http://mplnet.gsfc.nasa.gov.

The Hurricane and Severe Storm Sentinel (HS3), led by Scott Braun (Code 613.1) and Paul Newman (Code 613.4), was selected under the Earth Venture Program (EV–1). HS3 includes instruments by 613.1 scientists Gerald Heymsfield (HIWRAP), Matt McGill (UAV–CPL), and Bruce Gentry (TWiLiTE). HS3 held its first science team meeting in Greenbelt on Oct. 19–20, during which participants discussed instrument and aircraft (NASA's Global Hawk aircraft) status, science objectives, operational strategies, integration plans, among other things.

The ALVICE instrument measures upper tropospheric and lower stratospheric water vapor. This activity supports the development of a robust Raman water vapor lidar measurement capability within the NASA-supported Network for the Detection of Atmospheric Composition Change (NDACC). See the 2010 highlight article by Whiteman (Appendix 2). In July, the ALVICE Raman lidar system was fully accepted by NDACC as a mobile intercomparison instrument for water vapor profiling. The first deployment will be in Canada in July 2011.

Measurements and fruitful collaboration on measurement of water vapor and aerosols with scientists from Howard University (HU) continued at the HU Beltsville Research (HURB) site in 2009. A three-year program to assess performance of ground-based wind lidar was completed at the Howard University Beltsville Campus. The goal of the experiment was to compare two of NASA's state-of-the-art wind lidar technology instruments and candidates for NASA's Decadal Survey 3D-Winds Mission (VALIDAR and

GLOW). In collaboration with UMBC and Judd Welton (Code 613.1), the Depolarization and Backscatter Unattended Lidar (DABUL) is a new MPL-like lidar is being installed at HURB. The data is to be used for satellite validation as well as air pollution studies.

Also resident in the Branch is CoSMIR, an airborne conically scanning microwave radiometer that was refurbished this year to serve as a simulator for the GPM Microwave Radiometer (GMI) and support GPM algorithm development and validation. Gail Jackson is the Principal Investigator for this instrument, which is jointly maintained with the Microwave Sensors Engineering Branch (Code 555). Similarly, the Branch is also the home for CoSSIR, an airborne conically scanning submillimeter radiometer, that is used to measure cloud ice water path and is a simulator for an instrument planned for EV-I and ACE. David Starr heads this effort.

5.1.4. Numerical Modeling

Three different coupled modeling systems (fvGCM–GCE, WRF, GCE model) were again improved over the last year. These models are used in a wide range of studies, including investigations of the dynamic and thermodynamic processes associated with cyclones, hurricanes, winter storms, cold rainbands, tropical and midlatitude deep convective systems, as well as surface (i.e., ocean and land, including vegetation and soil) effects on atmospheric convection, cloud chemistry, cloud aerosol, and stratospheric-tropospheric interactions. Other important applications include long-term integrations of the models that allow for the study of transport, air-sea, cloud-aerosol, cloud-chemistry, and cloud-radiation interactions and their role in cloud-climate feedback mechanisms. Such simulations provide an integrated system-wide assessment of important factors such as surface energy, precipitation efficiency, radiative exchange processes, and diabatic heating and water budgets associated with tropical, subtropical, and midlatitude weather systems.

The recent advances in high-resolution global models and supercomputing technology at NASA may have the potential for achieving this. Seven-day high-resolution global simulations with real data show that the initial formation and intensity variations of TC Nargis can be realistically predicted up to five days in advance (bottom). Preliminary analysis suggests that improved representations of the following environmental conditions and their hierarchical multiscale interactions were the key to achieving this lead time: (1) a westerly wind burst and equatorial trough, (2) an enhanced monsoon circulation with a zero wind shear line, (3) good upper-level outflow with anti-cyclonic wind shear between 200 and 850 hPa, and (4) low-level moisture convergence. (Shen et al., 2010).

The GCE model has recently been improved to more robustly simulate the impact of atmospheric aerosol concentration on precipitation processes and the impact of land and ocean surfaces on convective systems in different geographic locations. Recently, long-term TRMM observations were used to improve the explicit bin microphysics. A forward radiative transfer model calculates TRMM Precipitation Radar (PR) reflectivity and TRMM Microwave Imager (TMI) 85 GHz brightness temperatures from simulated particle size distributions. The explicit bin microphysics allows for physical insights in errors in bin microphysics (Li et al., 2010).

In addition, simulated physical parameters (i.e., condensates or hydrometeors, temperature, and humidity profiles) from the multi-scale modeling system can be used to simulate top-of-the-atmosphere radiance and backscattering profiles consistent with NASA EOS satellite measurements through the NASA Goddard Earth Satellite Simulator (SDSU, Matsui et al., 20010). The Goddard SDSU is an end-to-end satellite simulator unit, which can compute satellite-consistent measurements (radiance or backscattering signals) from model-simulated or algorithm-assumed atmospheric profiles and aerosol/condensate particles using a passive microwave simulator, a radar simulator, a passive visible-IR simulator, a lidar simulator, and a broadband simulator (Fig. 5.1). The coupling between the model and SDSU permits (1) better evaluation of the Goddard physical packages by comparing model results with direct EOS satellite measurements (Matsui et al., 2010) and (2) support for current and future NASA's satellite missions (i.e., TRMM, CloudSat, Aqua-MODIS, AMSR–E, GPM, and ACE) by providing virtual satellite measurements as well as simulated atmospheric environments as an a priori database of physically based precipitation retrieval algorithms.

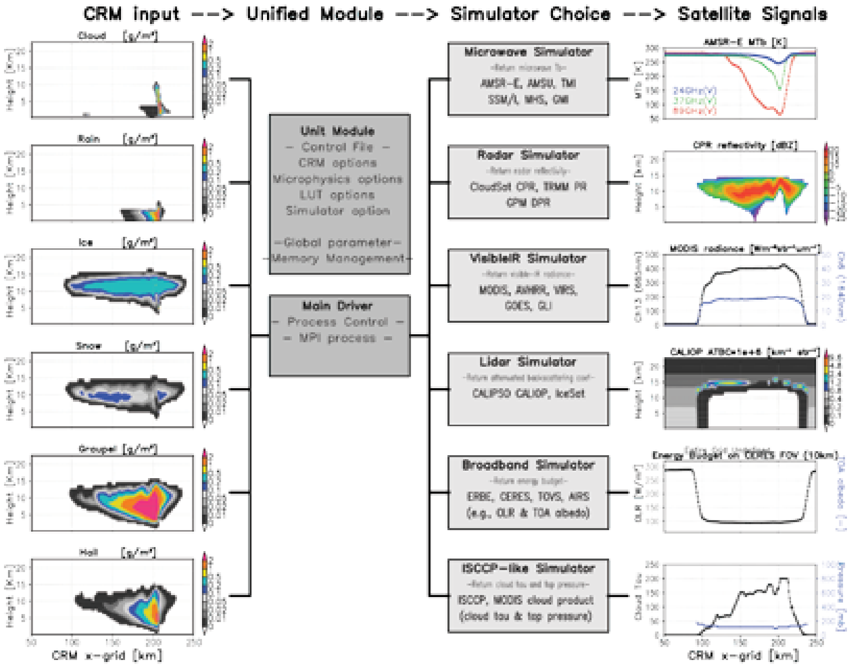

Fig. 5.1 The Goddard SDSU can simulate various satellite signals, which, for example, can be observed from the A-Train constellation of satellites. These transformations from model space to satellite radiance space can be done within a unified physics framework (i.e., simulated condensate amounts and size distributions as well as profiles of temperature and humidity from one model can be used to drive the simulators in same manner as for another model using the same physics package).

The modeling system was used to develop an improved convective-stratiform heating (CSH) algorithm to obtain the 3D structure of cloud heating over the tropics based on two sources of information: 1) rainfall information, namely its amount and the fraction due to light rain intensity, observed directly from the Precipitation Radar (PR) on board the TRMM satellite; and 2) synthetic cloud physics information obtained from cloud-resolving model (CRM) simulations of cloud systems. The cloud simulations provide details on cloud processes, specifically latent heating, eddy heat flux convergence and radiative heating/cooling that are not directly observable by satellite. Cloud heating data separated into these three components derived from the new CSH algorithm are readily available for a 10-year period at 0.5 × 0.5 degree resolution. The time resolution is approximately daily (Tao et al., 2010).

The scientific output from the modeling activities was again exceptional in 2010 with more than 16 new papers published and in press. For more information, please contact Wei-Kuo Tao (wei-kuo.tao.1@nasa.gov). The Web address for the Goddard Mesoscale Dynamic and Modeling group and multi-scale modeling system and its generated cloud library is http://portal.nccs.nasa.gov/cloudlibrary/index2.html.

HIGHLIGHTS

Branch scientists continue active research in the areas of hurricane formation, structure, and precipitation processes. We also use models and TRMM satellite data to study the organization of precipitation in winter storms and the mechanisms responsible for that organization.

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5.2. Climate and Radiation Branch, Code 613.2

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 Branch. The Branch has made major scientific contributions in five key areas: hydrologic processes and climate, aerosol-climate interaction, clouds and radiation, model physics improvement, and technology development. Examples of these contributions may be found in the list of refereed articles in Appendix II and in the material updated regularly on the Code 613.2 Branch Web site: http://atmospheres.gsfc.nasa.gov/climate/.

Key satellite observational efforts from the Branch 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. See the Projects link on the Climate and Radiation Branch Web site for recent significant findings in these areas.

The Branch continues to serve in key leadership positions on international programs, panels, and committees. Robert Cahalan continues to serve as President of the International Radiation Commission or IRC until 2012. Alexander Marshak chairs the IUGG/IAMAS session on 3D Radiative Transfer, IRC's three-dimensional Radiative Transfer working group, and also leads the International Intercomparison of three-dimensional Radiation Codes, or I3RC and is co-chair of the Gordon Research Conference on Climate and Radiation. Ralph Kahn is Vice-Chair for COSPAR Commission A (Earth Observation). COSPAR is the international Committee on Space Research. Lazaros Oreopoulos chairs the IRC's CIRC working group.

Warren Wiscombe, continues his participation with DOE's ARM Program. ARM merged with DOE's aerosol-climate program to create a new program named Atmospheric Systems Research (ASR). The ASR program took, as its purview, the cycle beginning with aerosol precursors, then to aerosols, to clouds, to precipitation, and back to aerosols again. The big new item was the addition of precipitation. At the same time, ARM received $60 million in stimulus funds for new instruments and spent roughly half of that on 18 new radars, including several precipitation radars, which makes ARM the largest deployer of cloud radars in the world. Dr. Wiscombe was instrumental in forging a partnership between NASA's GPM Ground Validation Program and ARM, leading directly to the Midlatitude Continental Convective Cloud

Experiment (MC3E) field campaign (May–June 2011) to study precipitation in the region around ARM's SGP site in Oklahoma using NASA radars, ARM's new radars, and radars from the Univ. of Oklahoma and NOAA. This is the largest such radar experiment ever conducted.

Branch personnel continue to serve in key project positions. Robert Cahalan serves as project scientist of Solar Radiation and Climate Experiment (SORCE) launched on January 25, 2003. SORCE is measuring both Total Solar Irradiance (TSI) and Spectral Solar Irradiance (SSI) with unprecedented accuracy and spectral coverage and has continued beyond its initial five-year nominal mission lifetime. Dr. Cahalan also serves as project scientist of the SORCE follow-on mission, Total and Spectral solar Irradiance System (TSIS), due to be launched in 2014. It is expected to become, along with CERES, one of the first two climate missions to become operational. Deputy project scientists in the branch include Si-Chee Tsay (Terra), Lazaros Oreopoulos (Aqua), N. Christina Hsu (NPOESS Preparatory Project) and Alexander Marshak (DSCOVR). Steven Platnick is now serving as EOS Senior project scientist following the retirement of Michael D. King, who moved to University of Colorado's LASP.

The Branch continues to make strides in many areas of science leadership, education, and outreach. Thanks to initial organizational efforts of the late Yoram Kaufman and the involvement of Lorraine Remer, Charles Ichoku, and Robert Levy (SSAI), as well as collaborations with Codes 613.1 and 613.3, the popular Aerocenter seminar series has continued into its tenth year. The biweekly seminars attract aerosol researchers from NOAA, NRL, the University of Maryland system, and other agencies and research institutions. The Aerocenter now webcasts most seminars, making it possible for dozens of colleagues at other institutions to hear and see the presentations. The AeroCenter visitor program continues to reap benefits including joint paper submissions. The Goddard Sun-Climate Center, like AeroCenter, is a cross-cutting activity within Goddard's Sciences and Exploration Directorate, and is co-hosted by the Climate and Radiation Branch and the Goddard Solar Physics Laboratory. The Center sponsors research on solar system climate and investigates new opportunities for advancing the understanding of the Sun's forcing of Earth's climate. Visiting scientists from Germany and Japan have joined this effort, and the Center receives advice from an international panel of experts. The Center encourages new collaborations between scientists studying Earth, the Sun, and Earth's moon.

The Branch benefits from our close association with the GSFC Earth Sciences Education and Outreach Program. This group produces the Earth Observatory Web site that continues to provide the science community with direct communication gateways to the latest breaking news on NASA Earth Sciences, as well as the more recent NASA Earth Observations (NEO) dataset visualization tool. Another educational resource is PUMAS, Practical Uses of Math and Science, developed and led by Ralph Kahn, and on the web at http://pumas.nasa.gov. PUMAS, written by scientists, provides K–12 teachers with grade-appropriate examples showing how topics taught in pre-college classes can actually be used in real life.

The branch also supported the GLOBE Student Research Campaign on Climate (SCRC) (http://globe.gov/) planning effort over a two-year period, beginning in January 2009. Starting in late 2010, the GLOBE program began to reorganize under an effort led by Charles Ichoku, and supported by Charles Gatebe and Robert Cahalan, as well as Lin Chambers at LARC. These NASA scientists assisted the GLOBE program's preparation for the SCRC, which is to be implemented worldwide between 2011 and 2013. Their activities included providing expertise on scientific approaches and data, developing the SCRC planning document jointly with GLOBE, writing science blogs posted on the GLOBE Web site, producing audio podcasts on scientific approaches for SCRC, responding to science questions from teachers online, and executing outreach activities to encourage participation of schools in non-active regions, as well as participation of scientists.

HIGHLIGHTS

In support of the NASA Earth Observing System (EOS) endeavor, GSFC's SMART and COMMIT ground-based mobile laboratories (http://smartlabs.gsfc.nasa.gov/) were conceptualized, built, and participated in numerous field campaigns. These two laboratories host a broad range of instruments, exceeding fifty active/passive sensors, for the remote sensing of atmospheric solar and terrestrial radiation, and for the in situ observations of the physicochemical properties of aerosols and precursor gases. Adding an array of microwave radars and radiometers to improve understanding of the aerosol-cloud interactions, a new ACHIEVE mobile laboratory has been constructed to complement SMART–COMMIT and is to begin operations in spring 2011. Collectively, SMART–COMMIT–ACHIEVE and additional campaign-specific instrumentation comprise the SMARTLabs (Surface-based Mobile Atmospheric Research and Testbed Laboratories). The SMARTLabs supersite and network facility is designed to pursue the following goals:

Enriching EOS and Decadal Survey missions

By collocating ground-based and space-borne observations, the Branch is able to reach a more thorough understanding regarding the composition of, and physical processes within, the Earth's atmosphere. Exploiting the complementary strengths of multiple sensors viewing the same atmosphere facilitates the direct validation and comparison between measured or retrieved properties of atmospheric constituents such as clouds and aerosols.

Piloting innovative science investigations

Equipped with a wide range of specialized instruments, SMARTLabs provide for the development of new methodologies to further explore the Earth's atmosphere system. In conjunction with satellite overpasses, the strategic deployment of SMARTLabs and distributed networks (e.g., AERONET/MPLNET) near or downwind of aerosol sources and along transport pathways optimize, for example, the investigation of complex aerosol-cloud interactions and the spatiotemporal evolution of aerosols and precursor gases.

Conducting educational and public outreach activities

Through its rich deployment history, comprehensive instrumentation, and extensive scientific research, SMARTLabs offer excellent opportunities for educational (e.g., K–12, undergraduate, and graduate) and public outreach activities (e.g., Earth Day, Maryland Day, and Goddard Day), as well as for close collaborations with research institutes or universities and either environmental monitoring or protection agencies. Since its inception in 2000, the SMARTLabs facility has collaborated with many domestic and international partners in more than a dozen major field campaigns, spanning a wide range of climatological regimes, in nine countries on three continents. The measurements made during these campaigns by the facility have led to more than 50 publications and numerous conference proceedings or presentations.

Examining the International Satellite Cloud Climatology (ISCCP)

This examination of near-global distribution of cloud regimes provides an opportunity to identify similarities and differences in these regime's Cloud Radiative Effects (CREs) and to rank them not only on the basis of CRE magnitude at the time of occurrence, but also in terms of relative contributions to the total CRE, which is greatly influenced by their frequency of occurrence. Branch scientists have found that the three most convectively active regimes are the ones with largest shortwave (SW), longwave (LW) and net CRE contributions to the overall daytime tropical CRE budget (Oreopoulos and Rossow, 2011). The boundary-layer dominated cloud regimes account for only 34 percent of the total SW CRE and 41 percent of the total net CRE, so to focus only on them in cloud feedback studies might be unwise. In the midlatitude zones it was shown that only two cloud regimes, the first and third most convectively active with large amounts of nimbostratus-type clouds, contribute ~40 percent to both the SW and net TOA CRE budgets, highlighting the fact that regimes associated with frontal systems are not only important for weather (precipitation) but also for climate (radiation budget).

It is known that the MODIS cloud optical property retrievals often have difficulty detecting thin cirrus clouds, namely thin wispy clouds composed of ice crystals. To help improve the thin cirrus capabilities of MODIS, a technique has been developed to estimate the optical thickness (i.e., the transparency) of cirrus clouds using the 1.38 μm water vapor channel (Meyer and Platnick, 2010). This technique involves pairing 1.38 μm with a second MODIS wavelength channel that is also reflected by clouds, but is not absorbed by the atmosphere (here, 1.24 μm), to estimate the water vapor content above the cloud. It has been found that, for select cases over the ocean, the 1.38 μm approach can increase cirrus cloud retrievals by up to 38 percent over the current MODIS cloud retrievals. This represents a considerable increase in the ability to estimate the optical properties, and thus the radiative effect, of thin cirrus clouds. In addition, because next-generation satellite instruments will include the 1.38 μm channel, the present technique should prove to be useful into the future.

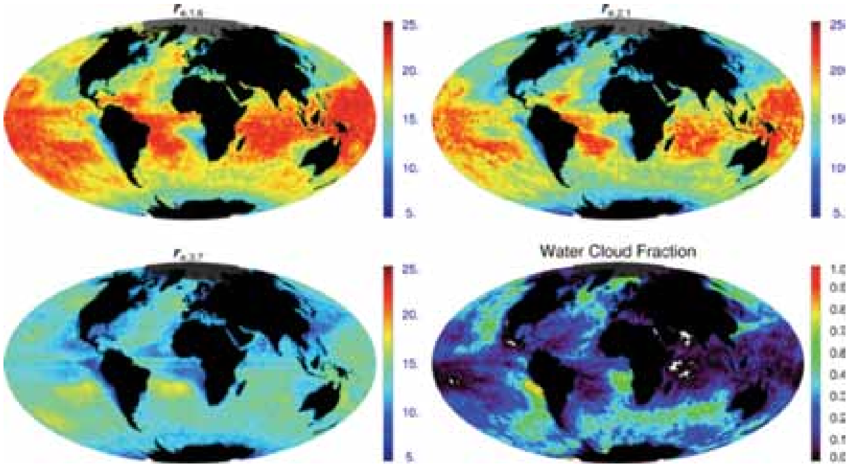


Figure 5.2: Monthly mean global MODIS *effective radius retrieval (r_e) for marine water clouds, from* MODIS *1.6μm, 2.1μm and 3.7μm bands. Note the substantial differences between $r_{e,3.7}$ and $r_{e,2.1}$ retrievals and the strong dependence of the difference on cloud regime.*

Findings from this study will help identify algorithm issues in MODIS re retrieval, improve our understanding of the microphysical structure of marine water clouds, and provide guidance for the science community on better use of MODIS cloud products. (How do aerosol particles change in the vicinity of clouds? The importance of this question results from the fact that areas near clouds occupy a large segment of all clear-sky regions. This implies that understanding aerosols near clouds is essential for understanding the role of aerosols in our climate. The Branch's results (Varnai and Marshak, 2011) provide the first observational evidence that near-cloud particle changes are sufficiently strong to alter global statistics of aerosol populations. NASA's CALIPSO lidar observes both stronger light scattering and increased particle size near clouds. The increases arise from processes such as aerosol particles swelling up in the humid air that surrounds clouds. The increase in particle scattering is substantial and typically exceeds 40 percent within 5 km of clouds. The finding that particle changes in the transition zone are sufficiently prevalent highlights the importance of better understanding of these changes, and considering them both in the interpretation of satellite data and in climate simulations. The ultimate goal of this project is to help reduce some of the largest sources of uncertainties in understanding human impacts on climate: aerosol-cloud interactions and aerosols reflecting or absorbing sunlight. (References: Várnai, T., and A. Marshak, 2011: Global CALIPSO observations of aerosol changes near clouds. *IEEE Geosci. Remote Sens. Lett*., 8, 19-23).

The Multi-angle Imaging SpectroRadiometer (MISR) and MODerate resolution Imaging Spectroradiometer (MODIS) instruments aboard the NASA Earth Observing System's Terra satellite both report aerosol optical depth (AOD) globally. This quantity is a key climate variable as aerosol direct radiative forcing and indirect impacts on clouds contribute to the global climate-change picture, in addition to the warming effect of increasing atmospheric greenhouse gas concentrations. As such, identifying the strengths and limitations of the MISR and MODIS AOD products and assessing their overall quality are essential steps in the climate-change application.

Density scatter plots were made to compare coincident MISR and MODIS AOD retrieval results over water and land, respectively, for the entire globe during all of January 2006. The vast majority of correlation coefficients are high—0.9 over water, and 0.7 over land. Artifacts and algorithmic differences are also evident, such as quantization noise in the MISR over-water retrievals and negative AOD values allowed by the MODIS algorithm over land.

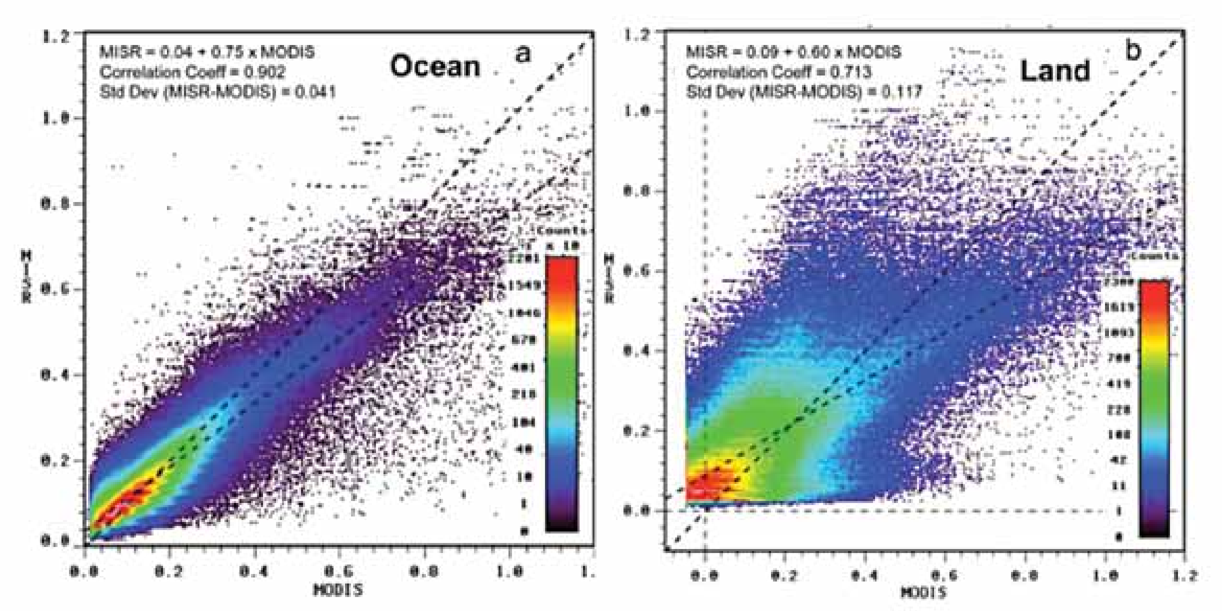


Figure 5.3: Density-scatter plots showing total-column, mid-visible AOD *values retrieved from coincident* MODIS *and* MISR *observations, for locations (a) over ocean and (b) over land. Dashed lines indicate the linear regression and 1:1 values; key statistics are given in the upper left of each plot. [From: Kahn et al.,* TGARS *2009.]*

Three clusters of outliers are also found in the over-land scatter plot. These are traced geographically to specific, known retrieval issues: (1) mixtures of spherical absorbing smoke particles with non-spherical desert dust in North Africa, (2) strongly absorbing pollution particles in the Indo-Gangetic plain in north India, and (3) unscreened bright surfaces in the MODIS retrievals over Patagonia and north-central Australia. These artifacts represent a tiny fraction of all retrievals; the MISR and MODIS teams are developing algorithm upgrades, based on these assessments and comparisons with coincident field campaign and network ground-truth observations. (Reference: Kahn, R.A., D.L. Nelson, M. Garay, R.C. Levy, M.A. Bull, D.J. Diner, J.V. Martonchik, S.R. Paradise, E.G. Hansen, and L.A. Remer, 2009. MISR Aerosol product attributes, and statistical comparisons with MODIS. *IEEE Trans. Geosci. Remt. Sens*., 4095-4114.)

Branch scientists have collaborated with those of the Goddard Earth Science Data and Information Center (GES DISC) to develop an online data system that facilitates integrated validation and intercomparison of aerosol products from multiple satellite sensors over ground-based AERONET sites and other important locations. This Multi-sensor Aerosol Products Sampling System (MAPSS, http://giovanni.gsfc.nasa.gov/mapss/) was developed through a joint effort by Charles Ichoku, Maksym Petrenko (ESSIC/Code 613.2), Gregory Leptoukh (Code 610.2), and several other colleagues. The system is currently being used by various aerosol science teams and scientists for satellite aerosol-measurements validation and intercomparison. Furthermore, a new statistical analysis tool (AeroStat, http://giovanni.gsfc.nasa.gov/aerostat/) has been built onto the MAPSS framework to enable more in depth statistical analysis of aerosol products from multiple sensors.

5.3. Atmospheric Chemistry and Dynamics Branch, Code 613.3

The Atmospheric Chemistry and Dynamics Branch 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. The area of chemical research dates back to the first satellite ozone missions and the Division has had a strong satellite instrument, aircraft instrument, and modeling presence in the community. Both the EOS Aura satellite and the OMI instrument U.S. Science team come from this group. The Branch also is a leader in the integration and execution of the NPP mission. The Branch is also providing leadership for the former NPOESS, now the newly reorganized Joint Polar Satellite System (JPSS).

The data record of the Earth's ozone shield now spans more than three decades, and provides scientists worldwide with valuable information about the complex influences of Sun, climate, and weather on ozone and ultraviolet radiation reaching the ground. We have updated our merged satellite total ozone dataset through December 2010. The data and information about how they were constructed can be found at http://acdb-ext.gsfc.nasa.gov/Data_services/merged/. It is expected that these data will be useful for trend analyses, ozone assessments, and scientific studies in general. For further information, contact Richard McPeters (Richard.D.McPeters@nasa.gov) or Stacey Frith (Stacey.M.Frith@nasa.gov).

The Branch has deployed advanced instrument and algorithm capability for ground-based validation of OMI satellite aerosol, NO_2, SO_2, and O_3 data. A lot of work this past year has concentrated on sulfur dioxide (SO_2). Sulfur dioxide (SO_2) is a short-lived atmospheric pollutant that is produced primarily by volcanoes, thermal power plants, smelters and refinery emissions, and burning of fossil fuels. Where SO_2 remains near the Earth's surface, it has detrimental health and acidifying effects. Volcanic SO_2 emitted directly into stratosphere is soon converted to sulfate aerosol that reflects solar radiation, and thus cools the climate. Since October 2004, the OMI on NASA Aura produces global daily column SO_2 data archived at Goddard Earth Sciences (GES) Data and Information Services Center (DISC) http://disc.sci.gsfc.nasa.gov/Aura/data-oldings/OMI/omso2g_v003.shtml. OMI near-real-time SO_2 images, within three hours of the Aura overpass, can be seen at the NOAA Web site, http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/index.html, and the FMI direct-broadcast Web site, http://omivfd.fmi.fi/. Archived daily OMI SO_2 images are available from UMBC site, http://so2.umbc.edu/omi/. With advances in retrieval techniques, current UV measurements have improved sensitivity to volcanic clouds and provided "top-down" constraints on anthropogenic SO_2 emissions. The SO_2 data have proved very useful in monitoring the spread of volcanic eruptions, including the Eyjafjallajökull volcano in Iceland. For further information, please contact Nickolay Krotkov (nickolay.a.krotkov@nasa.gov).

The above instruments also provide information about light penetration inside clouds. The launch of CloudSat into the A-train with Aura has demonstrated that the cloud pressures provided by UV/VIS1 measurements (referred to as optical centroid cloud pressures) are distinct from the physical cloud top and more appropriate for use in UV/VIS trace-gas retrievals. The OMI UV cloud algorithm retrieves an optical centroid pressure from the filling in of solar Fraunhofer lines in the ultraviolet due to rotational Raman scattering of air molecules. This pressure is used in some of the OMI trace-gas retrieval algorithms, as well as for other applications such as the detection of multi-layer clouds in conjunction with MODIS cloud top pressure. These data have been and will continue to be used in the reprocessing of the retrieved data from the OMI instrument. Data and further information can be found in the following Web site: http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omcldrr_v003.shtml.

The reflectivity data from TOMS, SBUV, SBUV–2, OMI, and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) have been combined and posted to a Web site as a preliminary long-term dataset. A number of calibration problems between the various satellites have been detected. The project is now working on correcting the inherent errors in the satellite datasets.

Measurements from the OMI and Microwave Limb Sounder (MLS) onboard the Aura satellite have been used to develop several years of daily and monthly mean global measurements of tropospheric ozone, beginning late August 2004. The tropospheric ozone data are given as both tropospheric column ozone (in Dobson Units) and mean equivalent volume mixing ratio (in ppbv). The data are made available to anyone via the Total Ozone Mapping Spectrometer (TOMS) Web site at http://toms.gsfc.nasa.gov. The Web site also provides long-time records of both tropospheric and stratospheric ozone in the tropics for the period January 1979 through December 2005. For more information, please contact Jerry Ziemke (Jerald.R.Ziemke@nasa.gov) who is the Principal Investigator on the American OMI science team for developing tropospheric ozone products.

The Global Modeling Initiative was initiated under the auspices of the Atmospheric Effects of Aviation Program in 1995. The chemistry, wet and dry deposition, and emission components of GMI have been tested by comparison to ground-based, aircraft, and satellite data. This testing has given confidence to the use of these components in the chemistry-climate model studies being carried out as a collaboration between the Atmospheric Chemistry and Dynamics Branch and the Global Modeling and Analysis Office (see below). In particular, the GMI "COMBO" (stratospheric-troposhperic) chemical mechanism has been incorporated in the above model. Work is also being carried out to incorporate ammonia and nitrate aerosols in this model.

Present efforts in chemistry/climate coupling focus on development and application of the coupled chemistry and climate model (CCM), a general circulation model (GCM) that includes a representation of photochemistry and in which changes in radiatively active gases feedback to the circulation through the radiative code. Simulated constituent fields exhibit many observed features. The Branch has participated in an initiative called CCM Val, sponsored by Stratospheric Processes and their Role in Climate (SPARC). CCM Val attempts to decrease uncertainty in prediction by developing tests of model performance-based processes that have been identified using observations, and using these tests to evaluate and improve models. The Goddard CCM ranked among one of the best in this comparison. The model also incorporates tropospheric chemistry and aerosols. More information about the CCM, including a list of publications, can be found at the following Web site, http://acdbext.gsfc.nasa.gov/Projects/GEOSCCM/index.html. For more information, contact Anne Douglass. (anne.r.douglass@nasa.gov), Richard Stolarski (richard.s.stolarski@nasa.gov), or Steven Pawson (steven.pawson-1@nasa.gov).

Finally, Branch members are active in the formulation of Decadal Survey missions (GEOCAPE, ACE, GACM), and participate in non-Decadal Survey missions, such as plans to incorporate SAGE III in the International Space Station, and continue development of a concept for deployment of SAGE III and the ACE-FTS instrument from Canada in a common platform. They are also leaders in the integration of the GloPac (Global Hawk Pacific) mission. Successful deployment of this mission in the spring of 2010 included deployment of a UV/VIS spectrometer developed by Branch scientists. The Branch also serves in the advisory board and participates in the FAA Aviation Climate Change Research Initiative (ACCRI).

5.4. Awards and Special Recognition

5.4.1. NASA Honors Awards

Jay Herman, Exceptional Service Medal

5.4.2. Goddard Honor Awards

Bryan Duncan, R.H.G. Exceptional Achievement Award for Science

5.5. External Awards and Recognition

This year, Eugenia Kalnay, currently professor at the University of Maryland, won the 54th International Meteorological Organization (IMO) prize of the WMO, the most prestigious prize awarded from that organization. She is the second woman to win this award. The first was Joanne Simpson, who also worked at the Goddard Laboratory for Atmospheres. The prize was awarded January 14 at the National Academy of Sciences. Among her many accomplishments, she was a branch head at Goddard in the Laboratory for Atmospheres and developer of a global circulation model that was used for many years at Goddard for data assimilation and modeling experiments. Several current and former members of the Laboratory for Atmospheres attended the award ceremony.

Charles Gatebe (GEST/Code 613.2), Rajesh Poudyal (SSAI/Code 613.2) and Eric Wilcox (Code 613.2) won the “Best Science Story” at the Third Annual Science and Exploration Directorate (Code 600) New Year’s Poster Party Blowout on January 28. The discovery of enhanced reflectance (>70%) in the solar principal plane by the wakes trailing large ships was serendipitous. Enhanced ship wake reflectance has potential global implications for the ocean energy balance and provides further evidence of the impact of human activities on climate.

Paul Newman, Code 613.3, has been selected as a Fellow of the American Geophysical Union. AGU fellows are selected each year from no more than 0.1 percent of the active AGU members who have achieved eminent stature in their field of research. Paul is selected for his outstanding research and leadership in stratospheric ozone and chemistry.

Lazaros Oraiopoulos (Code 613.2) has replaced Steven Platnick (Code 613.2) as Aqua Deputy Project Scientist following Dr. Platnick’s appointment as the EOS Project Scientist.

Partha Bhattacharjee (Code 613.2/GMU) received one of six student poster awards for a poster co-authored with Lazaros Oraiopoulos (Code 613.2) and Yogesh Sud (Emeritus/Code 613.2) and presented at DOE’s First Atmospheric System Research Science Team Meeting, March 15–19, in Bethesda, Maryland.

A story entry entitled "Predicting Tropical Cyclogenesis with a Global Mesoscale Model" will appear alongside of three other entries in the April "Research Breakthroughs," to be disseminated by the Division of Research at the University of Maryland at College Park. This entry is derived from a recent JGR paper entitled, "Predicting Tropical Cyclogenesis with a Global Mesoscale Model: Hierarchical Multiscale Interactions during the Formation of Tropical Cyclone Nargis (2008)" by Bo-Wen Shen (UMCP/ESSIC/ Code 613.1), Wei-Kuo Tao (Code 613.1) William. K. Lau (Code 613), and Robert Atlas (NOAA/AMOL). The inclusion of this discovery in "Research Breakthroughs" will result in $1,000 discretionary research funding to be transferred from the dean's office to ESSIC.

Dr. George J. Huffman was interviewed for the Earth Observatory article, "Severe Storms Strike U.S. East Coast," posted July 26 at http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=44772. He provided the meteorological context for satellite images of the squall line that caused widespread damage and power outages in the greater Washington, DC area on July 25.

On October 3, Dr. Christine Chiu (a member of the Climate and Radiation Branch until August when she joined the University of Reading) gave an invited lecture "Climate Observation from the Atmospheric Radiation Measurement (ARM) Program" at the annual meeting of the National Academy of Engineering (NAE). This is the venue at which newly elected members are inducted, and several high-profile lectures are given including one by White House Science Adviser John Holdren about climate change. The meeting was attended by such luminaries as Norman Augustine, Secretary of Energy Steve Chu, Warren Washington, and Michael King (GSFC Emeritus). Christine's was one of two Gilbreth lectures funded by the Armstrong Endowment for Young Engineers. Christine was introduced by Charles Vest, President of the NAE.

A new global (1° x1°) air-sea surface turbulent fluxes dataset—the Goddard Satellite-based Surface Turbulent Fluxes Version 2b (GSSTF2b) dataset (July 1987–December 2008)—has been produced and released in HDF–EOS5 format by the Goddard Earth Sciences Data and Information Services Center (GES DISC). GSSTF2b is part of a NASA Making Earth Science Data Records for Use in Research Environments (MEaSUREs)-funded project led by Chung-Lin Shie (UMBC, Code 613.1). The previous GSSTF dataset (GSSTF2; July 1987–December 2000), generated by the late Dr. Shu-Hsien Chou (Code 613.1), had been widely used by scientific communities for global energy and water-cycle research and regional and short-period data analysis since its official release in 2001. All of the GSSTF2b data types (daily, monthly, climatology, and individual SSM/I satellites daily data) in the HDF-EOS5 format are available along with documentation from the GES DISC MEaSUREs portal, http://disc.sci.gsfc.nasa.gov/measures.

Jun Wang, a visiting scientist in Code 613.2, has accepted the invitation to join the editorial board of Atmospheric Environment, an international journal dedicated to the publication of high-quality research in the field of air pollution and its societal impacts. The journal has a five-year impact factor of 3.58, according to the Journal Citation Reports published by Thomson Reuters 2010.

Scientists with the Climate and Radiation Branch provide the latest AERONET product, "Cloud Optical Depth." This product is the result of nearly 10 years of effort by Alexander Marshak (Code 613.2), Christine Chiu (formerly with UMBC/JCET and now with the University of Reading), and Stefani Huang (SSAI). Since there is no ground-based, global network for cloud observations, AERONET's well-established infrastructure makes it the ideal network to initiate and lead this effort in increasing operational cloud observations. Having co-located aerosol and cloud measurements is an important step for understanding the links between these two components of our climate system. Details are available at the AERONET Web page http://aeronet.gsfc.nasa.gov. Click on, "CLOUD MODE."

6. EDUCATION, OUTREACH, AND EXTERNAL COLLABORATION

6.1. Introduction

NASA's founding legislation directs the Agency to expand human knowledge of Earth and space phenomena and to preserve the role of the United States as a leader in aeronautics, space science, and technology. However, in recent years, undergraduate and graduate enrollment and the number of doctorates awarded in science and engineering have been declining. This trend, along with an aging workforce, places an increasing burden on NASA to maintain its level of achievement in science and technology.

The Laboratory's parent organization, The Earth Sciences Division (ESD, Code 610), has established the Committee for Education and Public Outreach, which is charged with coordinating these activities across the Division. Several Laboratory members are also on the ESD committee. Scott Braun, Paul Newman, and Lorraine Remer, are all working to achieve the committee's objectives. More information may be found at http://esdepo.gsfc.nasa.gov/index.php.

6.2. Education

6.2.1. PUMAS – Practical Uses of Math and Science

Figure 6.1: The PUMAS logo.

The Practical Uses of Math and Science (PUMAS) is an online journal, a Web-based collection of brief examples aimed at giving K–12 teachers insights into how the math and science they teach are actually used in everyday life. This site was founded and is edited by Ralph Kahn (Code 613.2), who joined the Laboratory in September 2007 from JPL. The examples are written primarily by scientists and engineers and are available to teachers, students, and other interested parties via the PUMAS Web site (http://pumas.nasa.gov). Scientists contribute their expertise by writing the examples, which may be activities, anecdotes, descriptions of "neat ideas," formal exercises, puzzles, or demonstrations. These examples are widely used by pre-college teachers around the world to enrich their presentation of topics in math and science. PUMAS offers researchers a way to make a substantial contribution to pre-college education with a relatively small investment of time and effort, and at the same time, to get a peer-reviewed science education journal article published on the web. For further information, please contact Ralph Kahn (ralph.kahn@nasa.gov), (301) 614-6193.

6.2.2. Interaction with Howard University

Partnerships with Howard University / University Research Center-BCCSO

A part of NASA's mission has been to initiate broad-based aerospace research capability by establishing research centers at the nation's HBCUs. The Beltsville Center for Climate Change observation (BCCSO) was established as a part of this initiative through a competitive award in 2009 at Howard University (HU), in Washington, DC. This research, which consists of teaching and research, has collaborations across the Lab. Extended information on this collaboration is available at http://bccso.org. It has also been a goal of the Laboratory and the Earth Sciences Division to partner with BCCSO to establish a self-supporting facility at Howard University for the study of terrestrial and extraterrestrial atmospheres with special emphasis on recruiting and training underrepresented minorities for careers in Earth and space science.

Participation with Howard University on the Beltsville Campus Research Site

For several years, Howard University has been in the process of building a multi-agency, multi-university field observation research station at the Howard University Research site at Beltsville (HURB). This research facility is part of the NOAA-Howard University Center for Atmospheric Science (NCAS). Bruce Gentry (Code 613.1), Gerry Heymsfield (Code 613.1), Alexander Marshak (Code 612.2), David Whiteman (Code 613.1), Belay Demoz (formerly of Code 613.1, now at Howard University), and others from GSFC are mentoring students and advising on instrument acquisition for the site. One of the main instruments at the site is a world-class Raman lidar built with major involvement from Code 613.1.

WAVES

During the summers of 2007, 2008, and 2009, students from HU participated in the WAVES field cam¬paign at the Beltsville site, participated as BCCSO summer interns at GSFC/Beltsville, or both. WAVES (Water Vapor Validation Experiments Satellite and Sondes) was a satellite validation, sonde, and other instrument inter-comparison field campaign centered on the Howard University Research Campus in Beltsville, Maryland. The main goal of this campaign was to acquire a statistically robust set of measurements of atmospheric water vapor, aerosols, and trace gases useful for Aura/Aqua satellite retrieval studies as well as for performing instrument accuracy assessments and for case studies of regional water vapor and aerosol variability. WAVES was the first major experiment held at HURB and required coordination within HU and with NASA's GSFC, NOAA/Boulder, NWS/Sterling, as well as with many universities, including the University of Maryland, College Park; the University of Maryland, Baltimore County; Pennsylvania State University; Bowie State; Trinity University, DC.; the University of Virginia, Charlottesville; Smith College, NH; the University of Wisconsin; and with universities in Brazil, Italy, and Bolivia.

WAVES was funded by NASA/SMD for two years. The core components of the WAVES funding include proposals awarded to HU, UMBC, and GSFC. For further information see the WAVES Web site, http://tropometrics.com, or contact David Whiteman (david.n.whiteman@nasa.gov) or Belay Demoz (bbdemoz@howard.edu).

Wind Lidar Intercomparison

In 2010, a three-year program to assess performance of ground based wind lidar was completed at the Howard University, Beltsville campus. The goal of the experiment was to compare two of NASA's state-of-the-art wind lidar technology instruments and candidates for NASA's Decadal Survey 3D-Winds Mission. The VALIDAR is an aerosol-based lidar system from NASA's LaRC while the GLOW is a molecular-based Doppler lidar from GSFC. This is the first experiment where these two techniques have been compared in side-by-side experiment. In addition, the commercial wind lidar from Leosphere, France (the WLS70(c)), a 915 MHz profiler, ACARS winds, and different types of radiosondes participated.

The wind lidar intercomparison experiment was funded by NASA's SMD for three years under as part of the wind lidar science program. For further information, contact Bruce Gentry (bruce.m.gentry@nasa.gov) or Belay Demoz (bbdemoz@howard.edu).

DABUL

In collaboration with UMBC and Judd Welton (Code 613.1), the Depolarization and Backscatter Unattended Lidar (DABUL) is a new MPL-like lidar is being installed at HURB. Timothy Berkoff of UMBC has started the work, which is ongoing. The lidar is to be operating from HURB, and its data is to be used for satellite validation as well as air pollution studies. For further information, please contact Timothy Berkoff (timothy.a.berkoff@nasa.gov) or Judd Welton (ellsworth.j.welton@nasa.gov).

6.3. Summer Programs

6.3.1. The Summer Institute in Earth Sciences (SIES) and Graduate Student Summer Program (GSSP)

The Summer Institute in Atmospheric, Hydrospheric, and Terrestrial Sciences was held from June 1 to August 6. The program is sponsored by the Earth Sciences Division (Code 610). In 2010, the Institute was coordinated and managed by GEST, who also managed the Center Graduate Student Summer Program, GEST–GSSP. The summer institute is designed to introduce undergraduate students majoring in all areas of the physical sciences to research opportunities in these areas. After a one-week series of introductory lectures, the students select from a list of research topics and are mentored by a Goddard scientist for a period of nine weeks. At the conclusion of this period, the students give a presentation of their results. Laboratory for Atmospheres scientists participating in the institute, students, and research topics are shown in Table 6.1.

NASA's GSFC's Earth Sciences Division, in collaboration with GEST Center of the University of Maryland, Baltimore County, offers a limited number of graduate student research opportunities through its Graduate Student Summer Program (GSSP). This prestigious program is in its ninth year and is designed to stimulate interest in interdisciplinary Earth sciences studies by enabling selected students to carry out an intensive research project at GSFC's Earth Sciences Division, which can be applied to the student's graduate thesis.

Positions are available to students interested in any Earth sciences field conducive to the research of the Earth Sciences Division. Each student is teamed with a Goddard scientist mentor with parallel scientific interests. NASA mentors can be drawn from any of the participating Earth Sciences Laboratories which include: the Laboratory for Atmospheres, the Laboratory for Hydrospheric and Biospheric Sciences, the Global Modeling and Assimilation Office, the Global Change Data Center, and the Software Integration and Visualization Office. During the summer program, there is a lecture series aimed at current popular

Earth sciences topics. At the conclusion of the program, students produce final oral and written reports on their summer research activities. Laboratory for Atmospheres scientists participating in the GSSP, students, and research topics are shown in Table 6.2.

A detailed report on SIES and GSSP prepared by Valeria Casasanto (GEST) summarizing the 2010 programs is shown below.

Table 6.1: 2010 Summer Institute Participants

Student	University	Mentor	Code	Project Title
Amanda DePasquale	University of Delaware	A. Prados	610.6	Making NASA Precipitation Information Accessible to the Public
Katherine Melocik	UMBC	D. Slayback	614.4	Andean Tropical Glacier Extent from Landsat Imagery
Gilman Ouellette	Penn State	E. Brown de Colstoun	610.0	Satellite Based Impervious Land Cover Estimation for the Chesapeake Bay Watershed
Derek Podowitz	Institute of Technology	R. Meneghini	613.1	Updated Comparisons between Ground Radar and Satellite Precipitation Radar at Melbourne, Florida
David Roberts	Hobart College	R. Soebiyanto	610.1	Meteorological and Environmental Indicators in Seasonal Influenza Transmission
Kamila Wisniewska	Hunter College	S. Daniel Jacob	614.1	Hurricane Induced Sea Surface Temperature Changes
Biebele Abel	Morgan State University	C. Ichoku	613.2	Satellite Observation of Biomass Burning Emission
Brittany Bruder	Georgia Institute of Technology	J. Moisan (Wallops Island)	614.6	Analysis and Modeling of Sea-Level Variability in the Chesapeake Bay using the Regional Ocean Modeling System (ROMS)
Sunny Choi	Georgia Institute of Technology	J. Joiner	613.3	Observation of Troposphere BrO over northern high latitudes from OMI during ARCTAS & ARCPAC
Tao Chu	University of Massachusetts Amherst	L. Tian	613.1	Rain Retrieval Algorithm Development for the HIWRAP instrument
Prajjwal Panday	Clark University	M. Brown	614.4	Snowmelt runoff modeling in the Tamor River Basin in the eastern Nepalese Himalaya
Sarah Smith	Eastern Michigan University	E. Brown de Colstoun	610.0	Satellite-Bases Estimation of Impervious/Pervious Land Cover Percentage of the Chesapeake Bay Watershed
Robert Velarde	University of Texas El Paso	S. Gasso	613.2	Satellite Characterization & Modeling of Dust Transport from the Copper River Valley, Alaska

Figure 6.2: Participants in the 2010 Summer Institute in Earth Sciences (SIES) and Graduate Student Summer Program (GSSP).

6.3.2. SIES Program Report

Background

The GSSP and SIES programs are sponsored by NASA Goddard's Earth Sciences Division and managed by the University of Maryland, Baltimore County (UMBC), Goddard Earth Sciences Technology Center (GEST). The GSSP summer program has been successfully running for the past ten years, and the SIES for more than 20 years. Valerie Casasanto of UMBC's GEST Center served as Program Manager. In addition, Ali Tokay (Code 613.1) served as selection committee Chair and Jeffrey Halverson, Associate Director of UMBC's Joint Center for Earth Systems Technology, served as advisor to the GSSP summer program.

General information and statistics

- Summer Programs 2010 took place from June 1 to August 6;
- For GSSP, ~20 applications were received, of which 7 students were accepted and fully funded; Student population included 4 PhD students and 3 master's degree students; 6 students worked at GSFC in Greenbelt, Maryland, and 1 student was based at Wallops Island. All were matched with a GSFC mentor;
- For SIES, ~60 applications were received, of which 8 undergraduate students were accepted and fully funded. (Two of the 8 students dropped out due to illness midway through the program.)
- GSFC-based students were housed at the Courtyard Marriott in Greenbelt and were provided with public transportation to Goddard daily. (Public bus stop located within very close walking distance to the Courtyard.)

Highlights and Events

- On arrival day, students met with Camilla Hyman of UMBC to complete paperwork for payroll. They then participated in the center-wide orientation for all Goddard interns and were briefed on what it is like working at NASA. They also were walked through security, IT security, and all other

Goddard-related issues. Afterwards, students were treated to a welcome lunch with their mentors and GEST's program coordinator. They then went with their mentors to begin discussions on their summer research projects. At the end of the day, students received the second part of their orientation session conducted by Jeffrey Halverson, Ali Tokay, and Valerie Casasanto, which covered NASA's Earth Sciences Division, logistics, and the steps to get the most out of their internship experience.

- During the first week of the program, a welcome dinner was held for students and mentors at the Courtyard Marriott. In addition, a tour of NASA Goddard for students was conducted by the program coordinator during the first week. Students enjoyed viewing the various labs, clean rooms, test facilities, centrifuge, and space hardware at GSFC. Tours of the NOMC and the television studio were also conducted during the summer.
- Individual meetings were conducted with each student to monitor progress, mentor the relationship, and assist project comprehension. These meetings were then followed by visits to each student at their work stations throughout the program.
- Every Friday, students met with the program coordinator for an informal "bag" lunch outside of the cafeteria, providing the opportunity to interact with other participants and get updated on the latest news.
- All students had a positive relationship with their mentors.
- Most students participated in research that will be utilized in their thesis.
- The Seminar Series featured experts in various areas of Earth Sciences. These seminars were scattered throughout the program and were approximately 1.5 hours in length. The series culminated in a presentation at the Goddard Visitor's Center utilizing data projected on the Science on a Sphere.
- Student final presentation seminars were held in Building 33 on the last day of the program. Each student gave a 15–20 minute seminar on the work completed this past summer, and time was given for questions and answers. Refreshments were provided. Mentors were also present for support.
- A farewell lunch was held at a nearby restaurant in Greenbelt, and certificates and gifts (books) were presented to participants.
- All student papers have been submitted and posted on the GEST Web sites:

  http://gest.umbc.edu/student_opp/2010_gssp_reports.html and

  http://gest.umbc.edu/student_opp/2010_sies_reports.html.

Notable comments from students

- Overall, students had a very positive experience, felt welcomed, enjoyed their research, had excellent camaraderie, and felt that this opportunity had provided a unique opportunity and made an impact on their lives and future careers.
- Opportunity to meet new people and work at Goddard was a great plus.
- Students enjoyed the "Friday lunches," which was something to look forward to as they met their peers and program coordinator outside in an informal setting.
- Housing at the Courtyard Marriott was a great experience for interns. (This was an improvement made based on student feedback from 2009.)
- Students enjoyed the seminar series.
- Housing at Leonardtown in College Park was satisfactory.

- Students expressed that they would prefer to have a few rental cars to go back and forth from NASA, as well as to use them to purchase groceries.

Items to consider for 2010 and lessons learned

- Students were limited on cooking in their rooms (microwave and fridge). May investigate a mechanism for them to do group cooking.
- Some students would like to see increased interaction between the interns and staff scientists and engineers and with program faculty such as Tokay and Halverson.

6.4. University Education

Laboratory members are active in supporting university education through teaching courses and advising graduate students. Table 6.2 lists the instructors and the courses that they taught.

Table 6.2 lists Laboratory members, the name of the university, and the title of the course.

Table 6.2: University Courses Taught

University	Title of Course	Instructor, Code
Chapman University	General Physics	Eyal Amitai, 613.1
Howard University	Lidar Special Topics	David Whiteman, 613.1
University of Maryland Baltimore County	Atmospheric Physics II	Tamas Varnai (co-instructor), 613.2/UMBC

Table 6.3 lists Laboratory members who serve as graduate student advisors, sit on student PhD committees, or both.

Table 6.3: Graduate Student Advising

Scientist		
Scott Braun *	Ralph Kahn *	Wei-Kuo Tao * (4)
Peter Colarco *	Steven Platnick *	Maria Tzortziou † *
Gerald Heymsfield * (2)	Lorraine Remer * (2)	David Whiteman * (2)
James Irons *	David Starr *	

† *Masters committees* * *Ph.D. committees*
Parentheses indicate number of students

6.5. NASA Postdoctoral Program

The Laboratory for Atmospheres actively participates in the NPP, a postdoctoral fellowship program administrated by the Oak Ridge Associated University (ORAU). NPP is aimed at early career scientists who are interested in working at NASA with a sponsor (usually a civil servant scientist) on space and earth science research. The Lab sponsors NPP research in a wide range of areas including aerosol, clouds, precipitation, radiation, mesoscale processes, climate dynamics, and stratospheric and tropospheric chemistry. This research can include the roles and interactions of the above range with climate change, with emphases on the use of NASA satellite data, modeling tools, and development of mission-related technology. The NPP provides a key pipeline for future generation of NASA civil servant scientists as well as candidates for faculty positions at universities. In 2010, the list of NPP candidates included:

Ended in 2010

- **KERRY MEYER**
  Sponsor: Steve Platnick
  Research: Quantifying the information content in the 1.38 μm MODIS band for use in thin cirrus detection and retrievals which represents an important component to a major NASA satellite dataset.
- **JASON SIPPLE**
  Sponsor: Scott Braun
  Research: Dr. Sipple investigated the role of the Saharan air layer in the evolution of Tropical Storm Debby using a 30-member, high-resolution numerical model ensemble. Data from the 30 simulations was used to relate different aspects of the storm's environment to its intensification. Jason also developed integrated data techniques for the assimilation of airborne radar and lidar wind data.

2010 Participants

- **VALENTINA AQUILA (2ND YEAR)**
  Sponsor: Richard Stolarski
  Research: Dr. Aquila studied the effects of the aerosol-chemistry coupling on climate and air quality.
- **MARIA CAZORLA (1ST YEAR)**
  Sponsor: Thomas Hanisco
  Research: Dr. Carzorla researched instrument development and mechanisms of the chemistry of the upper troposphere and lower stratosphere.
- **AFUSAT DIRISU (2ND YEAR)**
  Sponsor: Dave Whiteman
  Research: Dr. Dirisu's work was in the development of advanced calibration techniques for the Raman water vapor lidar. This work included fundamental measurements of Raman scattering cross section needed in an absolute calibration effort. These efforts directly related to the need to quantify atmospheric water vapor with sufficient accuracy to detect trends due to climate change.
- **STEVE GUIMOND (1ST YEAR)**
  Sponsor: Gerald Heymsfield
  Research: Dr. Guimond worked on a two-pronged approach to understanding the role of convection and turbulence in hurricane dynamics by using airborne doppler radar and a numerical simulation.
- **MARAGRET HURWITZ (2ND YEAR)**
  Sponsor: Paul Newman
  Research: Dr. Hurwitz worked on improving the understanding of stratospheric polar vortex dynamics and investigated the impact of tropical sea surface temperatures on the Antarctic ozone hole.

- **JASPER LEWIS (1ST YEAR)**
  Sponsor: Ellsworth Welton
  Research: Dr. Lewis used lidar to validate and improve atmospheric aerosol models.
- **AARON PRATT (2ND YEAR)**
  Sponsor: Jerry Heymsfield
  Research: Dr. Pratt investigated the effects of Saharan dust on intensification of convection in tropical systems using a modeling and observational approach.
- **SEGALYE THOMPSON (2ND YEAR)**
  Sponsor: W.K.Tao
  Research: Dr. Segayle Thompson used the new version of the Weather Research and Forecasting (WRF) model on the NASA system to conduct detailed studies of the impact of lidar assimilation on precipitation forecasting over the Washington, DC area. She examined GPM in rainfall data assimilation. He also worked with Goddard Mesoscale Modeling and Dynamics group in improving microphysics schemes for NASA Goddard Cumulus Ensemble (GCE) model and NASA unified WRF.

6.6. The Academic Community

The Laboratory relies on collaboration with university scientists to achieve its goals. Such relationships make optimum use of government facilities and capabilities with those of academic institutions. These relationships also promote the education of new generations of scientists and engineers. Educational programs include summer programs for faculty and students, fellowships for graduate research, and associateships for postdoctoral studies. A number of Laboratory members teach courses at nearby universities and give lectures and seminars at U.S. and foreign universities. The Laboratory frequently supports workshops on a wide range of scientific topics of interest to the academic community.

NASA and non-NASA scientists work together on NASA missions, experiments, and instrument and system development. Similarly, several Laboratory scientists work on programs at universities or other Federal agencies.

The Laboratory routinely makes its facilities, large datasets, and software available to the outside community. The list of refereed publications, presented in Appendix 2, reflects our many scientific interactions with the outside community; more than 85% of the publications involve coauthors from institutions outside the Laboratory.

Prime examples of the collaboration between the academic community and the Laboratory are given in this list of collaborative relationships via memoranda of understanding or cooperative agreements:

- Cooperative Institute of Meteorological Satellite Studies (CIMSS), with the University of Wisconsin, Madison;
- ESSIC, with the University of Maryland, College Park;
- GEST Center, with the University of Maryland, Baltimore County (and involving Howard University);
- JCET, with the University of Maryland, Baltimore County;
- Joint Center for Observation System Science (JCOSS), with the Scripps Institution of Oceanography, University of California, San Diego; and
- Cooperative agreement with Colorado State University, Fort Collins, Colorado.

These collaborative relationships have been organized to increase scientific interactions between the Laboratory for Atmospheres at GSFC and the faculty and students at the participating universities.

In addition, university and other outside scientists visit the Laboratory for periods ranging from one day to as long as three years. Some of these appointments are supported by the NASA Postdoctoral Program administered by the Oak Ridge Associated Universities while others by the Visiting Scientists and Visiting Fellows Programs currently managed by the GEST Center. Visiting scientists are appointed for up to two years and perform research in pre-established areas. Visiting fellows are appointed for up to one year and are free to carry out research projects of their own design.

6.7. Open Lecture Series

Distinguished Lecture Series

One aspect of the Laboratory's public outreach is a Distinguished Lecturer Seminar Series, which is held each year and is 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 the latest ideas from experts. The following were the lectures presented in 2010:

January – December 2010

- January 21, 2010
  PETER PILEWSKIE
  University of Colorado at Boulder
  The Sun, Climate, and the Total and Spectral Solar Irradiance Sensor
- February 18, 2010
  BILL RANDEL
  National Center for Atmospheric Research
  The Asian Monsoon Anticyclone, Pollution near the Tropopause and Transport to the Stratosphere
- April 15, 2010
  SIMONE TANELLI
  Jet Propulsion Laboratory
  Development of NASA's Integrated Instrument Simulator Suite for Atmospheric Remote Sensing from Spaceborne Platforms
- May 20, 2010
  STEPHAN FUEGLISTALER
  Princeton University
  Stratospheric Water Vapor: Enigma or Rosetta Stone?
- October 21, 2010
  ROBERT F. CALAHAN
  NASA GSFC, Code 613.2 Climate and Radiation Branch
  Modeling the Climate Responses to Spectral Solar Variability on Decadal and Centennial Time Scales
- November 18, 2010
  T.N. KRISHNAMIRTI
  Florida State University
  Seasonal Climate Forecasts Using a Suite of 16 Coupled Atmosphere Ocean Models

6.8. Public Outreach

January

DAVID WHITEMAN (Code 613.1) cotaught a seminar course at Howard University with Demetrius Venable of Howard. The subject matter was Raman Lidar.

JUDD WELTON (Code 613.1) gave a seminar entitled, "The NASA Micro Pulse Lidar Network (MPLNET): Overview, Current Activities, and Future Plans" at the University of Maryland's Earth System Science Interdisciplinary Center (ESSIC) on January 4.

February

ROBERT CAHALAN (Code 613.2) presented "Climate Change Overview" at the Earth to Sky IV NASA/National Park Service/US Fish & Wildlife Service Communicating Climate Change Workshop in Harper's Ferry, West Virginia on February 1–5. The Earth to Sky workshop is an interagency partnership that fosters collaborative work among rangers, scientists, and the education and outreach communities of NASA, NPS and USFWS. This year's workshop focused on climate change and features more than 15 NASA scientists, as well as a number of education and outreach professionals.

The Earth Observatory Group hosted its annual report for 2009 on February 2. Twenty team members, scientists, PAO, and outreach personnel were in attendance. The Earth Observatory Web site (http://earthobservatory.nasa.gov/) continued to experience consistent growth in audience and interaction and the content the group produced maintained broad syndication.

CHARLES ICHOKU (Code 613.2) gave an invited presentation entitled, "Biomass Burning Emissions from Fire Remote Sensing" at the UMBC atmospheric physics department seminar series on February 3.

WEI-KUO TAO (Code 613.1) was invited by the Department of Meteorology at The Pennsylvania State University to present the department colloquium on February 3. More than 75 graduate students and faculty attended. The talk was entitled, "Goddard Multi-Scale Modeling System with Unified Physics."

RICH KLEIDMAN (SSAI/Code 613.2) lead a course on the basics of atmosphere remote sensing in Bangalore, India from February 8–11, 2010. The Indian Institute of Science hosted the workshop with sponsorship by the Indian Space Research Organization. Joining Rich was **SHANA MATTOO** (SSAI/Code 613.2) and **LORRAINE REMER** (Code 613.2).

EYAL AMITAI (Code 613.1, Chapman University) was invited on Feb. 11 to The City College of New York as a guest speaker at the NOAA Cooperative Remote Sensing Science and Technology Center (CREST). Eyal spoke on the topic, "How Intense is Our Rainfall? A View from Space, Ground and Underwater."

JIM IRONS (Code 613.0) presented a talk entitled, "The Landsat Data Continuity Mission" to a group from the American Society of Photogrammetry and Remote Sensing (ASPRS), Potomac Region touring GSFC on February 12.

LORRAINE REMER (Code 613.2) presented a lecture entitled, "The Satellite View of the Global Aerosol and Cloud System" at the Weizmann Institute in Rehovot, Israel, February 17–19.

RICH KLEIDMAN and **ROB LEVY** (SSAI/Code 613.2) taught a short course on atmospheric remote sensing with air quality applications at the Technion University in Israel, February 21–25.

KEVIN WARD (Sigma Space/Code 613.2), Earth Observatory, met with staff at the Oregon Museum of Science and Industry (OMSI) to begin outlining a process to evaluate dataset imagery in NEO (NASA Earth Observations) for use with Science on a Sphere, Magic Planet, and other spherical display devices. The evaluation also involved the Liberty Science Center (Jersey City, NJ), Maurice Henderson (ADNET/Code 614.0), and the Science on a Sphere at the Goddard Visitors Center, and Steve Graham with the Magic Planet, who travels as part of the NASA booth to conferences and other events.

RICHARD KLEIDMAN (SSAI/Code 613.2) and **LORRAINE REMER** (Code 613.2) met with the chancellor of Vellore Institute of Technology in Tamil Nadu, India and each presented a seminar highlighting different facets of using space-based sensors to observe the global aerosol system.

RICHARD KLEIDMAN, **SHANA MATTOO** (SSAI/Code 613.2), and **LORRAINE REMER** (Code 613.2) presented a three-day, hands-on workshop on using MODIS data at the Indian Institute of Science in Bangalore, co-sponsored by ISRO. The 27 participants, mostly graduate students and post-docs, were selected from a field of more than 400 applicants.

March

Rasheen Connell of Howard University successfully defended his PhD dissertation, entitled "A Numerical Model Characterizing the Experimental Performance of the Howard University Raman Lidar System," on March 10. **DAVID WHITEMAN** (Code 613.1) and **TOM MCGEE** (Code 613.3) were members of his PhD committee.

T. L. BELL (Code 613.2/Emeritus) gave a talk to the group, Young Professionals in Foreign Policy in Washington, at the Goddard Visitors Center on March 12. The talk was entitled, "The Weekend Effect on Weather: A Weekly Climate-Change Experiment."

JIM IRONS (Code 613.0), the LDCM Project Scientist attended a U.S. Geological Survey (USGS) briefing to Congressional staff on March 26 at the Rayburn House Office Building. The briefing was on "The Landsat Program: A Clear View of Society and the Environment from Space." The briefing was sponsored by Senator Tim Johnson (SD), Senator John Thune (SD), and Representative Stephanie Herseth Sandlin (SD). Presentations were made by Tony Williardson of the Western States Water Council, Dr. Randy Wynne from Virginia Polytechnic Institute and State Universityand a member of the Landsat Science Team, and Dr. Bryant Cramer, the associate director for geography at the USGS.

April

WILLIAM LAU (613.0) presented a seminar entitled "Enhanced surface warming and accelerated snow melt in the Himalayas and Tibetan Plateau induced by absorbing aerosols" at the Department of Atmospheric and Oceanic sciences, on April 1. He met with students and faculty before and after the seminar to discuss research and recruitment of new scientist positions at GSFC.

The eruption of the Eyjafyallajokull volcano in Iceland sent a plume of volcanic ash, mostly mineral particles and gases, into the upper troposphere where it was dispersed over much of Europe, causing havoc in European and trans-Atlantic air traffic. 613.2 Branch members including **LORRAINE REMER** and the Earth Observatory team have been fielding requests from the European media for information and imagery of the plume. View the Climate & Radiation Branch Image of the Week for additional information. https://climate.gsfc.nasa.gov/viewImage.php?id=276

WEI-KUO TAO (Code 613.1) visited NOAA GFDL at Princeton, NJ on April 14. He gave a talk on the Goddard Multi-scale Modeling system, its developments (including major improvements in cloud physics), and its applications to understand the impact of microphysics on typhoon and precipitation systems. In his talk, he also demonstrated on how to use high-resolution (spatial and temporal) visualization to better analyze and interpret precipitation processes simulated by numerical models.

Several Laboratory members participated in Earth Day 2010 activities at the "NASA Village" tents, which contained three domed tents, to highlight the use of NASA science and technology to advance knowledge and awareness about our home planet and sustain our environment on the National Mall, April 17–25. The audience varied between adults, school kids, and environmentalists. The GSFC Outreach team under Winnie Humberson, Jennifer Brennan, and Steve Graham did a great job with setup and support. http://www.nasa.gov/topics/earth/earthday/earthday_mall.html

WILLIAM LAU (Code 613.0) presented a seminar, entitled "Rainfall Extreme, Tropical Cyclone and Climate Change," at the Scripps Institution of Oceanography, University of San Diego, on April 21. He also served as panelist on a panel discussion on "Climate Extreme and Human Health" at the Beyond Copenhagen Climate Conference, held at Chapman University, Orange County, on Earth Day, April 22.

PETER COLARCO (Code 613.3) was a co-organizer and attended the "Atmospheric Composition Forecasting Working Group: Aerosol Observability workshop at Naval Research Lab in Monterey, CA, April 27–29.

EYAL AMITAI (Code 613.1, Chapman University) gave an invited lecture on April 28, 2010 at the University of Nevada, Reno, as part of the Geography Department's spring 2010 colloquium series. His talk on "Testing the Water: Rainfall Intensities from Satellite, Ground, and Underwater Observations" was open to all students, the University community, and the public.

WARREN WISCOMBE (Code 613.2), hosted by Alex Khain of the Hebrew University of Jerusalem, Department of Atmospheric Science, presented a talk entitled, "The Atmospheric Radiation Measurements Program: A Revolutionary Approach to Field Campaigns" on April 29 and at the Weizmann Institute, Department of Environmental Science & Energy Research on May 2. On May 3, he presented a talk entitled, "A Personal Perspective on Climate Gate and the IPCC Conclusions about Climate Change."

May

WEI-KUO TAO (Code 613.1) participated in Marcia DeLonge's (University of Virginia) PhD defense on May 3, 2010. DeLonge applied the Goddard Cumulus Ensemble (GCE) model to study the impact of land surface properties and aerosol concentrations on the development of precipitation systems during NASA African Monsoon Multidisciplinary Analyses (NAMMA) field campaign.

On May 5, **SI-CHEE TSAY** (Code 613.2) and Brent Holben (Code 614.4) were invited by the National Academies of Science in Washington, DC to brief the Board of Atmospheric Sciences and Climate on two aerosol research topics: (1) State of the Science in Field Campaigns (by Holben and Tsay), and (2) Agency Perspectives (by Tsay and Holben, with contributions from Ralph Kahn, Mian Chin, and William Lau. Holben presented the current state of the science on aerosol, cloud, and monsoon water-cycle interactions, and briefed on recent (China, 2008; India, 2008/2009) and planned (7SEAS, 2010/2012; GVAX; 2011/2012) international deployments using supersite (SMART–COMMIT) and network (AERONET–MPLNET) operations as examples. Tsay started the presentation with aerosol research using NASA/EOS measurements: progressing from passive imagers to active sensors to the synergy of both with models. The pressing issues of aerosol research were discussed next and summarized with the ways forward to the next era of Decadal Survey, particularly ACE for the next generation of aerosol studies.

JUDD WELTON (Code 613.1) participated in the National Air and Space Museum's Space Day event on May 8. He represented the Glory mission, interacting with the public and informing them about NASA's next Earth Science mission scheduled to launch in November. The Glory booth was popular, especially the Glory kids' activity books and the Send Your Name Around the Earth campaign. Participants enter their name through a link on the Glory Web site, and their information was placed onboard the spacecraft prior to launch.

On May 10, **ROBERT CAHALAN** (Code 613.2) presented a talk entitled, "Temperature Responses To Spectral Solar Variability on Decadal Time Scales," as part of the Space Physics Seminar at the University of Maryland, College Park.

On May 14, **G. THOMAS ARNOLD** (Code 613.2/SSAI) gave presentations to the kindergarten and 1st grade classes for "Career Day" at Riverdale Elementary School. Recently, he participated as a judge in the Eleanor Roosevelt High School Science Fair.

In connection with their roles as NASA Scientists supporting the GLOBE Student Climate Research Campaign (SCRC), **CHARLES ICHOKU** (Code 613.2) and **CHARLES GATEBE** (UMBC/GEST/Code 613.2) attended the NASA Earth Science Education and Public Outreach (E/PO) Workshop in Warrenton, VA, May 17–20, together with several other people involved in education and outreach activities across the Division, center, and agency, as well as representative E/PO partner institutions.

WEI-KUO TAO (Code 613.1) was invited to give a lecture on numerical cloud resolving modeling research to graduate students and faculty members at Duke University on May 20.

WEI-KUO TAO (Code 613.1) participated in PhD student preliminary exam at Duke University on May 20. The student, Prabhakar Shrestha, used both observation and numerical models to study aerosol-cloud-rainfall interactions during pre-monsoon period in central Nepal.

ALI TOKAY (UMBC/Code 613.1) attended a "Career Day" activity at Nantucket Elementary School on May 21. He demonstrated the rain measurement through tipping bucket rain gauges. This activity was for third, fourth, and fifth graders.

The NASA/Applied Remote Sensing Education and Training (ARSET) group consisting of **RICHARD KLEIDMAN** (SSAI/Code 613.2), Ana Prados (UMBC/Code 610.2) and Sundar Christopher (Univ. of Huntsville, Alabama), with special guest lecturers P. Colarco (Code 613.3), G. Wind (SSAI/613.2) and M. Petrenko (ESSIC/Code 613.2), held a remote sensing and air quality training workshop on May 24–28 at the University of Maryland, Baltimore County campus. The goal of this project was to increase the utility of NASA datasets for a wide spectrum of users such as policy makers and professionals seeking to address societal and environmental needs, as well as students, teachers, and scientists. As part of the effort to achieve this goal, a group of NASA and university researchers, supported by the NASA Applied Sciences program, were engaged in professional outreach and educational activities in the area of remote sensing of the atmosphere. These activities focused on two areas: (1) creating and making available educational and training materials, and (2) providing training workshops and seminars.

June

On June 6–14, **JUDD WELTON** (Code 613.1) participated in a meeting in Vietnam with scientists at the Institute of Geophysics in Hanoi about joining the NASA Micro Pulse Lidar Network. He visited potential network site locations in South and North Vietnam. He also traveled to Taiwan from June 14–19 to participate in the workshop for the Seven South East Asian Studies (7SEAS) campaign, hosted by National Central University. 7SEAS is an international, interdisciplinary atmospheric sciences program to study the interactions of air pollution with regional climate and meteorology in South East Asia, with emphasis on aerosol-cloud interactions. Dr. Welton has coordinated MPLNET involvement in 7SEAS, including existing lidar sites in Taiwan, Singapore, and Dongsha Island, and planned sites in Vietnam, Malaysia, and Hong Kong.

WILLIAM LAU (613.0) presented an invited talk entitled, “Aerosols, Monsoon Rainfall and Climate Change” at a Forum on Environment and Energyat the Cosmo Club in Washington DC, on June 14. The forum was cosponsored by the Japan Society for the Promotion of Science Promotion (JSPS), the Japanese Embassy, DOE, NSF, and NIH.

On June 16, **GAIL SKOFRONICK JACKSON** provided Sumiko Mito (assistant to the NASA Japanese representative) and Gib Kirkham (NASA Headquarters, External Relations) science descriptions of the TRMM and GPM missions and a tour of the TRMM control operations center. Japanese partnerships for GPM and TRMM were emphasized during the discussion. Julio Marius (Code 584) assisted with the tour. This was to help Ms. Mito as she spoke with JAXA Headquarters and Ministry level counterparts to help them to understand NASA’s approach to Earth Science research and spacecraft operations.

CHARLES ICHOKU (Code 613.2) attended the 2010 Earth Science Technology Forum (ESTF) in Arlington, VA, June 22–24. The forum showcased a wide array of technology research and development related to NASA’s Earth science endeavors. Attendees were able to encounter the latest advances in NASA technology for Earth science observations—remote sensing instruments, platforms, components, advanced information systems, sensor web technologies, communications, automation, and modeling—within two parallel tracks of sessions. ESTF 2010 intended to promote collaboration and networking among technologists, scientists, and mission planners, as well as facilitate a more complete understanding of NASA technology requirements. http://esto.nasa.gov/conferences/estf2010/sessions.html

RICHARD KLEIDMAN (Code 613.2/SSAI) attended the Air & Waste Management Association’s 103rd Annual Conference & Exhibition in Calgary, Alberta, Canada, June 22–25. He presented a one-day course on remote sensing and air quality and also gave presentations at the NASA booth. http://www.awma.org/ACE2010/

WILLIAM LAU (Code 613.0) presented a keynote lecture, entitled, “Aerosols, Monsoon and Climate Change” at the West Pacific Geophysical Meeting (WPGM), in Taipei, Taiwan, June 22–25. He also gave an invited talk entitled, “Extreme Rainfall, Tropical Cyclones and Climate Change” at a session on tropical cyclones. He was one of the four panelist at a local press conference, arranged by the WPGM, on general topics of the science and society impacts of extreme events affecting Asian countries, including space weather, tsunami, aerosol and typhoon Molokot, which dumped 3,000 mm of rain in two days in central and southern Taiwan and caused devastating landslides, loss of property, and human life.

EYAL AMITAI (Code 613.1, Chapman University) accepted an invitation to visit the Universitat Politecnica de Catalunya in Barcelona, Spain, and to serve as a jury in Xavier Llort’s PhD defense on June 28. Dr. Llort is studying the structure of radar rainfall and its errors. His dissertation, written in English, should be useful for many scientists and students around the world both in academic institutions and in leading research and operational agencies (e.g., NASA and NOAA). In Spain, doctorate degrees are regulated by royal decree. They are granted by the university on behalf of the king, and its diploma has the force of a public document. The social standing of doctors in Spain is evidenced by the fact that only PhD holders, Grandees and Dukes can take seat and cover their heads in the presence of the King.

July

ROBERT CAHALAN and **CHARLES ICHOKU** (Code 613.2) presented talks at an education workshop held at the Goddard Visitor Center on July 8. Discussions were focused on climate change, the activities of GLOBE, and aerosol/fire remote sensing and impacts.

JUDD WELTON (Code 613.1) gave a presentation on aerosol climate impacts and NASA’s Glory mission to officials from the Department of Transportation onJuly 31. The DOT representatives were responding to a recent paper by Unger, et al. (“Attribution of Climate Forcing to Economic Sectors,” Proc. Nat. Acad. Sci., 2010), which concluded that the on-road transportation sector is the greatest contributor to atmospheric warming in the near term. Unger, et al. stated that motor vehicle emissions contain both greenhouse gases and significant amounts of black carbon that cause a warming effect, but emit a negligible amount of sulfate aerosols, which cool. The industrial and power economic sectors are traditionally targeted as the major contributors to warming, but both activities emit significant amounts of sulfate aerosols in addition to greenhouse gases and black carbon. At the present, warming from industrial and power activities is offset by cooling from sulfate aerosols, and the on-road sector was found to contribute the most to warming until 2100 when the power economic sector becomes dominant after years of accumulated CO_2 emissions. DOT officials were interested in learning more about NASA's aerosol measurements from space, and in particular how Glory will help monitor black carbon aerosols. The meeting was held at the Orbital Sciences Corporation facility in Dulles, VA. Orbital was building the Glory satellite. The meeting included a tour of the Orbital facility and a visit to see Glory.

August

B.-W. SHEN (UMCP/ESSIC/Code 613.1) was featured in NASA News, entitled "Supercomputer Reproduces a Cyclone's Birth, May Boost Forecasting," which is derived from the study by Shen, Tao, Lau and Atlas (2010, JGR). http://www.nasa.gov/topics/earth/features/supercomputer-cyclone.html. Shen provided Dr. Lucia Tsaoussi (NASA Headquarters) one slide with the most appropriate figure from the JGR paper referenced in this news story.

The Climate@Home initiative was featured recently in an article by the NASA Chief Information Officer. The Earth Science Division (ESD) and Office of the Chief Information Officer (OCIO) have strategically partnered to manage the Climate@Home initiative. This effort included collaborations between the 10 NASA Centers, the 13 Federal agencies of the USGCRP (United States Global Change Research Program) along with several universities and private organizations. **ROBERT CAHALAN** (Code 613.2) served as the project scientist and assembled an international team of scientists to help set science goals and determine which parameters to run. GSFC's senior advisor to the CIO, Myra Bambacus (Code 700), served as the project manager and has continued to run this initiative. http://www.nasa.gov/offices/ocio/ittalk/08-2010_climate.html

September

The faculty, staff and students of the STEM Collegian Center at Prince Georges Community College visited Goddard and the Climate and Radiation Branch. Scientists from the branch, **CAHALAN, KAHN, ICHOKU**, and **MARSHAK**, gave them a tour of the Earth Science Building and presented lectures on climate and remote sensing problems on September 17.

Nick White (Code 600), **ROBERT CAHALAN** (613.2) and others attended the signing of the NASA/University of Colorado (UCO/LASP) Space Act Agreement in Boulder, Colorado on September 29. This agreement is a partnership between Goddard and the university to promote Sun-climate research, using data from SORCE, SDO, Glory, TSIS, and other Sun-Earth missions.

October

W.-K. TAO (Code 613.0) was invited to give a lecture on reviewing on the developments and applications of the cloud resolving models and at Kyoto University, Japan, on October 4.

W.-K. TAO (Code 613.0) was invited to attend the first international workshop on non-hydrostatic numerical models in Kyoto, Japan. He gave a talk on microphysics developments and their applications for simulating tropical convective systems and typhoons or hurricanes. The co-authors of paper were S. Lang (SSAI/Code 613.1), R. Shi (GEST/Code 613.1), T. Matsui (ESSIC/Code 613.1), X. Zeng (GEST/Code 613.1), J. Chern (GEST/Code 613.1).

SCOTT BRAUN (Code 613.1) gave an invited seminar at the University of Illinois, Urbana-Champaign, on October 6, entitled, "Re-evaluating the Role of the Saharan Air Layer in Atlantic Tropical Cyclone Genesis and Evolution."

JIM IRONS (Code 613.0) gave a presentation, entitled "Remote Sensing of the Chesapeake Bay," on October 19 at a Chesapeake Bay-Focused Environmental Management System Training workshop at GSFC. The workshop was sponsored by the Environmental Protection Agency and hosted by the GSFC environmental protection group. The audience consisted of facility managers for federal facilities located within the Chesapeake Bay watershed. The talk emphasized the use of data from GSFC-managed satellite systems by the interagency Chesapeake Bay Program.

JUDD WELTON (Code 613.1) participated in the inaugural USA Science and Engineering Festival held in Washington, DC on October 23–24. The Festival was created "to re-invigorate the interest of our nation's youth in science, technology, engineering and math (STEM) by producing and presenting the most compelling, exciting, educational and entertaining science gatherings in the United States." Dr. Welton worked at the NASA Earth Science booth and discussed the importance of aerosols and clouds and how they affect climate and air quality. He helped prepare and present displays explaining NASA's Glory mission and existing ground networks: AERONET and MPLNET. The Glory display included a new 1/4 scale model of the Glory spacecraft (with moving parts) and the AERONET and MPLNET display had actual an actual sunphotometer and lidar from each network. More information on the festival is available on the web at http://www.usasciencefestival.org/.

Several members of Code 613.3 attended the A-train symposium in New Orleans the last week of October. The first day of the meeting consisted of a user's workshop. **P.K. BHARTIA, NICK KROTKOV,** and **JOANNA JOINER** made presentations on OMI data products. Other 613.3 members who attended and gave talks or posters include Susan Strahan (invited talk in the plenary session), **BRYAN DUNCAN, JACQUIE WITTE, MARK OLSEN, EDWARD CELARIER, MIAN CHIN, ANNE DOUGLASS,** and Henry Selkirk. Laura Layton (Aura outreach lead) presented talks on Aura to local teachers during a workshop and Joanna Joiner participated in lunches with local teachers. Edward Celarier visited a local school.

CHARLES ICHOKU (Code 613.2) and **CHARLES GATEBE** (Code 613.2/GEST/UMBC), together with Shahid Habib (Code 610.4) and Fritz Policelli (Code 610.4) attended the 8th international conference of the African Association of Remote Sensing of the Environment (AARSE) on October 25–29 in Addis Ababa, Ethiopia, where they gave presentations and met with several African-based scientists to discuss possible collaboration on their current NASA funded IDS–2009 project entitled, "Interactions and Feedbacks Between Biomass Burning and Water Cycle Dynamics across The Northern Sub-Saharan African Region."

November

RALPH KAHN (Code 613.2) gave talks at Pennsylvania State University on November 3 and at Carnegie Mellon University on November 12, entitled "Aerosol Remote Sensing from Space—What We've Learned, Where We're Headed."

A project demonstration, entitled "Recent Advances in Global Hurricane Modeling after Katrina," by **BO-WEN SHEN** (UMCP/ESSIC/Code 613.1) has been chosen as one of four demostrations to be highlighted in various media products for the Supercomputing Conference 2010 (SC10). The products included the news release, letter from the NASA administrator, pre-written articles and backgrounders for the media, and the NASA SC10 Web site. The SC10 was held in New Orleans, Louisiana, November 15–18. The attendance for SC10 drew a crowd of 10,000 people.

December

DAVID WHITEMAN (Code 613.1) served as a judge of 4th grade projects at the Robert Goddard French Immersion School STEM Fair held on December 1, 2010.

The MODIS Snow and Ice Global Mapping Project's Web site (http://modis-snow-ice.gsfc.nasa.gov) launched with a major upgrade and facelift. Ten years of gathering content and displaying it in a manner popular in 1999 left this website looking dated and difficult to navigate and maintain. **BRENT STEES** (613.2/SIGMA), web developer for Codes 613/614, designed and programmed the site upgrade, complete with custom programming language for optimal user experience (e.g., gallery, videos). The site was programmed to be easily retrofitted with a CMS system used with other Code 613/614 Web sites and a quick-switching of the design template without having to recode the content.

ACRONYMS

Acronyms defined and used only once in the text may not be included in this list. Two acronyms, NPP and GMI, have dual definitions. The meaning will be clear from context in this report.

3D	Three Dimensional
7–SEAS	7 South East Asian Studies
ACAM	Airborne Compact Atmospheric Mapper
ACARS	Aircraft Communications Addressing and Reporting System
ACCRI	Aviation Climate Change Research Initiative
ACE	Aerosols, Clouds, and Ecosystems
ACE–FTS	ACE Fourier Transform Spectrometer
ADMIRARI	Advanced Microwave Radiometer for Rain Identification
AERONET	Aerosol Robotic Network
AIRS	Atmospheric InfraRed Sounder
ALVICE	Atmospheric Lidar for Validation, Interagency Collaboration and Education
AMS	American Meteorological Society (?)
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
AMY	Asian Monsoon Years
APS	Aerosol Polarimetry Sensor
ARCTAS	Arctic Research of the Composition of the Troposphere from Aircraft and Satellites
ARPAC	Aerosol, Radiation, and Cloud Processes affecting Arctic Climate
ASCENDS	Active Sensing of CO_2 Emissions over Nights, Days, and Seasons
ASDC	Atmospheric Science Data Center
ATMS	Advanced Technology Microwave Sounder
AVDC	Aura Validation Data Center
BATC	Ball Aerospace and Technologies Corporation
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CASS	Chemical and Aerosol Sounding Satellite
CATS	Cloud-Aerosol Transport System

ACRONYMS

CCM	Chemistry-Climate Modeling
CDR	Critical Design Review
CERES	Cloud and Earth Radiant Energy System
CICS	Cooperative Institute for Climate and Satellites
CIMSS	Cooperative Institute of Meteorological Satellite Studies
CLIVAR	Climate Variability and Predictability Programme
COMBO	Combined Stratospheric-Tropospheric Model
CoSMIR	Conical Scanning Millimeter-wave Imaging Radiometer
COSPAR	Committee on Space Research
CoSSIR	Compact Scanning Submillimeterwave Imaging Radiometer
CPL	Cloud Physics Lidar
CrIS	Cross-track Infrared Sounder
CRS	Cloud Radar System
CTM	Chemical Transport Model
DAAC	Distributed Active Archive Center
DISC	Data and Information Services Center
DoD	Department of Defense
DOE	Department of Energy
DPR	Dual-frequency Precipitation Radar
DSCOVR	Deep Space Climate Observatory
ECWMF	European Centre for Medium-Range Weather Forecasts
EDOP	ER–2 Doppler Radar
EDU	Engineering Design Unit
ENSO	El Niño–Southern Oscillation
EOS	Earth Observatory System
ESA	European Space Agency
ESD	Earth Sciences Division
ESDR	Earth System Data Record

ESM	Exceptional Service Medal
ESSIC	Earth System Science Interdisciplinary Center
FPM	Functional Performance Model
FY	Fiscal Year
GACM	Global Atmospheric Composition Mission
GCE	Goddard Cumulus Ensemble
GEO–CAPE	Geostationary Coastal and Air Pollution Events
GEST	Goddard Earth Sciences and Technology Center
GEWEX	Global Energy and Water Cycle Experiment
GLOBE	Global Learning and Observations to Benefit the Environment
GloPac	Global Hawk Pacific Experiment
GMAO	Global Modeling and Assimilation Office
GMI	GPM Microwave Imager
GMI	Global Modeling Initiative
GOES	Geostationary Operational Environmental Satellites
GPM	Global Precipitation Measurement
GRIP	Genesis and Rapid Intensification Processes
GSFC	Goddard Space Flight Center
GSSP	Graduate Student Summer Program
HDF	Hierarchical Data Format
HIRDLS	High Resolution Dynamics Limb Sounder
HIWRAP	High-Altitude Imaging Wind and Rain Airborne Profiler
HS3	Hurricane and Severe Storm Sentinel
HSRL	High-Spectral-Resolution Lidar
HU	Howard University
HUPAS	Howard University Program in Atmospheric Sciences
HURB	Howard University Research site in Beltsville
IAMAS	International Association of Meteorology and Atmospheric Sciences

ICCP	International Commission on Clouds and Precipitation
ICESat	Ice, Cloud, and land Elevation Satellite
IFLEX	Intensity Forecasting Experiment
IMO	International Meteorological Organization
IPCC	Intergovernmental Panel on Climate Change
IUGG	International Union of Geodesy and Geophysics
JAMEX	Joint Aerosol Monsoon Experiment
JAXA	Japan Aerospace Exploration Agency
JCET	Joint Center for Earth Systems Technology
JCOSS	Joint Center for Observation System Science
JPL	Jet Propulsion Laboratory
JPP	Joint Planning Process
JPSS	Joint Polar Satellite System
LaRC	Langley Research Center
LASP	Laboratory for Atmospheric and Space Physics
LDCM	Landsat Data Continuity Mission
LIS	Lightning Imaging Sensor
LISIRD	LASP Interactive Solar Irradiance Datacenter
LPVEx	Light Precipitation Validation Experiment
MEaSUREs	Making Earth Science Data Records for Use in Research Environments
MISR	Multi-angle Imaging Spectroradiometer
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectroradiometer
MOHAVE	Measurement of Humidity in the Atmosphere and Validation Experiment
MOPITT	Measurement of Pollution in the Troposphere
MPL	Micro Pulse Lidar
MPLNET	Micro-Pulse Lidar Network
MSU	Microwave Sounding Unit

NAAPS	Navy Aerosol Analysis and Prediction System
NAVDAS–AOD	Navy Variational Analysis Data Assimilation System–Aerosol Optical Depth
NCAR	National Center for Atmospheric Research
NCAS	NOAA-Howard University Center for Atmospheric Science
NCEP	National Center for Environmental Prediction
NDACC	Network for the Atmospheric Composition Change
NISTAR	National Institute of Standards
NOAA	National Oceanic and Atmospheric Administration
NOMC	Network Operations Management Center
NPOESS	National Polar Orbiting Environmental Satellite System
NPP	NASA Postdoctoral Program
NPP	NPOESS Preparatory Project
NRC	National Research Council
NSF	National Science Foundation
OGO	Orbiting Geophysical Observatory
OLI	Operational Land Imager
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapping and Profiler Suite
OSSE	Observing System Simulation Experiment
OSTP	Office of Science and Technology Policy
PARSIVEL	Particle Size Velocity
PMC	Polar Mesospheric Cloud
POLDER	Polarization and Directionality of the Earth's Reflectances
PREDICT	Pre-Depression Investigation of Cloud-systems in the Tropics
PUMAS	Practical Uses of Math and Science
RCDF	Radiometric Calibration and Development Facility
ROSES	Research Opportunities in Space and Earth Sciences
SAGE–III	Stratospheric Aerosol Measurement III

ACRONYMS

SBUV	Solar Backscatter Ultraviolet
SCRC	Student Climate Research Campaign
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SG	Study Group
SHADOZ	Southern Hemisphere Additional OZonesondes
SIES	Summer Institute in the Earth Sciences
SIM	Spectral Irradiance Monitor
SMART	Surface-sensing Measurements for Atmospheric Radiative Transfer
SME	Solar Mesosphere Explorer
SOLSTICE	Solar-Stellar Irradiance Comparison Experiment
SORCE	Solar Radiation and Climate Experiment
SPE	Solar Proton Event
SSAI	Science Systems and Applications, Inc.
SSI	Solar Spectral Irradiance
TES	Tropospheric Emission Spectrometer
TIM	Total Irradiance Monitor
TIROS	Television Infrared Observation Satellite
TIRS	Thermal InfraRed Sensor
TOMS	Total Ozone Mapping Spectrometer
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TSI	Total Solar Irradiance
TSIS	Total and Spectral Solar Irradiance Sensor
TWiLiTE	Tropospheric Wind Lidar Technology Experiment
UARS	Upper Atmosphere Research Satellite
UAS	Unmanned Aircraft System
UMBC	University of Maryland, Baltimore County
UMCP	University of Maryland, College Park

UNIX	Uniplexed Information and Computing System
USGS	United States Geological Survey
UV	Ultraviolet
UV/VIS	Ultraviolet and Visible
UV-B	Ultraviolet-B light
VALIDAR	Validation Lidar
VIIRS	Visible Infrared Imaging Radiometer Suite
VIRS	Visible and Infrared Scanner
WACCM	Whole Atmosphere Community Climate Model
WAVES	Water Vapor Validation Experiments Satellite and Sondes
WCRP	World Climate Research Programme
WRF	Weather Research and Forecasting
XPS	X-ray Photoelectron Spectroscopy

ACRONYMS

APPENDIX 1: THE LABORATORY IN THE NEWS

e! Science News

The PARASOL Satellite moving off the A-Train's track

Published: Monday, January 4, 2010 - 17:30

Related images

Ed Hanka

After nearly 5 years of concurrent operations with the Afternoon Constellation, known as the "A-Train," the PARASOL satellite is going on another orbit "track." The A-Train includes a number of NASA satellites that orbit the Earth one behind the other on the same track and until this month, PARASOL has been part of that train. PARASOL is an Earth observation mission, managed by the French Space Agency (CNES). PARASOL stands for "Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar." According to CNES, it was maneuvered to leave its position inside the A-Train at 12:48 UTC, December 2, 2009.

The A-Train satellite formation currently consists of five satellites flying in close proximity: Aqua, CloudSat, CALIPSO, PARASOL and Aura. Each of these satellites cross the equator within a few minutes of each another at around 1:30 p.m. local time. By combining the different sets of nearly simultaneous observations, scientists are able to gain a better understanding its main mission, studying the important parameters related to climate change. As an additional benefit, the A-Train satellites provide unique information about tropical cyclones, the collective term for tropical depressions, tropical storms, hurricanes and typhoons.

The PARASOL satellite has now reached an orbit of 3.9 kilometers (2.4 miles) under the A-train, which will enable it to keep on sharing data periodically with the A-train members, while gradually leaving the A-Train neighborhood. Based on a typical decay of its orbit, it is expected to be completely out of the A-train neighborhood at the end of 2012. The CNES team will continue to coordinate operations with the A-Train Mission Operations Working Group to ensure safety.

PARASOL's measurement of aerosols is based on polarization, so is unique within the existing A-Train. Its departure leaves a data gap that will be filled when Glory (also a polarization spectrometer) launches in 2010. Cross-calibration between Glory and PARASOL, to merge the 2 datasets into a single long-term trending dataset, will take longer with PARASOL in a different orbit.

Steven Platnick, Acting Earth Observing System Project Scientist at NASA Goddard Space Flight Center in Greenbelt, Md. said, "With its novel combination of polarimetry and multiangle capabilities, PARASOL continues to provide a unique and important perspective on cloud and aerosol properties. More important, as a strong complement to other A-Train instruments, POLDER has contributed to an unprecedented data set that will be studied for years to come."

CNES launched PARASOL into the A-Train orbit in December 2004. For the past five years, PARASOL, originally designed to be a 2-year mission, flew within ~30 seconds of the CALIPSO and CloudSat satellites.

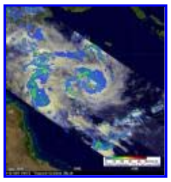
Source: NASA/Goddard Space Flight Center

e! Science News

NASA's TRMM Satellite sees Zelia born of System 94P

Published: Friday, January 14, 2011 - 17:01 in Earth & Climate

Related images



SSAI/NASA, Hal Pierce

The low pressure area known as System 94P on January 13 strengthened into the seventh tropical cyclone of the South Pacific Cyclone season, today becoming Tropical Storm Zelia. NASA's TRMM satellite found heavy rainfall was already occurring in the storm as it was turning away from New Zealand and heading toward New Caledonia. New Caledonia just dealt with Tropical Storm Vince today, and is expecting to feel winds and rains from Tropical Storm Zelia as it passes to the southwest of the island group this weekend.

The Tropical Rainfall Measuring Mission (TRMM) satellite, managed by NASA and the Japanese Space Agency flew over Tropical Storm Zelia on January 14 at 0417 UTC (Jan. 13 at 11:17 p.m. EST). TRMM noticed that the heaviest rainfall (falling at about 2 inches/50 mm per hour) appeared to be on the northwestern and southwestern sides of the storm.

TRMM images are pretty complicated to create. They're made at NASA's Goddard Space Flight Center in Greenbelt, Md. At Goddard, rain rates in the center of the swath (the satellite's orbit path over the storm) are created from the TRMM Precipitation Radar (PR) instrument. The TRMM PR is the only space borne radar of its kind. The rain rates in the outer portion of the storm are created from a different instrument on the satellite, called the TRMM Microwave Imager (TMI). The rain rates are then overlaid on infrared (IR) data from the TRMM Visible Infrared Scanner (VIRS). For more information about TRMM, visit: http://www.trmm.gsfc.nasa.gov/.

Infrared satellite imagery shows strong convection (rapidly rising air that condenses and forms the thunderstorms that power the tropical cyclone) consolidating over the western quadrant and near the center. The storm appears well-organized as bands of thunderstorms wrapping around the center were also evident in satellite imagery.

At 1500 UTC (10 a.m. EST/ 2 a.m. on Jan. 15, Pacific/Noumea local time) Tropical Storm Zelia had maximum sustained winds near 55 knots (63 mph/101 km/hr) with higher gusts. Zelia's center was located about 860 nautical miles north of Brisbane, Australia near 13.4 South and 152.3 East. Zelia is moving southeastward near 9 knots (10 mph/~16 km/hr).

The Joint Typhoon Warning Center expects Zelia to continue moving in a general southeastern direction and strengthen into a cyclone before becoming extra-tropical.

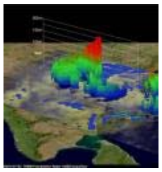
Source: NASA/Goddard Space Flight Center

e! Science News

NASA sees one of Cyclone Laila's thunderstorms almost 11 miles high

Published: Friday, May 21, 2010 - 15:11

Related images



NASA/SSAI, Hal Pierce

D look inside Cyclone Laila as it made landfall yesterday revealed a towering thunderstorm reaching almost 11 miles high! NASA's Tropical Rainfall Measuring Mission (TRMM) satellite has been capturing images of Cyclone Laila since it was born in the Northern Indian Ocean as tropical depression 1A earlier this week. Scientists at NASA can use TRMM data to provide meteorologists a 3-D look at the storm's cloud heights and rainfall, which are extremely helpful in forecasting.

"One of the interesting capabilities of the TRMM satellite is its ability to see through clouds with its Precipitation Radar (PR) and reveal the 3-D structure within storms such as Cyclone Laila," said Hal Pierce, on the TRMM mission team in the Mesoscale Atmospheric Processes Branch at NASA's Goddard Space Flight Center, Greenbelt, Md.

Pierce created a 3-D image of Laila. He used data captured on May 20 when TRMM also got a "top down" view of the storm's rainfall, and created a 3-D image that shows thunderstorm tops reaching to almost 17.5 kilometers (10.8 miles) high in the eastern side of the storm!

Laila brought nine-foot high waves and very heavy rains before it made landfall near the town of Bapatla which lies on the southeast coast of India. The Associated Press reports that 23 deaths have been attributed to the storm. Meanwhile, state officials reported widespread damage, downed trees, power outages, and flooding.

On May 21 at 1200 UTC (8 a.m. EDT), Laila had weakened into a depression as a result of tracking over the rugged terrain of southeastern India. At 8 a.m. EDT Laila's maximum sustained winds had waned to near 38 mph. It was located about 115 nautical miles west-southwest of Visakhapatnam, India and headed in that direction. It was moving north-northeast near 6 mph (5 knots). Widespread heavy rain and gusty winds can be expected from Andhra Pradesh today, and to areas northeast through the weekend as Laila tracks in that direction. For the most recent updates on Laila, go to the India Meteorological Department web site at: www.imd.gov.in/.

Laila is now a depression and is forecast to track in a northeasterly direction over the weekend, bringing moderate to heavy rains to the northeastern coast of India, as it heads to Bangladesh. The Joint Typhoon Warning Center expects Laila's remnants to emerge over the northern Bay of Bengal, intensify slightly and then dissipate before reaching southeastern Bangladesh. Forecasters will be keeping a close eye on the storm over the weekend.

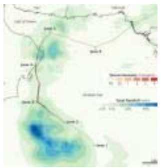
Source: NASA/Goddard Space Flight Center

e! Science News

NASA'S TRMM Satellite provides rainfall estimate for Cyclone Phet

Published: Tuesday, June 8, 2010 - 16:52

Related images



NASA /Jesse Allen

The Tropical Rainfall Measuring Mission satellite, known as TRMM is a "flying rain gauge" in space, and can provide rainfall estimates from its position in orbit around the Earth. Data accumulated from TRMM enabled visualizers to create a map of rainfall generated by Cyclone Phet as it marched through the Arabian Sea from May 31 to June 6. The heaviest rainfall occurred over open waters, but Phet dropped very heavy rainfall over parts of Oman and Pakistan. TRMM satellite rainfall data estimated Cyclone Phet's heaviest rainfall (600 or more millimeters/23.6 or more inches) occurred over open waters of the Arabian Sea. One area of northeast Oman received as much as 450 millimeters (17.7 inches), while Pakistan received between 150-300 millimeters/ 5.9-11.8 inches as Phet made landfall there this past weekend.

NASA's Jesse Allen created a rainfall image is based on data from the Multi-satellite Precipitation Analysis (MPA) produced at NASA's Goddard Space Flight Center in Greenbelt, Md. The image showed both rainfall amounts and the storm track for Phet from May 31 to June 6, 2010. The MPS analysis estimates rainfall by combining measurements from many satellites and calibrating them using rainfall measurements from the Tropical Rainfall Measuring Mission (TRMM) satellite.

Tropical Cyclone Phet brought not just strong winds but also heavy rains to the Arabian Sea, the Arabian Peninsula, and the coast of Pakistan in late May and early June. Phet reached its greatest intensity off the coast of Oman on June 3. After making landfall in Oman, Phet dissipated somewhat, but remained organized enough to move back over the Arabian Sea toward Pakistan.

Source: NASA/Goddard Space Flight Center

Science News

NASA Releases GOES-13 Satellite Movie of the Life and Times of Hurricane Alex

ScienceDaily (July 14, 2010) — NASA's GOES Project has just released a "movie" of satellite imagery showing the life and times of 2010's only June hurricane. From birth to death, the GOES-13 satellite kept an eye on the life and times of Hurricane Alex for two weeks in June, 2010.

Hurricane Alex struggled for life for two weeks in June 2010, and the Geostationary Operational Environmental Satellite (GOES) known as GOES-13 captured satellite images of the storm. Those satellite images were compiled into an animation by Dr. Dennis Chesters of NASA's GOES Project at NASA's Goddard Space Flight Center in Greenbelt, Md. "The animation is an example of one of the tropical-storm-in-ten which bloom into a hurricane," Chesters said.

GOES-13 is operated by the National Oceanic and Atmospheric Administration, and images are created by NASA's GOES Project, located at NASA's Goddard Space Flight Center, Greenbelt, Md.

Satellites like GOES-13 provide a great research tool for forecasters by showing where and how a tropical depression forms and where it tracks during its brief lifetime. GOES-13 captured Alex from its birth on Friday, June 25 at 6 p.m. EDT when "System 93L" developed into the first tropical depression of the Atlantic Ocean hurricane season. At 5 a.m. EDT on Saturday, June 26 that Tropical Depression One strengthened into a tropical storm and was named Alex. Tropical Storm Alex intensified by 11 p.m. EDT on June 29 and became the first hurricane of the 2010 Atlantic Ocean Hurricane Season.

Alex made landfall at 10 p.m. EDT in northeastern Mexico, about 110 miles south of Brownsville, Texas. By 8 a.m. EDT on July 1, Alex has weakened to a tropical storm and GOES satellite imagery showed it moving near the high mountains of Mexico. GOES-13 satellite imagery followed Alex's remnants as they moved inland over northeastern Mexico and southern Texas in the days following.

The first Atlantic Ocean basin hurricane of the season proved fatal to at least 30 people. Alex's heavy rainfall flooded towns, created mudslides, caused waterways to overflow and broke records.

To access and download the movie: http://goes.gsfc.nasa.gov/text/goes13results.html

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Story Source:

The above story is reprinted (with editorial adaptations by Science*Daily* staff) from materials provided by **NASA/Goddard Space Flight Center**, via EurekAlert!, a service of AAAS.

Find this article at:

http://www.nasa.gov/mission_pages/hurricanes/missions/grip/news/earl-update-430pm-et.html

APPENDIX 1: THE LABORATORY IN THE NEWS

The Telegraph - Calcutta (Kolkata) | Nation | Delhi shrugs off soot label

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Today's Edition | Thursday , December 9 , 2010 |

Front Page > Nation > Story

Delhi shrugs off soot label

JAYANTA BASU

Cancun (Mexico), Dec. 8: India is resisting attempts by European Union and US negotiators at the UN climate change conference here to add soot particles into the list of greenhouse gases implicated in altering the world's climate.

The attempts by the EU and the US follow scientific studies, including one by the US National Aeronautics and Space Administration last year, that have suggested that the Indo-Gangetic plain has become a hotspot for emissions of soot, also called black carbon.

The NASA study had suggested that winds can push black carbon and dust, which absorb heat from sunlight, towards the base of the Himalayas where they can accumulate and contribute as much or even more to global warming than greenhouse gases.

But India is opposing efforts to label black carbon as another "greenhouse gas".

"We will not allow black carbon to be included in the list of greenhouse gases as demanded by some negotiators," India's environment minister Jairam Ramesh said, adding that India is responsible for only four per cent of global black carbon production.

However, Ramesh said, India has decided to launch a national programme to monitor, model and measure black carbon. This exercise, expected to begin around mid-December this year, will make use of international scientific expertise, he said.

"In our case, it is less about climate change and more about public health, though its effect on the Himalayan glaciers remains a concern," the minister said. Old diesel vehicles and the traditional clay-and-oven stoves are among sources of black carbon in India.

Last year, NASA scientists have observed that rapid melting of snow in the western Tibetan plateau that begins each year in April and extends to October coincides with the time when concentrations of black carbon and dust transported from India and Nepal are most dense in the atmosphere. Over some areas of the Himalayas, the rate of warming is more than five times faster than warming globally, William Lau, a senior NASA scientist had said.

Early this year, physicist Surabi Menon at the Lawrence Berkeley National Laboratory and her collaborators had reported that airborne black carbon from India is a major contributor to the decline in the snow and ice cover on the Himalayan glaciers.

Studies suggest that the amount of black carbon emissions from India and China have climbed dramatically over the past few decades -- almost in tandem with the economic growth in the two countries.

Ramesh said India hopes to begin using satellites to monitor greenhouse gases as well as black carbon from 2012 onwards.

Emissions report

The world appears heading towards spewing at least five gigatonnes extra carbon dioxide than the benchmark level required to prevent the Earth warming beyond 2 C, a report from the United Nations Environment Programme has revealed.

The UNEP report tabled today here at the UN climate conference has computed the impacts of all cuts and curbs of emissions pledged at a similar meet in Copenhagen last year and found that under the best scenario, the world will overshoot the required target by five gigatonnes.

“Compared to what was pledged in Copenhagen, another 40 per cent increase of emissions cuts is required to keep the temperature rise to 2 degree C -- and every body has to contribute” said Achim Steiner, UNEP’s executive director.

Negotiations still fluid

With ministerial meetings just beginning at the conference, the status remains fluid though various leaders have expressed hope for a "legally non-binding but a forward looking treaty emerging from Cancun.

"I do not expect governments to reach an all encompassing global agreement in Cancun, but we need to see progress in all fronts -- climate adaptation, protecting forests, technology and some elements of finance," said UN secretary general Ban Ki Moon.

And there have been some movements in various sectors. A technical team has reached an overall agreement on how climate-friendly technologies could be shared across countries. The US has agreed to contribute to a "green fund" -- beyond whatever it pledged at Copenhagen.

But many negotiators fear that these advances may be undone if the conference adopts an "all-or-none" approach -- meaning all decisions are linked to each other. With no agreement on the future of the Kyoto Protocol -- the international treaty that legally binds industrialised countries to emissions cuts -- this kind of a linked decision-making could prove to be a dampener, negotiators said.

“It seems the challenge to the political negotiators over the next few days is to delink the contentious issues for future dialogue and take decisions wherever there is agreement” said a senior bureaucrat of Mexico.

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Retreating Mountain Glaciers Pose Freshwater Shortage

Climate's influence on Himalayan glaciers is still a looming concern for many scientists and governments, which
about how warming will affect the region's water cycle

By Lauren Morello and Climatewire | Wednesday, December 8, 2010

Norway said yesterday it will spend $12 million to expand monitoring of Himalayan glaciers and help the region's communities
climate change.

The Hindu Kush-Himalayas Climate Impact Adaptation Assessment Programme will run for five years, carried out by Norway's
for International Climate and Environmental Research, the U.N. Environment Programme and the Katmandu, Nepal-based
International Centre for Integrated Mountain Development.

"The overarching theme is people plagued by either too much or too little water in these regions," said Bjorn Brede Hansen, de
director-general of the Section for Environment and Sustainable Development within Norway's Ministry of Foreign Affairs. "Th
really the framework for everything -- agriculture, livelihoods ... [the role of] women."

Himalayan glaciers are sometimes referred to as Earth's "third pole" because they supply fresh water to communities througho
Southeast Asia. Roughly 210 million people live in the region, and another 1.3 billion people who live downstream depend on ri
in part by glaciers and mountain snowpack.

The plight of Himalayan glaciers briefly dominated news headlines last year, after news broke that the Intergovernmental Panel
Climate Change erred by stating the region's ice could disappear by 2035, instead of 2350. But while the IPCC bungled its numb
climate's influence on Himalayan glaciers is still a looming concern for many scientists and governments, which worry about ho
warming will affect the region's water cycle.

Yesterday, the U.N. Environment Programme said the majority of glaciers in the Hindu Kush-Himalayas and on the Tibetan Pla
retreating, with some exceptions. Some glaciers in the Karakoram mountains, for example, recently advanced into areas that ha
ice-free for a half-century. But in the northern Karakoram, in China, glaciers are receding. The thaw there is increasing the freq
glacial lake outburst floods, or "glofs," caused by runoff that forms into lakes that burst suddenly and inundate nearby areas.

Major risks for nearby communities

"We need to get the numbers right on [Himalayan] glaciers," Madhav Karki, deputy director of general programs at the Interna
Centre for Integrated Mountain Development, said yesterday at a news conference in Cancun, Mexico, at U.N. climate talks. "Th
that glaciers are retreating. Some are advancing, but by and large, they are retreating, and we need to study them. And they are
important element in our future adaptation."

That point is underscored in a recent report by the U.S. Agency for International Development, which last month warned that e
relatively slow shrinking of Himalayan glaciers presents major risks for nearby communities and those that depend on rivers fe
alpine ice.

"Even small changes in glacier melt will result in large impacts downstream from High Asia," the USAID report cautioned.

But efforts to understand the interplay between the climate and the glaciers are hampered by a lack of data. Scientists have data specific glaciers and are able to pick out some trends, but the information is too sparse to paint a clear picture of how fast glacie melting throughout the region -- sometimes, even within a single mountain range -- and how that compares to how they behave past.

Part of the problem is reaching glaciers that sit at high altitudes. The most-studied Himalayan glaciers are largely the most acce often those at lower altitudes, the USAID report said.
High-altitude puzzles

That's crucial because glaciers at the highest altitudes, where temperatures are more likely to stay below freezing, are behaving differently than their counterparts at lower elevations. For glaciers that extend from low to high elevation, measurements taken low end -- the glacier's "snout" -- may not tell scientists much about how the same ice sheet is behaving higher up the mountain

Scientists are also trying to figure out the role that aerosol particles -- including a component of soot known as black carbon -- p influencing the behavior of Himalayan glaciers.

William Lau, who heads the atmospheric science laboratory at NASA's Goddard Space Flight Center, says his research suggests carbon could rival greenhouse gases as a cause of warming in the Himalayas.

Particles of black carbon absorb heat from the sun, warming the atmosphere. When black carbon lands on white ice or snow, it a glacier's ability to reflect sunlight -- adding another source of heat to the mix.

"Up to now, most people thought, 'OK, greenhouse warming is the reason these high mountain glaciers are moving faster,'" he s "But another possibility is a contribution from the black carbon and other absorbing aerosols, including dust."

Still, he said, "we're not saying global warming is not important."

Reporters Lisa Friedman and Jean Chemnick contributed from Cancun, Mexico.

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Feature

GOES-13 Satellite Captures Powerful Snowmaker Leaving New England **12.27.10**

Snows are finally winding down in New England today, Dec. 27, as a powerful low pressure system brought blizzard conditions from northern New Jersey to Maine over Christmas weekend. The GOES-13 satellite captured an image of the low's center off the Massachusetts coast and saw the snowfall left behind.

The Geostationary Operational Environmental Satellite called GOES-13 captured the visible image. GOES satellites are operated by the National Oceanic and Atmospheric Administration, and NASA's GOES Project, located at NASA's Goddard Space Flight Center, Greenbelt, Md. creates some of the GOES satellite images and animations.

As of 1:30 p.m. EST, all blizzard warnings were canceled as the low has pulled much of its snow and rain away from land areas and into the North Atlantic Ocean. The winds behind the system are now causing more problems for residents along the U.S. East coast.

Snowfall ranged from 1.5 inches in Atlanta, Georgia to more than a foot in various areas of New Jersey, New York and the New England states. Near Wallops Island, Va. where NASA has a facility, more than 11 inches of snow was reported this morning. Newark, N.J. reported 17.7 inches of snow by midnight last night. Central Park in New York City reported 12.0 inches of snow had fallen just before midnight. Providence, Rhode Island reported 7.9 inches by midnight, while Boston, Mass. reported 9.9 inches at that time. More snow fell on top of those totals during the morning hours today.


On Monday, December 27 at 1731 UTC (12:31 p.m. EST) the GOES-13 satellite captured this visible image of the powerful low pressure system that brought snows from Georgia to Maine along the U.S. east coast. Some of the snowfall can be seen over South and North Carolina, Virginia, Maryland, Delaware, eastern Pennsylvania, New Jersey, and southeastern New York. The clouds of the low obscure New England in the image.
Credit: NOAA/NASA GOES Project
› Larger image

Some of those snows are visible in today's GOES-13 satellite image. Snowfall on the ground can be seen in the image over South and North Carolina, Virginia, Maryland, Delaware, eastern Pennsylvania, New Jersey, and southeastern New York. The clouds of the low obscure New England in the image.

From Maine south to the Carolinas winds are howling in excess of 30 mph, and power outages could occur as a result of the winds and the areas with the heaviest snows. The winds in Portland, Maine today are blowing from the northwest from 20 to 30 mph with gusts over 40 mph. Yesterday in Newark, N.J. sustained winds of 41 mph were reported with gusts as high as 51 mph. Going further south, the Raleigh, N.C. National Weather Service noted that sustained northwest winds of 10 to 20 mph with gusts up to 30 mph are expected today. Even further south, Atlanta, Georgia is also experiencing winds up to 20 mph today.

The winds are making clean-up efforts difficult along the east coast, but as temperatures are expected to slowly and steadily climb over the course of the week travel will become easier every day.

Rob Gutro
*NASA's **Goddard Space Flight Center,** Greenbelt, Md.*

Find this article at:

http://www.nasa.gov/centers/goddard/news/features/2010/goes13-snow.html

APPENDIX 2. REFEREED ARTICLES

Laboratory members' names are in boldface.

Code 613 2010 Publications

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APPENDIX 2: REFERREED ARTICLES

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APPENDIX 3. HIGHLIGHTED ARTICLES PUBLISHED IN 2010

Code 613.1 Highlighted Articles

Reevaluating the Role of the Saharan Air Layer in Atlantic Tropical Cyclogenesis and Evolution

SCOTT A. BRAUN

Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland

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ABSTRACT

The existence of the Saharan air layer (SAL), a layer of warm, dry, dusty air frequently present over the tropical Atlantic Ocean, has long been appreciated. The nature of its impacts on hurricanes remains unclear, with some researchers arguing that the SAL amplifies hurricane development and with others arguing that it inhibits it. The potential negative impacts of the SAL include 1) vertical wind shear associated with the African easterly jet; 2) warm air aloft, which increases thermodynamic stability at the base of the SAL; and 3) dry air, which produces cold downdrafts. Multiple NASA satellite datasets and NCEP global analyses are used to characterize the SAL's properties and evolution in relation to tropical cyclones and to evaluate these potential negative influences. The SAL is shown to occur in a large-scale environment that is already characteristically dry as a result of large-scale subsidence. Strong surface heating and deep dry convective mixing enhance the dryness at low levels (primarily below ~700 hPa), but moisten the air at midlevels. Therefore, mid- to-upper-level dryness is not generally a defining characteristic of the SAL, but is instead often a signature of subsidence. The results further show that storms generally form on the southern side of the jet, where the background cyclonic vorticity is high. Based upon its depiction in NCEP Global Forecast System meteorological analyses, the jet often helps to form the northern side of the storms and is present to equal extents for both strengthening and weakening storms, suggesting that jet-induced vertical wind shear may not be a frequent negative influence. Warm SAL air is confined to regions north of the jet and generally does not impact the tropical cyclone precipitation south of the jet.

Composite analyses of the early stages of tropical cyclones occurring in association with the SAL support the inferences from the individual cases noted above. Furthermore, separate composites for strongly strengthening and for weakening storms show few substantial differences in the SAL characteristics between these two groups, suggesting that the SAL is not a determinant of whether a storm will intensify or weaken in the days after formation. Key differences between these cases are found mainly at upper levels where the flow over strengthening storms allows for an expansive outflow and produces little vertical shear, while for weakening storms, the shear is stronger and the outflow is significantly constrained.

1. Introduction

Synoptic outbreaks of Saharan dust occur from late spring to early fall and can extend from western Africa across the tropical Atlantic Ocean to the Caribbean (Prospero et al. 1970; Prospero and Carlson 1970, 1972). The dust is carried predominantly westward within the Saharan air layer (SAL), which is formed by strong surface heating as westward-moving air crosses the Saharan desert. The heating produces a deep well-mixed layer with warm temperatures and low relative humidity (RH) at low levels. As the warm, dry air moves off the African coast, it is undercut by cooler, moister air to form the elevated SAL (Karyampudi and Carlson 1988). The vertical thermodynamic structure over the Atlantic consists of a well-mixed marine boundary layer capped by the trade wind inversion near 850 hPa, where the SAL begins (Carlson and Prospero 1972; Diaz et al. 1976; Prospero and Carlson 1981; Karyampudi and Carlson 1988; Karyampudi et al. 1999; Karyampudi and Pierce 2002). The SAL extends from ~800 to 550 hPa near the coast of Africa and is characterized by nearly constant potential temperature and vapor mixing ratio (Carlson and Prospero 1972; Karyampudi and Carlson 1988). The base of the SAL rises while the top of the SAL slowly sinks to the west. Temperatures near the top of the SAL

Corresponding author address: Dr. Scott A. Braun, NASA GSFC, Mail Code 613.1, Greenbelt, MD 20771.
E-mail: scott.a.braun@nasa.gov

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SPECIAL
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Characteristics of Deep Tropical and Subtropical Convection from Nadir-Viewing High-Altitude Airborne Doppler Radar

GERALD M. HEYMSFIELD
NASA Goddard Space Flight Center, Greenbelt, Maryland

LIN TIAN
GEST, University of Maryland, Baltimore County, Baltimore, Maryland

ANDREW J. HEYMSFIELD
National Center for Atmospheric Research, Boulder, Colorado

LIHUA LI
NASA Goddard Space Flight Center, Greenbelt, Maryland

STEPHEN GUIMOND
Department of Meteorology, The Florida State University, Tallahassee, Florida

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ABSTRACT

This paper presents observations of deep convection characteristics in the tropics and subtropics that have been classified into four categories: tropical cyclone, oceanic, land, and sea breeze. Vertical velocities in the convection were derived from Doppler radar measurements collected during several NASA field experiments from the nadir-viewing high-altitude ER-2 Doppler radar (EDOP). Emphasis is placed on the vertical structure of the convection from the surface to cloud top (sometimes reaching 18-km altitude). This unique look at convection is not possible from other approaches such as ground-based or lower-altitude airborne scanning radars. The vertical motions from the radar measurements are derived using new relationships between radar reflectivity and hydrometeor fall speed. Various convective properties, such as the peak updraft and downdraft velocities and their corresponding altitude, heights of reflectivity levels, and widths of reflectivity cores, are estimated. The most significant findings are the following: 1) strong updrafts that mostly exceed 15 m s^{-1}, with a few exceeding 30 m s^{-1}, are found in all the deep convection cases, whether over land or ocean; 2) peak updrafts were almost always above the 10-km level and, in the case of tropical cyclones, were closer to the 12-km level; and 3) land-based and sea-breeze convection had higher reflectivities and wider convective cores than oceanic and tropical cyclone convection. In addition, the high-resolution EDOP data were used to examine the connection between reflectivity and vertical velocity, for which only weak linear relationships were found. The results are discussed in terms of dynamical and microphysical implications for numerical models and future remote sensors.

1. Introduction

Measurements of updraft characteristics are important for understanding fundamental kinematic and microphysical processes in deep convection. These measurements are often difficult to obtain from in situ observations because of the transient nature of updrafts and the safety concerns arising from aircraft penetrating convective cores. Consequently, there have been relatively few comparisons between numerically simulated and measured vertical motions through the full depth of deep convective updrafts to evaluate model accuracy (e.g., Lang et al. 2007). Emphasis in recent years on global estimates of tropical latent heating from radar and microwave

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Corresponding author address: Gerald M. Heymsfield, Goddard Space Flight Center, Code 613.1, Greenbelt, MD 20771.
E-mail: gerald.heymsfield@nasa.gov

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The TRMM Multi-Satellite Precipitation Analysis (TMPA)

George J. Huffman, Robert F. Adler, David T. Bolvin, and Eric J. Nelkin

Abstract The Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) is intended to provide a "best" estimate of quasi-global precipitation from the wide variety of modern satellite-borne precipitation-related sensors. Estimates are provided at relatively fine scales (0.25° × 0.25°, 3-h) in both real and post-real time to accommodate a wide range of researchers. However, the errors inherent in the finest scale estimates are large. The most successful use of the TMPA data is when the analysis takes advantage of the fine-scale data to create time/space averages appropriate to the user's application. We review the conceptual basis for the TMPA, summarize the processing sequence, and focus on two new activities. First, a recent upgrade for the real-time version incorporates several additional satellite data sources and employs monthly climatological adjustments to approximate the bias characteristics of the research quality post-real-time product. Second, an upgrade for the research quality post-real-time TMPA from Versions 6 to 7 (in beta test at press time) is designed to provide a variety of improvements that increase the list of input data sets and correct several issues. Future enhancements for the TMPA will include improved error estimation, extension to higher latitudes, and a shift to a Lagrangian time interpolation scheme.

Keywords Precipitation · Satellite · Remote sensing · TRMM · GPM

1 Introduction

As elaborated elsewhere in this book, precipitation is a critical weather element for determining the habitability of different parts of the Earth, yet is difficult to measure adequately with surface-based instruments due to its small-scale variability in

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G.J. Huffman (✉)
Laboratory for Atmospheres, NASA/GSFC, Code 613.1, Greenbelt, MD 20771, USA
e-mail: george.j.huffman@nasa.gov

M. Gebremichael, F. Hossain (eds.), *Satellite Rainfall Applications for Surface Hydrology*, DOI 10.1007/978-90-481-2915-7_1, Quarterly Journal of the Royal Meteorological Society   *Q. J. R. Meteorol. Soc.* 136: 382–399, January 2010 Part B

Improving a spectral bin microphysical scheme using TRMM satellite observations

Xiaowen Li,[a,b]* Wei-Kuo Tao,[b] Toshihisa Matsui,[a,b] Chuntao Liu[c] and Hirohiko Masunaga[d]

[a]*Goddard Earth Science and Technology Center, University of Maryland, Baltimore, Maryland, USA*
[b]*Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA*
[c]*Department of Meteorology, University of Utah, Salt Lake City, Utah, USA*
[d]*Hydrospheric Atmospheric Research Centre, Nagoya University, Nagoya, Japan*
*Correspondence to: Xiaowen Li, Code 613.1, NASA/GSFC, Greenbelt, MD 20770, USA. E-mail: xli@agnes.gsfc.nasa.gov

TRMM-observed mature-stage squall lines during late spring and early summer in the central USA over a 9-year period are compiled and compared with a case simulation by the Goddard Cumulus Ensemble (GCE) model with a spectral bin microphysical scheme. During the quasi-steady state of the simulation, a forward radiative transfer model calculates TRMM Precipitation Radar (PR) reflectivity and 85 GHz brightness temperatures from simulated particle size distributions. Comparisons between model and TRMM observations using radar Contoured Frequency with Altitude Diagrams (CFADs) and 85 GHz brightness temperature probability density distributions are performed, in addition to CFADs from a surface C-band radar for the same case. Radar CFADs comparisons reveal that the model overestimates sizes of snow/aggregates in the stratiform region.

Three sets of sensitivity tests are carried out in order to improve the simulated radar reflectivity profiles: increase of aggregates' density and terminal fall velocity; changing temperature dependency of collection efficiency between ice-phase particles, particularly those of the plate-type; and adding a break-up scheme for large aggregates. While all three approaches mitigate the discrepancies, changing collection efficiency produces the best match in magnitudes and characteristics of radar CFADs. In addition, interactions between ice- and water-phase particles also need to be adjusted in order to have good comparisons in both radar CFADs and 85 GHz brightness temperature distributions. This study shows that long-term satellite observations, especially those with multiple sensors, can be very useful in constraining model microphysics.

Key Words: cloud-resolving model; squall line; microphysics

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1. Introduction

Proper representation of cloud and precipitation microphysics is one of the major challenges in cloud modelling and quantitative precipitation forecasting (e.g. Stoelinga *et al.*, 2003). Simple (one-moment) bulk microphysical schemes (e.g. Srivastava, 1967; Kessler, 1969; Cotton *et al.*, 1982; Lin *et al.*, 1983; Rutledge and Hobbs, 1984) have been used in cloud and mesoscale modelling for decades. There are numerous studies validating and improving bulk microphysical schemes (e.g. Tao and Simpson, 1989; McCumber *et al.*, 1991; Meyers *et al.*, 1992; Krueger *et al.*,

IN BOX
INSIGHTS and INNOVATIONS

Satellite Data Simulator Unit

A Multisensor, Multispectral Satellite Simulator Package

by Hirohiko Masunaga, Toshihisa Matsui, Wei-kuo Tao, Arthur Y. Hou, Christian D. Kummerow, Teruyuki Nakajima, Peter Bauer, William S. Olson, Miho Sekiguchi, and Takashi Y. Nakajima

Since the earliest meteorological satellites were sent into orbit in the 1960s, satellite remote sensing has been the vital means to monitor clouds and precipitation uniformly across the Earth. Present-day spaceborne remote sensors have great variety in terms of spectral range (visible, infrared, and microwave) and measuring principle (active and passive), each of which has its own strengths and limitations. Satellite imagers equipped with visible and infrared channels are an optimal instrument for deriving cloud-top height and optical thickness, while microwave radiometry is sensitive to the whole cloud column, providing more of a physical link to the underlying rainfall structure. Microwave radiometers, however, typically have a spatial resolution as low as 50 km at the lowest microwave frequencies (e.g., 6 and 10 GHz) and do not resolve the vertical structure of atmospheric constituents. Two spaceborne radars—the TRMM PR and CloudSat CPR (expansions of all acronyms are listed at the end of the article)—launched within the last decade literally added a new dimension to cloud and precipitation measurements from space. The increasing variety of satellite sensors has greatly expanded the applicability of satellite data, particularly when different sensors are combined to exploit the information content beyond the capability of an individual sensor. Multisensor data analyses vastly enrich the quality (and quantity) of data to be processed, requiring sophisticated analysis software that helps us interpret the observations. Potentially useful for this purpose is a multisensor satellite simulator, or a computer program to derive synthetic measurements for various satellite instruments computed with given meteorological parameters virtually representing the atmospheric and ground state.

AFFILIATIONS: Masunaga—Hydrospheric Atmospheric Research Center, Nagoya University, Nagoya, Japan; Matsui, Tao, Hou, and Olson—NASA Goddard Space Flight Center, Greenbelt, Maryland; Kummerow—Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado; Te. Nakajima—Atmosphere and Ocean Research Institute, University of Tokyo, Chiba, Japan; Bauer—European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom; Sekiguchi—Faculty of Marine Technology, Tokyo University of Marine Science and Technology, Tokyo, Japan; Ta. Y. Nakajima—Research and Information Center, Tokai University, Tokyo, Japan
CORRESPONDING AUTHOR: Hirohiko Masunaga, Hydrospheric Atmospheric Research Center, Nagoya University, F3-1(200) Furocho Chikusa-ku, Nagoya 464-8601, Japan
E-mail: masunaga@hyarc.nagoya-u.ac.jp

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Several multisensor simulator packages are being developed by different research groups across the world. Such simulator packages [e.g., COSP (http://cfmip.metoffice.com/COSP.html), CRTM (www.star.nesdis.noaa.gov/smcd/spb/CRTM), ECSIM (Voors et al. 2007), RTTOV (Matricardi et al. 2004; Bauer et al. 2006), ISSARS (under development, Tanelli 2009), and SDSU (this article), among others] share overall aims, although some are targeted more on particular satellite programs or specific applications (for research purposes or for operational use) than others. The SDSU or Satellite Data Simulator Unit is a general-purpose simulator composed of Fortran 90 codes and applicable to spaceborne microwave radiometer, radar, and visible/infrared imagers including, but not limited to, the sensors listed in Table 1. Table 1 shows satellite programs particularly suitable for multisensor data analysis: some are single satellite missions carrying two or more instruments, while others are constellations of satellites flying in formation. The TRMM and A-Train are ongoing satellite missions carrying diverse sensors that observe clouds and precipitation, and will be continued or augmented within the decade to come by future multisensor missions such as the GPM and EarthCARE. The ultimate goals of these present and proposed satellite programs are not restricted to clouds

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Influence of Arctic sea ice extent on polar cloud fraction and vertical structure and implications for regional climate

Stephen P. Palm,[1] Sara T. Strey,[2] James Spinhirne,[3] and Thorsten Markus[4]

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[1] Recent satellite lidar measurements of cloud properties spanning a period of 5 years are used to examine a possible connection between Arctic sea ice amount and polar cloud fraction and vertical distribution. We find an anticorrelation between sea ice extent and cloud fraction with maximum cloudiness occurring over areas with little or no sea ice. We also find that over ice-free regions, there is greater low cloud frequency and average optical depth. Most of the optical depth increase is due to the presence of geometrically thicker clouds over water. In addition, our analysis indicates that over the last 5 years, October and March average polar cloud fraction has increased by about 7% and 10%, respectively, as year average sea ice extent has decreased by 5%–7%. The observed cloud changes are likely due to a number of effects including, but not limited to, the observed decrease in sea ice extent and thickness. Increasing cloud amount and changes in vertical distribution and optical properties have the potential to affect the radiative balance of the Arctic region by decreasing both the upwelling terrestrial longwave radiation and the downward shortwave solar radiation. Because longwave radiation dominates in the long polar winter, the overall effect of increasing low cloud cover is likely a warming of the Arctic and thus a positive climate feedback, possibly accelerating the melting of Arctic sea ice.

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1. Introduction

[2] In recent years, much attention has been given to the Arctic because of its sensitivity to climate change. Evidence of change has been seen at an accelerating rate over the last decade or more. Surface temperatures, though scarce in the Arctic, show a 1°C–2°C increase over the last 20 years [*Rigor et al.*, 2000]. During this period, Arctic sea ice extent has decreased by an average of 15%–20% [*Serreze et al.*, 2007]. Dramatic reduction in the thickness of the remaining sea ice has also been measured over the last decade [*Kwok and Rothrock*, 2009]. The decrease in sea ice extent and subsequent increase in open water will have two immediate effects: (1) an increase in the surface fluxes of heat and moisture from the ocean to the atmosphere and (2) a marked decrease in the surface albedo. The first effect will tend to cool the ocean and moisten and warm the atmosphere, possibly leading to changes in cloud properties such as coverage, vertical structure, phase, and optical depth. The second effect will allow more solar radiation to be absorbed at the surface, thereby heating the ocean. These combined effects could have implications for regional climate and larger-scale weather patterns as well. Changes in cloud properties could have profound effects on radiative balance. For instance, *Shupe and Intrieri* [2004] found that cloud longwave (LW) and shortwave forcing were related to cloud fraction based on yearlong measurements over pack ice during Surface Heat Budget of the Arctic (SHEBA). Furthermore, they found that an increase in cloud fraction will impart greater surface warming relative to current conditions for most of the year, except for a few weeks in midsummer when the shortwave cooling dominates LW warming.

[3] In addition to regional changes in clouds and radiative forcing, a number of studies, both theoretical [*Deser et al.*, 2007; *Alexander et al.*, 2004] and observational [*Francis et al.*, 2009], have found connections between Arctic sea ice extent and general circulation and precipitation patterns. *Francis et al.* [2009] show that there are measurable effects of decreased summertime Arctic sea ice extent on surface pressure and precipitation in the following autumn and winter including locations far from the Arctic. Presumably, these effects may in some way be related to the increased fluxes of heat and moisture from the surface to the atmosphere [*Bhatt et al.*, 2008]. However, the exact cause of these effects is not fully known. Obviously, the changes in sea ice extent and thickness now ongoing in the Arctic warrant a close examination of its effect on the atmosphere and on recent polar cloud trends.

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[1] Science Systems and Applications, Inc. at NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[2] Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, Illinois, USA.

[3] Department of Electrical and Computer Engineering, University of Arizona, Tucson, Arizona, USA.

[4] NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

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Predicting tropical cyclogenesis with a global mesoscale model: Hierarchical multiscale interactions during the formation of tropical cyclone Nargis (2008)

B.-W. Shen,[1,2] W.-K. Tao,[1] W. K. Lau,[1] and R. Atlas[3]

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[1] Very severe cyclonic storm Nargis devastated Burma (Myanmar) in May 2008, caused tremendous damage and numerous fatalities, and became one of the 10 deadliest tropical cyclones (TCs) of all time. To increase the warning time in order to save lives and reduce economic damage, it is important to extend the lead time in the prediction of TCs like Nargis. As recent advances in high-resolution global models and supercomputing technology have shown the potential for improving TC track and intensity forecasts, the ability of a global mesoscale model to predict TC genesis in the Indian Ocean is examined in this study with the aim of improving simulations of TC climate. High-resolution global simulations with real data show that the initial formation and intensity variations of TC Nargis can be realistically predicted up to 5 days in advance. Preliminary analysis suggests that improved representations of the following environmental conditions and their hierarchical multiscale interactions were the key to achieving this lead time: (1) a westerly wind burst and equatorial trough, (2) an enhanced monsoon circulation with a zero wind shear line, (3) good upper-level outflow with anti-cyclonic wind shear between 200 and 850 hPa, and (4) low-level moisture convergence.

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1. Introduction

[2] Each year tropical cyclones (TCs) cause tremendous economic losses and many fatalities throughout the world. For example, Katrina (2005), the costliest Atlantic hurricane in history, caused severe destruction in New Orleans and the surrounding Gulf Coast region and was responsible for about $80 billion in damage. Recently, TC Nargis devastated Myanmar in the Indian Ocean in early May 2008, causing over 133,000 fatalities and $10 billion in damage. In response to this tragedy, more than 40 countries sent relief to Myanmar, showing the broad range of its impact. To reduce these losses, it is crucial that the lead time for the accurate prediction of TC formation, intensification, and movement is extended. However, although TC track forecasts have steadily improved over the past decades, progress on short-term intensity and formation forecasts has been very slow. A major challenge in the prediction of TC genesis is, among other things, the accurate simulation of complex interactions across a wide range of scales, from the large-scale environment (deterministic), to mesoscale flows, down to convective-scale motions (stochastic).

[3] Historically, numerical modeling has been a very powerful way to hypothesize and test the physical mechanisms associated with TC formation and intensification. Our current level of understandings on this topic suggests that the following processes may be involved: (i) large-scale processes such as baroclinic/barotropic instability, tropical easterly waves, the Madden-Julian Oscillation (MJO) [*Madden and Julian*, 1971; *Maloney and Hartmann*, 2000a, 2000b] and monsoons, (ii) mesoscale processes such as vortex mergers and vortex axisymmetrization [*Hendrick et al.*, 2004; *Montgomery et al.*, 2006; *Ritchie and Holland*, 1997; *Simpson et al.*, 1997] and (iii) small-scale processes such as latent heat release by deep convection (e.g., conditional instability of the second kind or CISK) [*Charney and Eliassen*, 1964; *Ooyama*, 1964] and surface heat and moisture fluxes from the ocean (e.g., wind induced surface heat exchange or WISHE) [*Emanuel*, 1986]. A review is given by *Dunkerton et al.* [2008]. Processes from the above three categories have been shown to be applicable at different stages of a TC's life cycle, including the early, the transient, and the deepening stage.

[4] As smaller-scale (convective) processes (associated with a vortex) could be modulated and/or constrained by larger-scale deterministic processes [e.g., *Simpson et al.*,

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[1] Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[2] ESSIC, University of Maryland, College Park, Maryland, USA.

[3] AOML, NOAA, Miami, Florida, USA.

SPECIAL
TRMM Diabatic Heating
COLLECTION

Relating Convective and Stratiform Rain to Latent Heating

WEI-KUO TAO

Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland

STEPHEN LANG

Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, and Science Systems and Applications, Inc., Lanham, Maryland

XIPING ZENG

Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, and Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore County, Baltimore, Maryland

SHOICHI SHIGE

Graduate School of Science, Kyoto University, Kyoto, Japan

YUKARI TAKAYABU

Center for Climate System Research, University of Tokyo, Tokyo, Japan

(Manuscript received 5 June 2009, in final form 23 October 2009)

ABSTRACT

The relationship among surface rainfall, its intensity, and its associated stratiform amount is established by examining observed precipitation data from the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR). The results show that for moderate–high stratiform fractions, rain probabilities are strongly skewed toward light rain intensities. For convective-type rain, the peak probability of occurrence shifts to higher intensities but is still significantly skewed toward weaker rain rates. The main differences between the distributions for oceanic and continental rain are for heavily convective rain. The peak occurrence, as well as the tail of the distribution containing the extreme events, is shifted to higher intensities for continental rain. For rainy areas sampled at 0.5° horizontal resolution, the occurrence of conditional rain rates over 100 mm day^{-1} is significantly higher over land. Distributions of rain intensity versus stratiform fraction for simulated precipitation data obtained from cloud-resolving model (CRM) simulations are quite similar to those from the satellite, providing a basis for mapping simulated cloud quantities to the satellite observations.

An improved convective–stratiform heating (CSH) algorithm is developed based on two sources of information: gridded rainfall quantities (i.e., the conditional intensity and the stratiform fraction) observed from the TRMM PR and synthetic cloud process data (i.e., latent heating, eddy heat flux convergence, and radiative heating/cooling) obtained from CRM simulations of convective cloud systems. The new CSH algorithm-derived heating has a noticeably different heating structure over both ocean and land regions compared to the previous CSH algorithm. Major differences between the new and old algorithms include a significant increase in the amount of low- and midlevel heating, a downward emphasis in the level of maximum cloud heating by about 1 km, and a larger variance between land and ocean in the new CSH algorithm.

Corresponding author address: Dr. W.-K. Tao, Laboratory for Atmospheres, NASA GSFC, Greenbelt, MD 20771.
E-mail: wei-kuo.tao-1@nasa.gov

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A Study of Cirrus Ice Particle Size Distribution Using TC4 Observations

LIN TIAN,* GERALD M. HEYMSFIELD,+ ANDREW J. HEYMSFIELD,# AARON BANSEMER,#
LIHUA LI,+ CYNTHIA H. TWOHY,@ AND RAMESH C. SRIVASTAVA*,&

* *Goddard Earth Science and Technology Center, University of Maryland, Baltimore County, Baltimore, Maryland*
\+ *NASA Goddard Space Flight Center, Greenbelt, Maryland*
\# *National Center for Atmospheric Research, Boulder, Colorado*
@ *University of Oregon, Eugene, Oregon*
& *Department of the Geophysical Sciences, University of Chicago, Chicago, Illinois*

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ABSTRACT

An analysis of two days of in situ observations of ice particle size spectra, in convectively generated cirrus, obtained during NASA's Tropical Composition, Cloud, and Climate Coupling (TC4) mission is presented. The observed spectra are examined for their fit to the exponential, gamma, and lognormal function distributions. Characteristic particle size and concentration density scales are determined using two (for the exponential) or three (for the gamma and lognormal functions) moments of the spectra. It is shown that transformed exponential, gamma, and lognormal distributions should collapse onto standard curves. An examination of the transformed spectra, and of deviations of the transformed spectra from the standard curves, shows that the lognormal function provides a better fit to the observed spectra.

1. Introduction

In recent years, there has been considerable interest in the study of the size distribution of ice particles in clouds. Study of the ice particle size distribution (IPSD) is important for at least three reasons. First, it is of intrinsic value for validating and advancing our understanding of the microphysical processes underlying the production and evolution of the ice particles. Second, it is of importance in climate studies because the IPSD and the particle shapes affect the radiation balance of the earth–atmosphere system. Finally, knowledge of the IPSD helps in remote sensing of ice water content (IWC), mean size of ice particles, and other parameters of the IPSD, which affect the earth's climate. Indeed, climate studies have been the main impetus for the recent explosion in the study of ice in clouds.

A number of authors have presented in-depth analyses of extensive in situ measurements of IPSDs (e.g., Heymsfield and Platt 1984; Brown and Francis 1995; Heymsfield et al. 2002; Delanoë et al. 2005; Field et al. 2005, 2007; Tinel et al. 2005). One objective of these studies has been to find a few parameters that are sufficient to describe an entire IPSD. For this purpose, many authors have normalized the particle size and concentration using one or two moments of the IPSD. Plots of normalized concentration against normalized particle size, called normalized spectra, for a population of IPSDs, have been found to cluster around a "universal" curve or distribution, irrespective of the values of the moments of individual IPSDs. Knowledge of the universal distribution and the moments, used for the normalization, are then sufficient to recover an entire distribution and calculate its properties. Field et al. (2005, 2007) presented an analysis of this type; they found that the universal distribution could be represented by the sum of an exponential and a gamma function.

In this paper, we present an analysis of IPSDs observed in tropical cirrus during the National Aeronautics and Space Administration's (NASA's) Tropical Composition, Cloud, and Climate Coupling (TC4) mission (see http://www.espo.nasa.gov/tc4/). Our aim is to find the best functional representation of the observed IPSDs. In section 2, we present an overview of the data and their meteorological context. In section 3, we present methods for transforming IPSDs that can collapse the exponential, gamma, and lognormal function distributions onto curves

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Corresponding author address: Lin Tian, NASA Goddard Space Flight Center, Code 613.1, Greenbelt, MD 20771.
E-mail: tian@agnes.gsfc.nasa.gov

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Airborne and Ground-Based Measurements Using a High-Performance Raman Lidar

DAVID N. WHITEMAN,[a] KURT RUSH,[a] SCOTT RABENHORST,[b] WAYNE WELCH,[c] MARTIN CADIROLA,[d]
GERRY MCINTIRE,[e] FELICITA RUSSO,[f] MARIANA ADAM,[g] DEMETRIUS VENABLE,[h] RASHEEN CONNELL,[h]
IGOR VESELOVSKII,[i] RICARDO FORNO,[j] BERND MIELKE,[k] BERNHARD STEIN,[k] THIERRY LEBLANC,[l]
STUART MCDERMID,[l] AND HOLGER VÖMEL[m]

[a] *NASA GSFC, Greenbelt, Maryland*
[b] *University of Maryland, College Park, College Park, Maryland*
[c] *Welch Mechanical Designs, Belcamp, Maryland*
[d] *Ecotronics, LLC, Clarksburg, Maryland*
[e] *SGT, Lanham, Maryland*
[f] *CNR, Potenza, Italy*
[g] *European Commission–JRC, Ispra, Italy*
[h] *Howard University, Washington, D.C.*
[i] *University of Maryland, Baltimore County, Baltimore, Maryland*
[j] *Universidad Mayor de San Andres, La Paz, Bolivia*
[k] *Licel, Berlin, Germany*
[l] *Jet Propulsion Laboratory, California Institute of Technology, Table Mountain Facility, Table Mountain, California*
[m] *Lindenberg Observatory, Lindenberg, Germany*

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ABSTRACT

A high-performance Raman lidar operating in the UV portion of the spectrum has been used to acquire, for the first time using a single lidar, simultaneous airborne profiles of the water vapor mixing ratio, aerosol backscatter, aerosol extinction, aerosol depolarization and research mode measurements of cloud liquid water, cloud droplet radius, and number density. The Raman Airborne Spectroscopic Lidar (RASL) system was installed in a Beechcraft King Air B200 aircraft and was flown over the mid-Atlantic United States during July–August 2007 at altitudes ranging between 5 and 8 km. During these flights, despite suboptimal laser performance and subaperture use of the telescope, all RASL measurement expectations were met, except that of aerosol extinction. Following the Water Vapor Validation Experiment—Satellite/Sondes (WAVES_2007) field campaign in the summer of 2007, RASL was installed in a mobile trailer for ground-based use during the Measurements of Humidity and Validation Experiment (MOHAVE-II) field campaign held during October 2007 at the Jet Propulsion Laboratory's Table Mountain Facility in southern California. This ground-based configuration of the lidar hardware is called Atmospheric Lidar for Validation, Interagency Collaboration and Education (ALVICE). During the MOHAVE-II field campaign, during which only nighttime measurements were made, ALVICE demonstrated significant sensitivity to lower-stratospheric water vapor. Numerical simulation and comparisons with a cryogenic frost-point hygrometer are used to demonstrate that a system with the performance characteristics of RASL–ALVICE should indeed be able to quantify water vapor well into the lower stratosphere with extended averaging from an elevated location like Table Mountain. The same design considerations that optimize Raman lidar for airborne use on a small research aircraft are, therefore, shown to yield significant dividends in the quantification of lower-stratospheric water vapor. The MOHAVE-II measurements, along with numerical simulation, were used to determine that the likely reason for the suboptimal airborne aerosol extinction performance during the WAVES_2007 campaign was a misaligned interference filter. With full laser power and a properly tuned interference filter, RASL is shown to be capable of measuring the main water vapor and aerosol parameters with temporal resolutions of between 2 and 45 s and spatial resolutions ranging from 30 to 330 m from a flight altitude of 8 km with precision of generally less than 10%, providing performance that is competitive with some airborne Differential Absorption Lidar (DIAL) water vapor and High Spectral Resolution Lidar (HSRL) aerosol instruments. The use of diode-pumped laser technology would improve the performance of an airborne Raman lidar and permit additional instrumentation to be carried on board a small research aircraft. The combined airborne and ground-based measurements presented here demonstrate a level of versatility in Raman lidar that may be impossible to duplicate with any other single lidar technique.

Corresponding author address: David N. Whiteman, NASA/GSFC, Code 613.1, Bldg. 33, Rm. D404, Greenbelt, MD 20771.
E-mail: david.n.whiteman@nasa.gov

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Code 613.2 Highlighted Articles

GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L07705, doi:10.1029/2009GL041898, 2010

Temperature responses to spectral solar variability on decadal time scales

Robert F. Cahalan,[1] Guoyong Wen,[1,2] Jerald W. Harder,[3] and Peter Pilewskie[3]

Received 1 December 2009; revised 24 February 2010; accepted 1 March 2010; published 6 April 2010.

[1] Two scenarios of spectral solar forcing, namely Spectral Irradiance Monitor (SIM)-based out-of-phase variations and conventional in-phase variations, are input to a time-dependent radiative-convective model (RCM), and to the GISS modelE. Both scenarios and models give maximum temperature responses in the upper stratosphere, decreasing to the surface. Upper stratospheric peak-to-peak responses to out-of-phase forcing are ~0.6 K and ~0.9 K in RCM and modelE, ~5 times larger than responses to in-phase forcing. Stratospheric responses are in-phase with TSI and UV variations, and resemble HALOE observed 11-year temperature variations. For in-phase forcing, ocean mixed layer response lags surface air response by ~2 years, and is ~0.06 K compared to ~0.14 K for atmosphere. For out-of-phase forcing, lags are similar, but surface responses are significantly smaller. For both scenarios, modelE surface responses are less than 0.1 K in the tropics, and display similar patterns over oceanic regions, but complex responses over land. **Citation:** Cahalan, R. F., G. Wen, J. W. Harder, and P. Pilewskie (2010), Temperature responses to spectral solar variability on decadal time scales, *Geophys. Res. Lett.*, *37*, L07705, doi:10.1029/2009GL041898.

1. Introduction

[2] Solar forcing is the primary external forcing of Earth's climate. In order to fully understand the climate system one needs to have a better understanding of the climate response to this unique external forcing. Efforts have been made to reconstruct historical spectral solar irradiance (SSI) [e.g., *Lean*, 2000], to model the climate response to solar variations [e.g., *Rind et al.*, 1999; *Shindell et al.*, 1999; *Meehl et al.*, 2009], and to seek evidence for sun-climate connections from observations [e.g., *White*, 2006; *Camp and Tung*, 2007; *Lean and Rind*, 2008]. Modeling studies and empirical evidence together have connected solar variations with corresponding climate responses [*Haigh*, 2003]. Despite these advances, the role of solar forcing in climate change remains relatively poorly understood, compared for example to that of greenhouse gas forcing.

[3] Satellite observations over the past 30 years show that the total solar irradiance (TSI) changes with solar activity. The magnitude of change in TSI is about 0.1% over an 11-year solar cycle. However the change of TSI does not provide a complete description of solar variations, and is not sufficient for sun-climate studies. Total solar output energy consists of radiation of different wavelengths, with primary contributors to TSI ranging from ultraviolet (UV) to visible (VIS) and near infrared (NIR). The Earth's atmosphere and ocean respond differently to different wavelengths of solar radiation. The UV spectrum is responsible for stratospheric heating, and formation of the ozone layer. The VIS spectrum heats the ocean mixed layer and drives upper oceanic circulation. The NIR directly heats the troposphere by water vapor absorption. Thus the mechanisms by which solar irradiance varies at different wavelengths, and the corresponding mechanisms by which Earth's climate responds to such variations, are fundamental questions in sun-climate studies.

[4] Precise observations of variations in the UV spectrum of solar radiation began with the Upper Atmosphere Research Satellite (UARS) in 1991. However observations of the full SSI are not available until the launch of the Solar Radiation and Climate Experiment (SORCE) in January 2003. Although recent observations from SORCE have not yet completed a full solar cycle, solar variations that solar physicists and climate scientists did not fully anticipate have already been observed. For example, "the long-standing belief that the contributions of active regions to solar irradiance at wavelengths in the range of 1.2–3 μm is negative" is incorrect [*Fontenla et al.*, 2004]. Recently *Harder et al.* [2009] discovered that during the declining phase of solar cycle 23, SSI at one wavelength band has a multi-year trend out-of-phase with that of another band. Variations of SSI do not preserve the shape of the spectral distribution.

[5] As SORCE continues to make valuable TSI and SSI measurements, current available datasets may be used to provide possible scenarios and clues of long-term solar irradiance variations. The goal of this paper is not to provide definitive answers on how solar irradiance varies and how Earth's climate responds. Rather we study possible climate responses implied by the new observations, employing for that purpose a simple radiative-convective model (RCM) and also full GCM simulations, focusing on physical understanding of the responses.

[6] In section 2 we summarize SORCE observational evidence of the SSI variations that motivate this research. Section 3 describes the RCM and GCM climate models used in this research. Section 4 describes the model experiments with in-phase and out-of-phase SSI, and also presents the modeling results. Finally, section 5 summarizes results and conclusions.

2. Solar Spectral Forcing

[7] A major finding from SIM observations is that the temporal variation of SSI differs dramatically from what

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[1] NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[2] Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County, Baltimore, Maryland, USA.

[3] Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado, USA.

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IOP PUBLISHING REPORTS ON PROGRESS IN PHYSICS
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Solar radiation transport in the cloudy atmosphere: a 3D perspective on observations and climate impacts

Anthony B Davis[1,3] **and Alexander Marshak**[2]

[1] Los Alamos National Laboratory, Space and Remote Sensing Group, Los Alamos, NM 87545, USA
[2] NASA—Goddard Space Flight Center, Climate and Radiation Branch, Greenbelt, MD 20771, USA

E-mail: Anthony.B.Davis@jpl.nasa.gov and Alexander.Marshak@nasa.gov

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Abstract

The interplay of sunlight with clouds is a ubiquitous and often pleasant visual experience, but it conjures up major challenges for weather, climate, environmental science and beyond. Those engaged in the characterization of clouds (and the clear air nearby) by remote sensing methods are even more confronted. The problem comes, on the one hand, from the spatial complexity of *real* clouds and, on the other hand, from the dominance of multiple scattering in the radiation transport. The former ingredient contrasts sharply with the still popular *representation* of clouds as homogeneous plane-parallel slabs for the purposes of radiative transfer computations. In typical cloud scenes the opposite asymptotic transport regimes of diffusion and ballistic propagation coexist. We survey the three-dimensional (3D) atmospheric radiative transfer literature over the past 50 years and identify three concurrent and intertwining thrusts: first, how to assess the damage (bias) caused by 3D effects in the operational 1D radiative transfer models? Second, how to mitigate this damage? Finally, can we exploit 3D radiative transfer phenomena to innovate observation methods and technologies? We quickly realize that the smallest scale resolved computationally or observationally may be artificial but is nonetheless a key quantity that separates the 3D radiative transfer solutions into two broad and complementary classes: stochastic and deterministic. Both approaches draw on classic and contemporary statistical, mathematical and computational physics.

(Some figures in this article are in colour only in the electronic version)

This article was invited by A Kostinski.

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[3] Now at: Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA.

Contents

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Atmos. Chem. Phys., 10, 2777-2794, 2010
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Simultaneous retrieval of aerosol and surface optical properties from combined airborne- and ground-based direct and diffuse radiometric measurements

C. K. Gatebe[1,2], O. Dubovik[3], M. D. King[2,4], and A. Sinyuk[2,5]
[1]Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore County, Baltimore, Maryland 21228, USA
[2]NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, USA
[3]Laboratoire d'Optique Atmospherique, Centre National de la Research Scientifique et Université des Sciences et Technologies de Lille, 59655 Villeneuve d'Ascq, France
[4]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado, 80309-0392, USA
[5]Sigma Space Corp., Lanham, MD, 20706, USA

Abstract. This paper presents a new method for simultaneously retrieving aerosol and surface reflectance properties from combined airborne and ground-based direct and diffuse radiometric measurements. The method is based on the standard Aerosol Robotic Network (AERONET) method for retrieving aerosol size distribution, complex index of refraction, and single scattering albedo, but modified to retrieve aerosol properties in two layers, below and above the aircraft, and parameters on surface optical properties from combined datasets (Cloud Absorption Radiometer (CAR) and AERONET data). A key advantage of this method is the inversion of all available spectral and angular data at the same time, while accounting for the influence of noise in the inversion procedure using statistical optimization. The wide spectral (0.34–2.30 μm) and angular range (180°) of the CAR instrument, combined with observations from an AERONET sunphotometer, provide sufficient measurement constraints for characterizing aerosol and surface properties with minimal assumptions. The robustness of the method was tested on observations made during four different field campaigns: (a) the Southern African Regional Science Initiative 2000 over Mongu, Zambia, (b) the Intercontinental Transport Experiment-Phase B over Mexico City, Mexico (c) Cloud and Land Surface Interaction Campaign over the Atmospheric Radiation Measurement (ARM) Central Facility, Oklahoma, USA, and (d) the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) over Elson Lagoon in Barrow, Alaska, USA. The four areas are dominated by different surface characteristics and aerosol types, and therefore provide good test cases for the new inversion method.

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SPECIAL
TCSP NAMMA
COLLECTION

An Assessment of the Surface Longwave Direct Radiative Effect of Airborne Saharan Dust during the NAMMA Field Campaign

R. A. HANSELL,[*,+] S. C. TSAY,[+] Q. JI,[*,+] N. C. HSU,[+] M. J. JEONG,[+,#]
S. H. WANG,[*,+,@] J. S. REID,[&] K. N. LIOU,[**] AND S. C. OU[**]

[*] *University of Maryland, College Park, College Park, Maryland*
[+] *NASA Goddard Space Flight Center, Greenbelt, Maryland*
[#] *Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore County, Baltimore, Maryland*
[@] *Department of Atmospheric Sciences, National Central University, Chung-Li, Taiwan*
[&] *Naval Research Laboratory, Monterey, California*
[**] *Department of Atmospheric and Oceanic Sciences, and Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, Los Angeles, California*

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ABSTRACT

In September 2006, NASA Goddard's mobile ground-based laboratories were deployed to Sal Island in Cape Verde (16.73°N, 22.93°W) to support the NASA African Monsoon Multidisciplinary Analysis (NAMMA) field study. The Atmospheric Emitted Radiance Interferometer (AERI), a key instrument for spectrally characterizing the thermal IR, was used to retrieve the dust IR aerosol optical depths (AOTs) in order to examine the diurnal variability of airborne dust with emphasis on three separate dust events. AERI retrievals of dust AOT are compared with those from the coincident/collocated multifilter rotating shadowband radiometer (MFRSR), micropulse lidar (MPL), and NASA Cloud–Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) sensors. The retrieved AOTs are then inputted into the Fu–Liou 1D radiative transfer model to evaluate local instantaneous direct longwave radiative effects ($\mathrm{DRE_{LW}}$) of dust at the surface in cloud-free atmospheres and its sensitivity to dust microphysical parameters. The top-of-atmosphere $\mathrm{DRE_{LW}}$ and longwave heating rate profiles are also evaluated. Instantaneous surface $\mathrm{DRE_{LW}}$ ranges from 2 to 10 W $\mathrm{m^{-2}}$ and exhibits a strong linear dependence with dust AOT yielding a $\mathrm{DRE_{LW}}$ of 16 W $\mathrm{m^{-2}}$ per unit dust AOT. The $\mathrm{DRE_{LW}}$ is estimated to be ~42% of the diurnally averaged direct shortwave radiative effect at the surface but of opposite sign, partly compensating for the shortwave losses. Certainly nonnegligible, the authors conclude that $\mathrm{DRE_{LW}}$ can significantly impact the atmospheric energetics, representing an important component in the study of regional climate variation.

1. Introduction

For over a decade, there have been many observational and theoretical efforts to determine the radiative impact of airborne mineral dust on the earth–atmosphere system (e.g., Mahowald et al. 2006; Haywood et al. 2003, 2005; Zhang and Christopher 2003; Hsu et al. 2000; Sokolik and Toon 1996a,b; Ackerman and Chung 1992). Less attention, however, has been given to the longwave (LW) contributions, mainly because the shortwave (SW) measurements are easier to make in the field. In addition, the limited experimental data on dust optical properties at infrared wavelengths and the large uncertainties in the spatially and temporally dependent particle properties—size, shape, and composition (Sokolik and Toon 1999)—have indeed made it a difficult challenge to constrain the LW impact.

The term "aerosol radiative forcing" is now commonly used for gauging changes in the radiative fluxes due to anthropogenic aerosols since the beginning of the industrial era (~1750) (Forster et al. 2007). We therefore use the term "direct radiative effect" (DRE) to quantify the difference between radiative fluxes in dust and dust-free atmospheres. In doing so we also maintain consistency with other published literature (e.g., Yu et al. 2006; Haywood et al. 2005).

The overall cooling SW DRE of dust (hereafter $\mathrm{DRE_{SW}}$) has already been studied by a number of

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Corresponding author address: Richard A. Hansell Jr., NASA Goddard Space Flight Center, Greenbelt, MD 20771.
E-mail: richard.a.hansell@nasa.gov

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Journal of Quantitative Spectroscopy & Radiative Transfer

Response to "Toward unified satellite climatology of aerosol properties. 3. MODIS versus MISR versus AERONET"

Ralph A. Kahn [a,*], Michael J. Garay [b], David L. Nelson [b], Robert C. Levy [c], Michael A. Bull [d], David J. Diner [d], John V. Martonchik [d], Earl G. Hansen [d], Lorraine A. Remer [a], Didier Tanré [e]

[a] Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[b] Raytheon Company, 299 N. Euclid Ave., Suite 500, Pasadena, CA 91101, USA
[c] Science Systems and Applications, Inc., Lanham, MD 20706, USA
[d] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA
[e] Universite' des Sciences et Technologies de Lille, Villeneuve d'Ascq., France

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ABSTRACT

A recent paper by Mishchenko et al. compares near-coincident MISR, MODIS, and AERONET aerosol optical depth (AOD), and gives a much less favorable impression of the utility of the satellite products than that presented by the instrument teams and other groups. We trace the reasons for the differing pictures to whether known and previously documented limitations of the products are taken into account in the assessments. Specifically, the analysis approaches differ primarily in (1) the treatment of outliers, (2) the application of absolute vs. relative criteria for testing agreement, and (3) the ways in which seasonally varying spatial distributions of coincident retrievals are taken into account. Mishchenko et al. also do not distinguish between observational sampling differences and retrieval algorithm error. We assess the implications of the different analysis approaches, and cite examples demonstrating how the MISR and MODIS aerosol products have been applied successfully to a range of scientific investigations.

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1. Introduction

To begin this response, we offer some context by briefly reviewing the roles the Multi-angle Imaging SpectroRadiometer (MISR) and MODerate resolution Imaging Spectroradiometer (MODIS) play in satellite aerosol remote sensing, and the validation efforts that are central to the instrument programs. MISR and MODIS, both of which fly aboard the NASA Earth Observing System's Terra spacecraft, represent significant advances over the previous generation of space-based aerosol instruments. Relatively high spatial resolution imaging, calibration accuracy, and radiometric stability, along with an increased number of spectral bands for MODIS and the combination of spectral bands and multiple view angles for MISR, have led to more robust aerosol optical depth (AOD) retrievals over both water and land, with less-restrictive algorithmic assumptions [1–5]. In addition, the MODIS algorithm derives coarse vs. fine-mode ratio over water, whereas MISR can distinguish about a dozen aerosol air mass types under favorable retrieval conditions, based on particle size, shape, and single-scattering albedo constraints. And unlike most remote sensing algorithms that assume aerosol properties based on seasonally and/or geographically fixed prescriptions, MISR AOD retrievals are performed self-consistently, using aerosol types retrieved without prescribed spatial or temporal constraints.

Critical to the application of these satellite products is validation, which entails establishing uncertainties,

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[*] Corresponding author. Tel.: +13016146193.
E-mail address: ralph.kahn@nasa.gov (R.A. Kahn).

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SPECIAL
TRMM Diabatic Heating
COLLECTION

Characteristics of Precipitation, Cloud, and Latent Heating Associated with the Madden–Julian Oscillation

K.-M. LAU

Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland

H.-T. WU

Science Systems and Applications, Inc., Lanham, Maryland

(Manuscript received 7 November 2008, in final form 12 June 2009)

ABSTRACT

This study investigates the evolution of cloud and rainfall structures associated with Madden–Julian oscillation (MJO) using Tropical Rainfall Measuring Mission (TRMM) data. Two complementary indices are used to define MJO phases. Joint probability distribution functions (PDFs) of cloud-top temperature and radar echo-top height are constructed for each of the eight MJO phases. The genesis stage of MJO convection over the western Pacific (phases 1 and 2) features a bottom-heavy PDF, characterized by abundant warm rain, low clouds, suppressed deep convection, and higher sea surface temperature (SST). As MJO convection develops (phases 3 and 4), a transition from the bottom-heavy to top-heavy PDF occurs. The latter is associated with the development of mixed-phase rain and middle-to-high clouds, coupled with rapid SST cooling. At the MJO convection peak (phase 5), a top-heavy PDF contributed by deep convection with mixed-phase and ice-phase rain and high echo-top heights (>5 km) dominates. The decaying stage (phases 6 and 7) is characterized by suppressed SST, reduced total rain, increased contribution from stratiform rain, and increased nonraining high clouds. Phase 7, in particular, signals the beginning of a return to higher SST and increased warm rain. Phase 8 completes the MJO cycle, returning to a bottom-heavy PDF and SST conditions similar to phase 1. The structural changes in rain and clouds at different phases of MJO are consistent with corresponding changes in derived latent heating profiles, suggesting the importance of a diverse mix of warm, mixed-phase, and ice-phase rain associated with low-level, congestus, and high clouds in constituting the life cycle and the time scales of MJO.

1. Introduction

The Madden–Julian oscillation (MJO; Madden and Julian 1972) is a dominant feature in the tropical ocean–atmosphere, linking weather and climate variability. Theories and observational characteristics of MJO and its influence on tropical cyclones, midlatitude weather, monsoon variability, air–sea interaction, relationships with atmospheric angular momentum and El Niño, and predictability have been reported in a large number of previous studies. [See Lau and Waliser (2005) for a review of observations and theories related to MJO.] Because of the highly multiscale organization associated with MJO (Nakazawa 1988; Lau et al. 1989; Hendon and Liebmann 1994; Wheeler and Kiladis 1999; Masunaga et al. 2006), realistic simulation of MJO is now considered one of the most fundamental tests of climate model physics and a major challenge to climate modeling. Early theoretical studies (Lau and Peng 1987; Kemball-Cook and Weare 2001) found large sensitivity of the MJO propagation to the vertical heating distribution, demonstrating that a lower heating profile can produce a slower phase speed closer to the observed MJO. Wu (2003) has argued that low-level heating is essential in the build-up phase of the MJO and is critical in determining the time scale of MJO. Lin et al. (2004) have shown that heating profile associated with MJO is top heavy, indicating the importance of stratiform rain. Other mechanisms such as evaporation–wind feedback, frictional Ekman pumping, discharge–recharge, radiative heating feedback, moisture-convergence and air–sea interaction, as well as

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Corresponding author address: Dr. K.-M. Lau, Chief, Laboratory for Atmospheres, Code 613, Building 33, Rm. C121, NASA Goddard Space Flight Center, Greenbelt, MD 20771.
E-mail: william.k.lau@nasa.gov

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Analysis of snow bidirectional reflectance from ARCTAS Spring-2008 Campaign

A. Lyapustin[1,2], C. K. Gatebe[1,2], R. Kahn[2], R. Brandt[3], J. Redemann[4], P. Russell[5], M. D. King[6], C. A. Pedersen[7], S. Gerland[7], R. Poudyal[2,8], A. Marshak[2], Y. Wang[1,2], C. Schaaf[9], D. Hall[2], and A. Kokhanovsky[10]

[1]University of Maryland Baltimore County, Baltimore, MD, USA
[2]NASA Goddard Space Flight Center, Greenbelt, MD, USA
[3]University of Washington, Seattle, Washington, USA
[4]Bay Area Environmental Research Institute (BAERI), Sonoma, CA USA
[5]NASA Ames Research Center, Moffett Field, CA, USA
[6]University of Colorado, Boulder, CO, USA
[7]Norwegian Polar Institute, 9296 Tromso, Norway
[8]Science Systems and Applications, Inc., Lanham, MD, USA
[9]Boston University, Geography Department, Boston, MA, USA
[10]Institute of Environmental Physics, University of Bremen, 28359 Bremen, Germany

Abstract. The spring 2008 Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) experiment was one of major intensive field campaigns of the International Polar Year aimed at detailed characterization of atmospheric physical and chemical processes in the Arctic region. A part of this campaign was a unique snow bidirectional reflectance experiment on the NASA P-3B aircraft conducted on 7 and 15 April by the Cloud Absorption Radiometer (CAR) jointly with airborne Ames Airborne Tracking Sunphotometer (AATS) and ground-based Aerosol Robotic Network (AERONET) sunphotometers. The CAR data were atmospherically corrected to derive snow bidirectional reflectance at high 1° angular resolution in view zenith and azimuthal angles along with surface albedo. The derived albedo was generally in good agreement with ground albedo measurements collected on 15 April. The CAR snow bidirectional reflectance factor (BRF) was used to study the accuracy of analytical Ross-Thick Li-Sparse (RTLS), Modified Rahman-Pinty-Verstraete (MRPV) and Asymptotic Analytical Radiative Transfer (AART) BRF models. Except for the glint region (azimuthal angles $\varphi<40°$), the best fit MRPV and RTLS models fit snow BRF to within ±0.05. The plane-parallel radiative transfer (PPRT) solution was also analyzed with the models of spheres, spheroids, randomly oriented fractal crystals, and with a synthetic phase function. The latter merged the model of spheroids for the forward scattering angles with the fractal model in the backscattering direction. The PPRT solution with synthetic phase function provided the best fit to measured BRF in the full range of angles. Regardless of the snow grain shape, the PPRT model significantly over-/underestimated snow BRF in the glint/backscattering regions, respectively, which agrees with other studies. To improve agreement with experiment, we introduced a model of macroscopic snow surface roughness by averaging the PPRT solution over the slope distribution function and by adding a simple model of shadows. With macroscopic roughness described by two parameters, the AART model achieved an accuracy of about ±0.05 with a possible bias of ±0.03 in the spectral range 0.4–2.2 μm. This high accuracy holds at view zenith angles below 55–60° covering the practically important range for remote sensing applications, and includes both glint and backscattering directions.

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NOWCAST

MODELING

THE CONTINUAL INTERCOMPARISON OF RADIATION CODES (CIRC)

Assessing Anew the Quality of GCM Radiation Algorithms

BY LAZAROS OREOPOULOS AND ELI MLAWER

THE PROBLEM AT HAND AND CURRENT KNOWLEDGE. The simulation of changes in the Earth's climate due to solar and thermal radiative processes with global climate models (GCMs) is highly complex, depending on the parameterization of a multitude of nonlinearly coupled physical processes. In contrast, the germ of global climate change, the radiative forcing from enhanced abundances of greenhouse gases, is relatively well understood. The impressive agreement between detailed radiation calculations and highly resolved spectral radiation measurements in the thermal infrared under cloudless conditions (see, for example, Fig. 1) instills confidence in our knowledge of the sources of gaseous absorption. That the agreement spans a broad range of temperature and humidity regimes using instruments mounted on surface, aircraft, and satellite platforms not only attests to our capability to accurately calculate radiative fluxes under present conditions, but also provides confidence in the spectroscopic basis for computation of fluxes under conditions that might characterize future global climate (e.g., radiative forcing). Alas, the computational costs of highly resolved spectral radiation calculations cannot be afforded presently in GCMs. Such calculations have instead been used as the foundation for approximations implemented in fast—but generally less accurate—algorithms performing the needed radiative transfer (RT) calculations in GCMs.

AFFILIATIONS: OREOPOULOS—NASA Goddard Space Flight Center, Greenbelt, Maryland; MLAWER—Atmospheric and Environmental Research Inc., Lexington, Massachusetts
CORRESPONDING AUTHOR: Lazaros Oreopoulos, NASA GSFC, Code 613.2, Greenbelt, MD 20771
E-mail: Lazaros.Oraiopoulos@nasa.gov

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GCM RADIATION ALGORITHMS AND PRIOR INTERCOMPARISONS. Credible climate simulations by GCMs cannot be ensured without accurate solar and thermal radiative flux calculations under all types of sky conditions: pristine cloudless, aerosol-laden, and cloudy. The need for accuracy in RT calculations is not only important for greenhouse gas forcing scenarios, but is also profoundly needed for the robust simulation of many other atmospheric phenomena, such as convective processes. Despite the approximations used in GCM RT algorithms, their share of CPU resources in climate simulations is still typically the largest of all the parameterizations of physical processes. Given the importance of radiation calculations to climate simulations and the relatively settled status of spectrally detailed clear-sky radiative transfer, one would think that GCM radiation codes would by now faithfully reproduce the radiative effects of greenhouse gases computed by more detailed models at present and projected future concentrations, thereby allowing confidence in this critical aspect of the simulation when tackling nonpristine atmospheric states. Unfortunately, this has not generally been the case. For example, a 2006 study in the *Journal of Geophysical Research* (*JGR*) by Collins et al. presented forcing intercomparisons between line-by-line (LBL) radiative transfer models and their speedier, but coarser, GCM counterparts that participated in the Intergovernmental Panel for Climate Change (IPCC) 4th Assessment Report. The exercise was primarily targeted at well-mixed greenhouse gases, and in some respects updated a similar effort completed more than a decade earlier under the auspices of the Intercomparison of Radiation Codes in Climate Models (ICRCCM). Collins et al. reported that for many of the cases analyzed, GCM codes exhibited "substantial discrepancies" relative to the detailed spectral LBL standards, a finding echoing earlier conclusions by ICRCCM. While the mostly cloudless synthetic cases in both these studies provided the benefit of well-defined controlled experiments, a major deficiency was the lack of validation of the baseline reference results with mea-

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Uncertainties in Ice-Sheet Altimetry From a Spaceborne 1064-nm Single-Channel Lidar Due to Undetected Thin Clouds

Yuekui Yang, Alexander Marshak, Tamás Várnai, Warren Wiscombe, and Ping Yang

***Abstract*—In support of the Ice, Cloud, and land Elevation Satellite (ICESat)-II mission, this paper studies the bias in surface-elevation measurements caused by undetected thin clouds. The ICESat-II satellite may only have a 1064-nm single-channel lidar onboard. Less sensitive to clouds than the 532-nm channel, the 1064-nm channel tends to miss thin clouds. Previous studies have demonstrated that scattering by cloud particles increases the photon-path length, thus resulting in biases in ice-sheet-elevation measurements from spaceborne lidars. This effect is referred to as atmospheric path delay. This paper complements previous studies in the following ways: First, atmospheric path delay is estimated over the ice sheets based on cloud statistics from the Geoscience Laser Altimeter System onboard ICESat and the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra and Aqua. Second, the effect of cloud particle size and shape is studied with the state-of-the-art phase functions developed for MODIS cirrus-cloud microphysical model. Third, the contribution of various orders of scattering events to the path delay is studied, and an analytical model of the first-order scattering contribution is developed. This paper focuses on the path delay as a function of telescope field of view (FOV). The results show that reducing telescope FOV can significantly reduce the expected path delay. As an example, the average path delays for $FOV = 167$ μrad (a 100-m-diameter circle on the surface) caused by thin undetected clouds by the 1064-nm channel over Greenland and East Antarctica are illustrated.**

***Index Terms*—Atmospheric path delay, Ice, Cloud, and land Elevation Satellite (ICESat)-II, lidar altimetry, polar cloud, radiative transfer.**

I. INTRODUCTION

SPACEBORNE lidars, such as the Geoscience Laser Altimeter System (GLAS) onboard the Ice, Cloud, and land Elevation Satellite (ICESat), provide measurements of ice sheets and sea ice on a global scale. These data are used to address important climate questions, such as "how is the cryosphere responding to the climate change?" and "how is the change in ice sheets affecting the global sea level?" [1]. To answer these questions, accurate ice-surface-elevation measurements are needed. The ICESat science objectives require detecting long-term elevation changes with an accuracy of < 1.5 cm/year over ice-sheet areas of 100×100 km^2 [1], [2].

Atmospheric factors, e.g., clouds, aerosols, and atmosphere humidity, may affect the accuracy of the derived ice surface elevation. Among these factors, clouds probably cause the most uncertainty due to the large variability in their properties. Clouds affect lidar measurements through particle forward scattering [3], which increases the photon-path length and makes the surface appear farther from the satellite. This effect is referred to as "atmospheric path delay." Some of the pioneering studies on this effect were reported by Duda *et al.* [2] and Mahesh *et al.* [4]. These studies demonstrated that the magnitude of the atmospheric path delay is a function of cloud height, cloud optical depth (COD, referred hereinafter as τ), cloud particle size and shape, and the telescope field of view (FOV). It was found that the delay could reach tens of centimeters even for optically thin clouds with a low cloud base.

The challenge in cloud-induced atmospheric path delay is twofold. First, if we know that the lidar beam hits a cloud, how do we correct the retrieved surface elevation? Second, if some clouds are not detected due to the low signal-to-noise ratio of the instrument, how large may the bias be in the altimetry products? Much progress has been made in addressing the first question [2], [4]. The second question is not a pressing issue for ICESat, because the GLAS lidar has two channels, one at 1064 nm and one at 532 nm. The 532-nm channel, used as the primary channel for GLAS atmospheric products, is very sensitive to the presence of clouds [5], [6]. It has been shown that cloud layers with an optical thickness as low as 0.01 generally were detectable with a well-functioning 532-nm laser channel [5]. However, the ICESat-II mission may only have the 1064-nm channel, and undetected clouds will become an important issue. It is critical to understand the probability that the 1064-nm channel may miss the detection of some clouds, and how the missed clouds may affect the altimetry measurements.

The ICESat-II mission is recommended by the National Research Council's Decadal Survey as one of the top-priority NASA missions [7]. However, without the 532-nm channel, its ability to detect clouds will be less than that of the current ICESat mission. Following [5], Fig. 1 shows this problem. The figure shows the percentage of the undetected clouds by

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Y. Yang is with the Goddard Earth Science and Technology Center, University of Maryland, Baltimore County, Baltimore, MD 21228 USA (e-mail: yuekui.yang@nasa.gov).

A. Marshak and W. Wiscombe are with the NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA (e-mail: Alexander.marshak@nasa.gov; warren.j.wiscombe@nasa.gov).

T. Várnai is with the Joint Center for Earth Systems Technology of the University of Maryland, Baltimore County, Baltimore, MD 21228 USA, and of the NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA (e-mail: tamas.varnai@nasa.gov).

P. Yang is with the Department of Atmospheric Sciences, Texas A&M University, College Station, TX 77843 USA (e-mail: pyang@ariel.met.tamu.edu).

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Global view of aerosol vertical distributions from CALIPSO lidar measurements and GOCART simulations: Regional and seasonal variations

Hongbin Yu,[1,2,3] Mian Chin,[2] David M. Winker,[4] Ali H. Omar,[4] Zhaoyan Liu,[4,5]
Chieko Kittaka,[4,6] and Thomas Diehl[1,2]

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[1] This study examines seasonal variations of the vertical distribution of aerosols through a statistical analysis of the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) lidar observations from June 2006 to November 2007. A data-screening scheme is developed to attain good quality data in cloud-free conditions, and the polarization measurement is used to separate dust from non-dust aerosol. The CALIPSO aerosol observations are compared with aerosol simulations from the Goddard Chemistry Aerosol Radiation Transport (GOCART) model and aerosol optical depth (AOD) measurements from the MODerate resolution Imaging Spectroradiometer (MODIS). The CALIPSO observations of geographical patterns and seasonal variations of AOD are generally consistent with GOCART simulations and MODIS retrievals especially near source regions, while the magnitude of AOD shows large discrepancies in most regions. Both the CALIPSO observation and GOCART model show that the aerosol extinction scale heights in major dust and smoke source regions are generally higher than that in industrial pollution source regions. The CALIPSO aerosol lidar ratio also generally agrees with GOCART model within 30% on regional scales. Major differences between satellite observations and GOCART model are identified, including (1) an underestimate of aerosol extinction by GOCART over the Indian sub-continent, (2) much larger aerosol extinction calculated by GOCART than observed by CALIPSO in dust source regions, (3) much weaker in magnitude and more concentrated aerosol in the lower atmosphere in CALIPSO observation than GOCART model over transported areas in midlatitudes, and (4) consistently lower aerosol scale height by CALIPSO observation than GOCART model. Possible factors contributing to these differences are discussed.

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1. Introduction

[2] Aerosol can have significant impacts on air quality, weather, and climate. Assessing these impacts requires an adequate, observational characterization of large temporal and spatial variations of aerosol. The emerging capability of satellite remote sensing provides an unprecedented opportunity to advance the understanding of aerosol-air quality-climate linkages. Recent improvements in satellite remote sensing mainly aerosol optical depth (AOD) from passive sensors such as the Moderate resolution Imaging Spectroradiometer (MODIS) [*Remer et al.*, 2005; *Levy et al.*, 2007] and Multiangle Imaging Spectroradiometer (MISR) [*Kahn et al.*, 2005], have resulted in strong observational constraints for the aerosol direct effect on solar radiation at the top-of-atmosphere (TOA) [e.g., *Remer and Kaufman*, 2006; *Yu et al.*, 2004, 2006, 2009]. Satellite AOD data have also been used to enhance the surface air quality monitoring networks for air quality forecast [e.g., *Al-Saadi et al.*, 2005] and to provide observation-based estimates of the long-range transport of aerosol [*Kaufman et al.*, 2005; *Yu et al.*, 2008; *Rudich et al.*, 2008]. However, passive sensors mainly provide total column quantities in cloud-free scenes with little information on the vertical distribution of aerosols except the plume height [*Kahn et al.*, 2007; *Pierangelo et al.*, 2004]. Current assessments of aerosol impacts on climate and air quality remain very uncertain [e.g., *Schulz et al.*, 2006] because the assessments rely largely on model simulations of

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[1] Goddard Earth Science and Technology Center, University of Maryland Baltimore County, Baltimore, Maryland, USA.
[2] Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.
[3] Now at Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, USA.
[4] NASA Langley Research Center, Hampton, Virginia, USA.
[5] National Institute of Aerospace, Hampton, Virginia, USA.
[6] Science System and Applications Inc., Hampton, Virginia, USA.

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Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth

Peter Colarco,[1] Arlindo da Silva,[2] Mian Chin,[1] and Thomas Diehl[1,3]

Received 13 July 2009; revised 19 October 2009; accepted 19 January 2010; published 30 July 2010.

[1] We have implemented a module for tropospheric aerosols (GOCART) online in the NASA Goddard Earth Observing System version 4 model and simulated global aerosol distributions for the period 2000–2006. The new online system offers several advantages over the previous offline version, providing a platform for aerosol data assimilation, aerosol-chemistry-climate interaction studies, and short-range chemical weather forecasting and climate prediction. We introduce as well a methodology for sampling model output consistently with satellite aerosol optical thickness (AOT) retrievals to facilitate model-satellite comparison. Our results are similar to the offline GOCART model and to the models participating in the AeroCom intercomparison. The simulated AOT has similar seasonal and regional variability and magnitude to Aerosol Robotic Network (AERONET), Moderate Resolution Imaging Spectroradiometer, and Multiangle Imaging Spectroradiometer observations. The model AOT and Angstrom parameter are consistently low relative to AERONET in biomass-burning-dominated regions, where emissions appear to be underestimated, consistent with the results of the offline GOCART model. In contrast, the model AOT is biased high in sulfate-dominated regions of North America and Europe. Our model-satellite comparison methodology shows that diurnal variability in aerosol loading is unimportant compared to sampling the model where the satellite has cloud-free observations, particularly in sulfate-dominated regions. Simulated sea salt burden and optical thickness are high by a factor of 2–3 relative to other models, and agreement between model and satellite over-ocean AOT is improved by reducing the model sea salt burden by a factor of 2. The best agreement in both AOT magnitude and variability occurs immediately downwind of the Saharan dust plume.

Citation: Colarco, P., A. da Silva, M. Chin, and T. Diehl (2010), Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth, *J. Geophys. Res.*, *115*, D14207, doi:10.1029/2009JD012820.

1. Introduction

[2] Aerosols scatter and absorb solar and longwave radiation, perturbing the energy balance of Earth's atmosphere [*McCormick and Ludwig*, 1967; *Charlson and Pilat*, 1969; *Atwater*, 1970; *Mitchell*, 1971]. Aerosols additionally have complex and not yet well-understood effects on cloud brightness [*Twomey*, 1974] and the occurrence and intensity of precipitation [*Gunn and Phillips*, 1957; *Liou and Ou*, 1989; *Albrecht*, 1989] and so play a role in modulating Earth's climate and hydrological cycle [e.g., *Ramanathan et al.*, 2001a]. Long-range transport of aerosol pollutants can as well impact the air quality and visibility far from sources [e.g., *Prospero*, 1999; *Jaffe et al.*, 2003; *Bertschi et al.*, 2004; *Colarco et al.*, 2004]. The extent of anthropogenic influence on the global aerosol system is the determinate and key uncertainty in anthropogenic radiative forcing of Earth's climate system [*Intergovernmental Panel on Climate Change*, 2007].

[3] Because of this role of aerosols in modulating Earth's climate, a considerable aerosol observing system has evolved, especially since the late 1990s. This observing system includes space-based remote sensing platforms [e.g., *Herman et al.*, 1997; *Goloub et al.*, 1999; *King et al.*, 1999; *Kaufman et al.*, 2002; *Stephens et al.*, 2002; *Winker et al.*, 2003], networks of ground-based sampling [e.g., *Malm et*

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[1] Atmospheric Chemistry and Dynamics Branch, Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[2] Global Modeling and Assimilation Office, Laboratory for Atmospheres, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[3] Also at Goddard Earth Science and Technology Center, University of Maryland, Baltimore, Maryland, USA.

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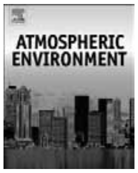

Application of OMI observations to a space-based indicator of NO_x and VOC controls on surface ozone formation

Bryan N. Duncan[a,*], Yasuko Yoshida[a,b], Jennifer R. Olson[c], Sanford Sillman[d], Randall V. Martin[e,f], Lok Lamsal[e], Yongtao Hu[g], Kenneth E. Pickering[a], Christian Retscher[a,b], Dale J. Allen[h], James H. Crawford[c]

[a] Atmospheric Chemistry and Dynamics Branch, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[b] Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore, MD, USA
[c] Chemistry and Dynamics Branch, NASA Langley Research Center, Hampton, VA, USA
[d] Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, MI, USA
[e] Department of Physics and Atmospheric Science, Dalhousie University, Halifax, NS, Canada
[f] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA
[g] School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA, USA
[h] Department of Atmospheric and Oceanic Sciences, University of Maryland, College Park, MD, USA

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ABSTRACT

We investigated variations in the relative sensitivity of surface ozone formation in summer to precursor species concentrations of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) as inferred from the ratio of the tropospheric columns of formaldehyde to nitrogen dioxide (the "Ratio") from the Aura Ozone Monitoring Instrument (OMI). Our modeling study suggests that ozone formation decreases with reductions in VOCs at Ratios <1 and NO_x at Ratios >2; both NO_x and VOC reductions may decrease ozone formation for Ratios between 1 and 2. Using this criteria, the OMI data indicate that ozone formation became: 1. more sensitive to NO_x over most of the United States from 2005 to 2007 because of the substantial decrease in NO_x emissions, primarily from stationary sources, and the concomitant decrease in the tropospheric column of NO_2, and 2. more sensitive to NO_x with increasing temperature, in part because emissions of highly reactive, biogenic isoprene increase with temperature, thus increasing the total VOC reactivity. In cities with relatively low isoprene emissions (e.g., Chicago), the data clearly indicate that ozone formation became more sensitive to NO_x from 2005 to 2007. In cities with relatively high isoprene emissions (e.g., Atlanta), we found that the increase in the Ratio due to decreasing NO_x emissions was not obvious as this signal was convolved with variations in the Ratio associated with the temperature dependence of isoprene emissions and, consequently, the formaldehyde concentration.

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1. Introduction

In polluted areas, unhealthy levels of ozone form from a complex series of reactions involving nitrogen oxides ($NO_x = NO + NO_2$) and volatile organic compounds (VOCs) in the presence of sunlight (Haagen-Smit, 1952). Therefore, ozone formation can be controlled by reducing either emissions of NO_x or VOCs, depending on which is in excess (Dodge, 1987). These two states are commonly referred to as NO_x-limited and VOC-limited photochemical regimes. However, the VOC-limited regime is better described as the radical-limited regime, since ozone production first requires the formation of the hydroxyl radical (OH) through the photolysis of ozone itself, and its subsequent oxidation of VOCs, forming peroxy radicals (e.g., Kleinman, 1994). In order to determine the regime, one must estimate the total reactivity with OH of the myriad of VOCs in the urban atmosphere, as reaction with OH is often the rate-limiting step of many oxidation pathways (Chameides et al., 1992). In the absence of such information, one can use the formaldehyde (HCHO) concentration as a proxy for VOC reactivity as it is a short-lived oxidation product of many VOCs and is positively correlated with peroxy radicals (Sillman, 1995). Sillman used correlations between the afternoon concentrations of various trace gases (e.g., HCHO and total reactive nitrogen (NO_y)) to determine chemical sensitivity, which is considered NO_x-limited when the ratio of HCHO to NO_y is high and radical-limited when the ratio is low; in this way, HCHO and NO_y are 'indicator species'.

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[*] Corresponding author. Tel.: +1 301 614 5994; fax: +1 301 614 5903.
E-mail address: Bryan.N.Duncan@nasa.gov (B.N. Duncan).

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Global increase in UV irradiance during the past 30 years (1979–2008) estimated from satellite data

Jay R. Herman[1]

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[1] Zonal average ultraviolet irradiance (flux ultraviolet, F_{UV}) reaching the Earth's surface has significantly increased since 1979 at all latitudes except the equatorial zone. Changes are estimated in zonal average F_{UV} caused by ozone and cloud plus aerosol reflectivity using an approach based on Beer's law for monochromatic and action spectrum weighted irradiances. For four different cases, it is shown that Beer's Law leads to a power law form similar to that applied to erythemal action spectrum weighted irradiances. Zonal and annual average increases in F_{UV} were caused by decreases in ozone amount from 1979 to 1998. After 1998, midlatitude annual average ozone amounts and UV irradiance levels have been approximately constant. In the Southern Hemisphere, zonal and annual average UV increase is partially offset by tropospheric cloud and aerosol transmission decreases (hemispherical dimming), and to a lesser extent in the Northern Hemisphere. Ozone and 340 nm reflectivity changes have been obtained from multiple joined satellite time series from 1978 to 2008. The largest zonal average increases in F_{UV} have occurred in the Southern Hemisphere. For clear-sky conditions at 50°S, zonal average F_{UV} changes are estimated (305 nm, 23%; erythemal, 8.5%; 310 nm, 10%; vitamin D production, 12%). These are larger than at 50°N (305 nm, 9%; erythemal, 4%; 310 nm, 4%; vitamin D production, 6%). At the latitude of Buenos Aires, Argentina (34.6°S), the clear-sky F_{UV} increases are comparable to the increases near Washington, D. C. (38.9°N): 305 nm, 9% and 7%; erythemal, 6% and 4%; and vitamin D production, 7% and 5%, respectively.

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1. Introduction

[2] Changes in the amount of UVB (280–315 nm) and short wavelength UVA (315–325 nm) irradiances that reach the earth's surface are dependent on changes in the amounts of ozone (O_3), aerosol, and cloud albedo. Changes in aerosol and cloud albedo also affect UVA (315–400 nm), VIS (400–700 nm), and NIR (700–2000 nm). From the viewpoint of exposure (time integral of irradiance from sunrise to sunset) to UV, very high clear-sky UV irradiances F_{UV} and exposures E_{UV} occur in tropic latitudes, ±23.3°, following the seasonal subsolar point, also at high mountain altitudes and occasionally when the elongated ozone hole passes over southern Chile and Argentina. In general, UV erythemal, UV-A, and UV-B irradiances decrease with increasing latitude outside of the equatorial zone, due to the decreases in maximum daily noon solar elevation angles and increases in ozone amount with increasing latitude. At the equator, larger UV monthly average irradiance exposure occurs when the Sun is directly overhead during March equinox conditions, which has lower cloud cover than during September. The difference is related to the annual cycle of the cloud cover associated with the Intertropical Convergence Zone (ITCZ), which is usually over the equator in September, but is south of the equator in March. Two examples of very high E_{UV} occur in the South American Andes (e.g., the sparsely populated Atacama Desert in Chile at 4400 m to 5600 m altitude and in the city Cuzco, Peru 13.5°S, 72°W) during January (noon solar zenith angle SZA = 9.5°) and in the Himalayan Mountains during July (over 100 peaks exceeding 7000 m with Everest at 28°N, 27°E, SZA = 5.5°). In both cases, the summer Sun is nearly overhead.

[3] In January the Earth's elliptical orbit is closest to the Sun (perihelion near January 3) compared to the Northern Hemisphere (NH) summer (aphelion near 4 July) causing a 6% increase in Southern Hemisphere (SH) irradiance at the top of the atmosphere around perihelion compared to the NH near aphelion.

[4] Based on the combined multisatellite ozone data set used in this paper [*Stolarski and Frith*, 2006], average summer ozone in the midlatitude SH (30°S–50°S) (Decembe 2007; 288 DU) is lower than at corresponding latitudes in the NH (June 2008; 305 DU) by about 6%, which contributes to higher summer clear-sky UVB irradiances in the SH. The exact percentage of ozone interhemispheric difference is a function of latitude, longitude, year, and season. In

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21st century trends in Antarctic temperature and polar stratospheric cloud (PSC) area in the GEOS chemistry-climate model

M. M. Hurwitz[1] and P. A. Newman[2]

Received 16 October 2009; revised 21 May 2010; accepted 3 June 2010; published 7 October 2010.

[1] This study examines trends in Antarctic temperature and A_{PSC}, a temperature proxy for the area of polar stratospheric clouds, in an ensemble of Goddard Earth Observing System (GEOS) chemistry-climate model (CCM) simulations of the 21st century. A selection of greenhouse gas, ozone-depleting substance, and sea surface temperature scenarios is used to test the trend sensitivity to these parameters. One scenario is used to compare temperature trends in two versions of the GEOS CCM. An extended austral winter season is examined in detail. In May, June, and July, the expected future increase in CO_2-related radiative cooling drives temperature trends in the Antarctic lower stratosphere. At 50 hPa, a 1–3 K cooling is expected between 2000 and 2100. Ozone levels increase, despite this robust cooling signal and the consequent increase in A_{PSC}, suggesting the enhancement of stratospheric transport in future. In the lower stratosphere, the choice of climate change scenarios does not affect the magnitude of the early winter cooling. Midwinter temperature trends are generally small. In October, A_{PSC} trends have the same sign as the prescribed halogen trends. That is, there are negative A_{PSC} trends in "realistic future" simulations, where halogen loading decreases in accordance with the Montreal Protocol and CO_2 continues to increase. In these simulations, the speed of ozone recovery is not influenced by either the choice of sea surface temperature and greenhouse gas scenarios or by the model version.

Citation: Hurwitz, M. M., and P. A. Newman (2010), 21st century trends in Antarctic temperature and polar stratospheric cloud (PSC) area in the GEOS chemistry-climate model, *J. Geophys. Res.*, *115*, D19109, doi:10.1029/2009JD013397.

1. Introduction

[2] The stratosphere cooled in the late 20th and early 21st century [*Randel et al.*, 2009]. This recent stratospheric cooling has been attributed to increasing greenhouse gas concentrations [*Ramaswamy et al.*, 2001 and 2006] and, in the polar lower stratosphere where the largest decreases in temperature have been observed, to ozone depletion [*Ramaswamy et al.*, 2001; *Manzini et al.*, 2003]. In the Antarctic, stratospheric cooling has been most evident in late winter and spring: The breakup date of the Southern Hemisphere (SH) polar vortex has been delayed in recent decades, due to the radiative cooling associated with springtime ozone depletion [*Akiyoshi et al.*, 2009].

[3] *Eyring et al.* [2007] evaluated chemistry-climate model (CCM) simulations of the 21st century using boundary conditions representing a "realistic future" in which atmospheric CO_2 concentrations continue to increase while compliance with the Montreal Protocol leads to decreased halogen loading. The vertical profile of the predicted global and annual mean cooling was consistent with increasing atmospheric greenhouse gas concentrations. Midwinter polar temperature trends (January–February in the Northern Hemisphere, NH; August–September in the SH) varied widely between models in the NH and were generally negative but not statistically significant in the SH.

[4] Previous studies have examined the relationship between polar stratospheric temperature and polar ozone. *Rex et al.* [2004 and 2006] found a linear, empirical relationship between chemical ozone loss and V_{PSC} (a high-latitude temperature integral representing the volume of polar stratospheric clouds, PSCs) in Arctic winters. Similarly, *Tilmes et al.* [2007] found a compact, linear relationship between ozone loss and the potential for chlorine activation (PACl, a combined measure of stratospheric chlorine and temperature), in a chemistry-climate simulation of the late 20th century. While the linearity of the relationship between ozone loss and measures of the wintertime-averaged potential for ozone depletion may not persist in the future [*Braesicke et al.*, 2006], polar stratospheric temperature may remain an important indicator of the potential for chemical ozone loss. For example, *Newman et al.* [2004] predicted that, in the early 21st century, halogen-related decreases in the size of the Antarctic ozone hole

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[1] NASA Postdoctoral Program, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[2] NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

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Dispersion and lifetime of the SO_2 cloud from the August 2008 Kasatochi eruption

N. A. Krotkov,[1] M. R. Schoeberl,[2] G. A. Morris,[3] S. Carn,[4] and K. Yang[5]

Received 1 February 2010; revised 23 September 2010; accepted 29 September 2010; published 21 December 2010.

[1] Hemispherical dispersion of the SO_2 cloud from the August 2008 Kasatochi eruption is analyzed using satellite data from the Ozone Monitoring Instrument (OMI) and the Goddard Trajectory Model (GTM). The operational OMI retrievals underestimate the total SO_2 mass by 20–30% on 8–11 August, as compared with more accurate offline Extended Iterative Spectral Fit (EISF) retrievals, but the error decreases with time due to plume dispersion and a drop in peak SO_2 column densities. The GTM runs were initialized with and compared to the operational OMI SO_2 data during early plume dispersion to constrain SO_2 plume heights and eruption times. The most probable SO_2 heights during initial dispersion are estimated to be 10–12 km, in agreement with direct height retrievals using EISF algorithm and IR measurements. Using these height constraints a forward GTM run was initialized on 11 August to compare with the month-long Kasatochi SO_2 cloud dispersion patterns. Predicted volcanic cloud locations generally agree with OMI observations, although some discrepancies were observed. Operational OMI SO_2 burdens were refined using GTM-predicted mass-weighted probability density height distributions. The total refined SO_2 mass was integrated over the Northern Hemisphere to place empirical constraints on the SO_2 chemical decay rate. The resulting lower limit of the Kasatochi SO_2 e-folding time is ~8–9 days. Extrapolation of the exponential decay back in time yields an initial erupted SO_2 mass of ~2.2 Tg on 8 August, twice as much as the measured mass on that day.

Citation: Krotkov, N. A., M. R. Schoeberl, G. A. Morris, S. Carn, and K. Yang (2010), Dispersion and lifetime of the SO_2 cloud from the August 2008 Kasatochi eruption, *J. Geophys. Res.*, *115*, D00L20, doi:10.1029/2010JD013984.

1. Introduction

[2] Kasatochi Volcano (52.18°N, 175.51°W) is one of many mostly submarine volcanoes whose summit emerges from the waters of the Bering Sea off the southwest coast of Alaska. After short precursory seismic activity starting on 7 August, Kasatochi erupted several times injecting sulfur dioxide (SO_2) and ash directly into the Arctic lower stratosphere [*Dean et al.*, 2008; *Waythomas et al.*, 2010]. Satellite measurements of the SO_2 loading by ultraviolet (UV) and infrared (IR) sensors found a maximum total SO_2 mass of ~0.5–2.7 Tg in the Kasatochi volcanic cloud [*Richter et al.*, 2009; *Corradini et al.*, 2010; *Karagulian et al.*, 2010; *Kristiansen et al.*, 2010; *Prata et al.*, 2010; *Yang et al.*, 2010]. Emission of ~2–3 Tg SO_2 ranks the 2008 Kasatochi eruption as the largest SO_2 release measured since the August 1991 eruption of Cerro Hudson (Chile), and the largest at high northern latitudes since the beginning of space-based SO_2 measurements in 1978 [*Carn et al.*, 2003].

[3] Compared to volcanic ash clouds that have atmospheric residence times of a few days, the lifetime of volcanic SO_2 in the upper troposphere and lower stratosphere (UTLS) is typically longer [*Bluth et al.*, 1992; *Guo et al.*, 2004; *Prata and Bernardo*, 2007; *Eckhardt et al.*, 2008], allowing for the monitoring of plume dispersion for extended time periods. The main mechanism of removal of stratospheric SO_2 is photochemical conversion to sulfuric acid though gas-phase reaction with the hydroxyl radical, OH [*McKeen et al.*, 1984; *Chin et al.*, 1996, 2000; *Koch et al.*, 1999; *Barth et al.*, 2000]. Sulfuric acid is hygroscopic and subsequently forms sulfate aerosol with stratospheric residence times from months to years [*Junge et al.*, 1961; *Rosen*, 1971]. Sulfate aerosol plays an important role in climate change and atmospheric chemistry [e.g., *Robock*, 2000]. By scattering and absorbing solar and terrestrial radiation, they cause a direct radiative forcing of climate. Sulfate particles also influence the microphysics of meteorological clouds formed in their presence, resulting in indirect aerosol effects (e.g., impacts on the reflectivity of clouds) [*Twomey*, 1977]. By providing the surface for heterogeneous chemical reactions that liberate chlorine,

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[1] NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.
[2] Science and Technology Corporation, Columbia, Maryland, USA.
[3] Department of Physics and Astronomy, Valparaiso University, Valparaiso, Indiana, USA.
[4] Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, Michigan, USA.
[5] Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County, Baltimore, Maryland, USA.

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Narrowing of the upwelling branch of the Brewer-Dobson circulation and Hadley cell in chemistry-climate model simulations of the 21st century

Feng Li,[1] Richard. S. Stolarski,[2] Steven Pawson,[2] Paul A. Newman,[2] and Darryn Waugh[3]

Received 22 April 2010; revised 24 May 2010; accepted 1 June 2010; published 10 July 2010.

[1] Changes in the width of the upwelling branch of the Brewer-Dobson circulation and Hadley cell in the 21st Century are investigated using simulations from a coupled chemistry-climate model. In these model simulations the tropical upwelling region narrows in the troposphere and lower stratosphere. The narrowing of the Brewer-Dobson circulation is caused by an equatorward shift of Rossby wave critical latitudes and Eliassen-Palm flux convergence in the subtropical lower stratosphere. In the troposphere, the model projects an expansion of the Hadley cell's poleward boundary, but a narrowing of the Hadley cell's rising branch. Model results suggest that eddy forcing may also play a part in the narrowing of the rising branch of the Hadley cell. **Citation:** Li, F., R. S. Stolarski, S. Pawson, P. A. Newman, and D. Waugh (2010), Narrowing of the upwelling branch of the Brewer-Dobson circulation and Hadley cell in chemistry-climate model simulations of the 21st century, *Geophys. Res. Lett.*, *37*, L13702, doi:10.1029/2010GL043718.

1. Introduction

[2] Strong evidence of a tropical belt expansion during the last three decades has been reported. Observational studies have shown that the Tropics have widened since 1979 by more than two degrees latitude – these studies use different empirical measures of the tropical width, such as the distance between the subtropical jets in the two hemispheres [*Hu and Fu*, 2007], the latitudinal range of tropical outgoing longwave radiation [*Hu and Fu*, 2007], and the subtropical tropopause height [*Seidel and Randel*, 2007]. Expansion of the Hadley circulation in the 20th and 21st Century is also simulated by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) models [*Lu et al.*, 2007]. The widening of the Tropics is associated with changes in the precipitation pattern, the hydrological cycle, jet streams, and storm tracks, and therefore has important implications in climate change [*Seidel et al.*, 2008]. Understanding the mechanisms responsible for the tropical belt widening, particularly for the expansion of the Hadley cell, is an active research area.

[3] There are two important aspects of tropical expansion that have not been examined in detail in previous studies. The first is the width of the stratospheric tropical circulation under global warming. The stratospheric circulation in the Tropics is characterized by a slow, rising motion that forms the upwelling branch of the Brewer-Dobson circulation (BDC). The BDC plays a crucial role in the distribution of trace gases, such as ozone and water vapor, in the stratosphere. Because of its important implications for stratospheric ozone recovery, changes in the strength of the BDC in the 21st Century have been extensively studied and nearly all middle-atmosphere models predict an acceleration of the BDC [*Butchart et al.*, 2006]. However so far there has been no dedicated study on the width of the BDC. It is important to understand whether tropical expansion extends into the stratosphere and how the width change of the BDC is related to the strengthening of the BDC.

[4] The second topic is the width of the ascending branch of the Hadley cell. Note that Hadley cell widening refers to the expansion of its descending branch, which does not necessarily indicate an expansion of its ascending branch. Studying the width of the ascending branch of the Hadley cell may help to understand tropical expansion.

[5] The purpose of this study is to investigate the response of the width of the upwelling branch of the BDC and Hadley cell to climate change in the 21st Century. Here, we use simulations from the Goddard Earth Observing System Coupled Chemistry-Climate Model (GEOSCCM) to show a narrowing of tropical upwelling in the lower stratosphere and troposphere.

2. Simulations and Methods

[6] Details of the model used in this study, the GEOSCCM Version 1, are given in the work of *Pawson et al.* [2008]. For this work, we analyzed two simulations of the 21st Century (2001–2099), referred to as FA1b and FA2, which used IPCC GHG scenarios A1b and A2. For consistency with the GHG scenarios, the two model runs use single realizations of sea surface temperature (SST) and sea ice from appropriate AR4 scenarios run with the National Center for Atmospheric Research (NCAR) Community Climate System Model 3.0 (CCSM3). Both simulations use an identical halogen scenario (WMO 2003 scenario AB) and all other external forcing is identical. Annual-mean results are presented in this study.

[7] The BDC is the mean mass transport circulation in the stratosphere and it should be regarded as a Lagrangian-Mean circulation, but *Dunkerton* [1978] showed that the BDC could be approximated by the residual circulation under the Transformed Eulerian-Mean (TEM) framework. In section 3 we investigate the width of the BDC's upwelling branch, which is defined as the latitudinal range of positive residual vertical velocity in the Tropics. We also study the

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[1] GEST, University of Maryland Baltimore County, Baltimore, Maryland, USA.
[2] NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.
[3] Johns Hopkins University, Baltimore, Maryland, USA.

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Atmospheric Chemistry and Physics

Finding the missing stratospheric Br_y: a global modeling study of $CHBr_3$ and CH_2Br_2

Q. Liang[1,2,*], **R. S. Stolarski**[1], **S. R. Kawa**[1], **J. E. Nielsen**[3,4], **A. R. Douglass**[1], **J. M. Rodriguez**[1], **D. R. Blake**[5], **E. L. Atlas**[6], and **L. E. Ott**[3,7]

[1]NASA Goddard Space Flight Center, Atmospheric Chemistry and Dynamics Branch, Code 613.3, Greenbelt, MD 20771, USA
[2]Oak Ridge Associated Universities, NASA Postdoctoral Program, Oak Ridge, Tennessee 37831, USA
[3]NASA Goddard Space Flight Center, Global Modeling and Assimilation Office, Code 610.1, Greenbelt, MD 20771, USA
[4]Science Systems and Applications Inc., Lanham, Maryland, USA
[5]University of California, 570 Rowland Hall, Irvine, CA 92697, USA
[6]University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, USA
[7]Goddard Earth Sciences & Technology Center, University of Maryland, Baltimore County, Maryland, USA
[*]now at: Goddard Earth Sciences & Technology Center, University of Maryland, Baltimore County, Maryland, USA

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Abstract. Recent in situ and satellite measurements suggest a contribution of ~5 pptv to stratospheric inorganic bromine from short-lived bromocarbons. We conduct a modeling study of the two most important short-lived bromocarbons, bromoform ($CHBr_3$) and dibromomethane (CH_2Br_2), with the Goddard Earth Observing System Chemistry Climate Model (GEOS CCM) to account for this missing stratospheric bromine. We derive a "top-down" emission estimate of $CHBr_3$ and CH_2Br_2 using airborne measurements in the Pacific and North American troposphere and lower stratosphere obtained during previous NASA aircraft campaigns. Our emission estimate suggests that to reproduce the observed concentrations in the free troposphere, a global oceanic emission of 425 Gg Br yr^{-1} for $CHBr_3$ and 57 Gg Br yr^{-1} for CH_2Br_2 is needed, with 60% of emissions from open ocean and 40% from coastal regions. Although our simple emission scheme assumes no seasonal variations, the model reproduces the observed seasonal variations of the short-lived bromocarbons with high concentrations in winter and low concentrations in summer. This indicates that the seasonality of short-lived bromocarbons is largely due to seasonality in their chemical loss and transport. The inclusion of $CHBr_3$ and CH_2Br_2 contributes ~5 pptv bromine throughout the stratosphere. Both the source gases and inorganic bromine produced from source gas degradation (Br_y^{VSLS}) in the troposphere are transported into the stratosphere, and are equally important. Inorganic bromine accounts for half (2.5 pptv) of the bromine from the inclusion of $CHBr_3$ and CH_2Br_2 near the tropical tropopause and its contribution rapidly increases to ~100% as altitude increases. More than 85% of the wet scavenging of Br_y^{VSLS} occurs in large-scale precipitation below 500 hPa. Our sensitivity study with wet scavenging in convective updrafts switched off suggests that Br_y^{VSLS} in the stratosphere is not sensitive to convection. Convective scavenging only accounts for ~0.2 pptv (4%) difference in inorganic bromine delivered to the stratosphere.

1 Introduction

Oceanic emission of very short-lived substances (VSLS) is thought to contribute significantly to reactive bromine in the stratosphere in addition to long-lived halons and methyl bromide (Kurylo and Rodriguez, 1999). VSLS are not accounted for in most chemistry climate models. In the stratosphere, inorganic bromine produced from VSLS (Br_y^{VSLS}) contributes to catalytic destruction of ozone (e.g., McElroy et al., 1986; Solomon et al., 1995; Garcia and Solomon, 1994;

Correspondence to: Q. Liang
(qing.liang@nasa.gov)

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Interannual variability of ozone in the winter lower stratosphere and the relationship to lamina and irreversible transport

Mark A. Olsen,[1] Anne R. Douglass,[2] Mark R. Schoeberl,[3] Jose M. Rodriquez,[2]
and Yasuko Yoshida[1,4]

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[1] We use the high-resolution dynamic limb sounder (HIRDLS) high-vertical resolution ozone profiles in the northern hemisphere lower stratosphere to examine the meridional transport out of the tropics. We focus on February 2005–2007 when there are differences in the dynamical background in the lower stratosphere due to the states of the quasi-biennial oscillation and polar vortex. HIRDLS data reveal a large number of low ozone laminae that have the characteristics of tropical air at midlatitudes. More laminae are observed in February in 2006 than in 2005 or 2007. Because laminae can form, move out of the tropics, and return to the tropics without mixing into the midlatitude ozone field, the number of laminae is not directly related to the net transport. We use equivalent latitude coordinates to discriminate between reversible and irreversible laminar transport. The equivalent latitude analysis shows greater irreversible transport between the tropics and lower midlatitudes in both 2005 and 2007 compared to 2006 despite the higher number of laminae observed in 2006. Our conclusion that there was more irreversible transport of tropical air into the lower midlatitudes in 2005 and 2007 is supported by equivalent length analysis of mixing using microwave limb sounder N_2O measurements. This study shows that reversibility must be considered in order to infer the importance of lamination to net transport.

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1. Introduction

[2] Understanding the variability of ozone in the lower extratropical stratosphere is important for evaluating midlatitude ozone trends, attribution to changes in composition, and the development of reliable models for prediction. Two processes contribute to this variability. The first is the descent of ozone from the upper stratosphere into the lower stratosphere where ozone chemical lifetimes are long. Vertical propagation and dissipation of planetary waves that are linked to stratospheric warmings and the phase of the quasi-biennial oscillation (QBO) control the seasonal variation in the ozone descent rate. The second process is the direct eddy transport of low ozone air out of the tropics into the midlatitude stratosphere. Mass continuity assures that there must be some outflow from the tropics into the extratropical lower stratosphere since the mean vertical velocity does not increase with height as rapidly as the atmospheric density decreases, as confirmed by the vertical propagation of the tropical tape recorder signal [e.g., *Mote et al.*, 1996; *Schoeberl et al.*, 2008]. The phase of the QBO and state of the polar vortex are also associated with tropical outflow and mixing [e.g., *Shuckburgh et al.*, 2001; *Waugh*, 1993]. *Randel and Wu* [2007] show a strong correlation between the QBO and midlatitude lower stratospheric ozone. Modulation of the tropical outflow or the large-scale descent or both could produce this link.

[3] Low ozone laminae are created in the lower stratosphere as wave propagation and differential advection shear zones of tropical air into the higher background ozone of the middle latitudes. *Dobson* [1973] first identified these thin layers of ozone minima in the middle latitude, upper troposphere/lower stratosphere as signatures of poleward isentropic transport from the tropics. Studies of ozonesonde records indicate that lamination occurs most frequently during winter or spring around 14 to 15 km altitude [*Dobson*, 1973; *Reid and Vaughan*, 1991; *Hwang et al.*, 2007]. *Reid and Vaughan* [1991] examined multiyear ozonesonde records from 20 stations and found large interannual variability in the number of observed laminae.

[4] Theoretical studies have demonstrated that the formation and propagation of laminae is one of the principal means of meridional transport into the extratropical lower

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[1] Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore, Maryland, USA.

[2] Atmospheric Chemistry and Dynamics Branch, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[3] Science and Technology Corporation, Hampton, Virginia, USA.

[4] Now at Science Systems and Applications, Inc., Lanham, Maryland, USA.

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Multimodel assessment of the factors driving stratospheric ozone evolution over the 21st century

L. D. Oman,[1,2] D. A. Plummer,[3] D. W. Waugh,[2] J. Austin,[4] J. F. Scinocca,[3]
A. R. Douglass,[1] R. J. Salawitch,[5] T. Canty,[5] H. Akiyoshi,[6] S. Bekki,[7] P. Braesicke,[8]
N. Butchart,[9] M. P. Chipperfield,[10] D. Cugnet,[7] S. Dhomse,[10] V. Eyring,[11] S. Frith,[1,12]
S. C. Hardiman,[9] D. E. Kinnison,[13] J.-F. Lamarque,[13] E. Mancini,[14] M. Marchand,[7]
M. Michou,[15] O. Morgenstern,[16] T. Nakamura,[6] J. E. Nielsen,[1,12] D. Olivié,[15] G. Pitari,[14]
J. Pyle,[8] E. Rozanov,[17,18] T. G. Shepherd,[19] K. Shibata,[20] R. S. Stolarski,[1,2]
H. Teyssèdre,[15] W. Tian,[10] Y. Yamashita,[6] and J. R. Ziemke[1,21]

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[1] The evolution of stratospheric ozone from 1960 to 2100 is examined in simulations from 14 chemistry-climate models, driven by prescribed levels of halogens and greenhouse gases. There is general agreement among the models that total column ozone reached a minimum around year 2000 at all latitudes, projected to be followed by an increase over the first half of the 21st century. In the second half of the 21st century, ozone is projected to continue increasing, level off, or even decrease depending on the latitude. Separation into partial columns above and below 20 hPa reveals that these latitudinal differences are almost completely caused by differences in the model projections of ozone in the lower stratosphere. At all latitudes, upper stratospheric ozone increases throughout the 21st century and is projected to return to 1960 levels well before the end of the century, although there is a spread among models in the dates that ozone returns to specific historical values. We find decreasing halogens and declining upper atmospheric temperatures, driven by increasing greenhouse gases, contribute almost equally to increases in upper stratospheric ozone. In the tropical lower stratosphere, an increase in upwelling causes a steady decrease in ozone through the 21st century, and total column ozone does not return to 1960 levels in most of the models. In contrast, lower stratospheric and total column ozone in middle and high latitudes increases during the 21st century, returning to 1960 levels well before the end of the century in most models.

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1. Introduction

[2] Projecting the evolution of ozone in the 21st century is a critical issue. While changes in ozone are presently controlled primarily by declines in halogen concentrations, variations in temperature, circulation, and oxides of nitrogen and hydrogen also affect ozone [*World Meteorological Organization* (*WMO*), 2003, 2007]. Throughout the stratosphere, there will be long-term changes in various processes as well as the relative importance of these processes on

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[1] NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

[2] Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, Maryland, USA.

[3] Canadian Centre for Climate Modelling and Analysis, Victoria, British Columbia, Canada.

[4] NOAA Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, USA.

[5] Department of Chemistry and Biochemistry, University of Maryland, College Park, Maryland, USA.

[6] National Institute for Environmental Studies, Tsukuba, Japan.

[7] LATMOS-IPSL, UPMC, Paris, France.

[8] NCAS-Climate-Chemistry, Centre for Atmospheric Science, Department of Chemistry, University of Cambridge, Cambridge, UK.

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[9] Met Office Hadley Centre, Exeter, UK.

[10] School of Earth and Environment, University of Leeds, Leeds, UK.

[11] Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany.

[12] Science Systems and Applications, Inc., Lanham, Maryland, USA.

[13] NCAR, Boulder, Colorado, USA.

[14] Dipartimento di Fisica, University of L'Aquila, L'Aquila, Italy.

[15] GAME/CNRM, Météo-France, CNRS, Toulouse, France.

[16] National Institute of Water and Atmospheric Research, Lauder, New Zealand.

[17] Physical-Meteorological Observatory Davos, World Radiation Center, Davos, Switzerland.

[18] IAC, ETHZ, Zurich, Switzerland.

[19] Department of Physics, University of Toronto, Toronto, Ontario, Canada.

[20] Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Japan.

[21] Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore County, Catonsville, Maryland, USA.

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A new ENSO index derived from satellite measurements of column ozone

J. R. Ziemke[1,2], **S. Chandra**[1,2], **L. D. Oman**[2], **and P. K. Bhartia**[2]

[1]Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County, Baltimore, Maryland, USA
[2]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

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Abstract. Column Ozone measured in tropical latitudes from Nimbus 7 total ozone mapping spectrometer (TOMS), Earth Probe TOMS, solar backscatter ultraviolet (SBUV), and Aura ozone monitoring instrument (OMI) are used to derive an El Nino-Southern Oscillation (ENSO) index. This index, which covers a time period from 1979 to the present, is defined as the "Ozone ENSO Index" (OEI) and is the first developed from atmospheric trace gas measurements. The OEI is constructed by first averaging monthly mean column ozone over two broad regions in the western and eastern Pacific and then taking their difference. This differencing yields a self-calibrating ENSO index which is independent of individual instrument calibration offsets and drifts in measurements over the long record. The combined Aura OMI and MLS ozone data confirm that zonal variability in total column ozone in the tropics caused by ENSO events lies almost entirely in the troposphere. As a result, the OEI can be derived directly from total column ozone instead of tropospheric column ozone. For clear-sky ozone measurements a +1 K change in Nino 3.4 index corresponds to +2.9 Dobson Unit (DU) change in the OEI, while a +1 hPa change in SOI coincides with a -1.7 DU change in the OEI. For ozone measurements under all cloud conditions these numbers are +2.4 DU and -1.4 DU, respectively. As an ENSO index based upon ozone, it is potentially useful in evaluating climate models predicting long term changes in ozone and other trace gases.

1 Introduction

It is well known that El Nino Southern Oscillation (ENSO) events in the tropical Pacific are associated with an atmosphere-ocean coupled interaction which induces inter-annual ($\sim$2–7 year periods) planetary-scale changes in ocean sea-surface temperature and currents, surface pressure, atmospheric temperature and winds, clouds and precipitation, and trace gases in the troposphere. The term "ENSO" is commonly referred to either El Nino (anomalously warm ocean temperatures in the tropical eastern Pacific – i.e., "warm phase") or La Nina (anomalously cool ocean temperatures in the tropical eastern Pacific – i.e., "cool phase"). ENSO events represent changes in tropical sea-surface temperature and other geophysical parameters relative to average conditions which are driven by the persistent Walker Circulation. The Walker Circulation is characterized by warm ocean temperatures and moist convection in the western Pacific and cooler ocean temperatures and smaller convective activity in the eastern Pacific.

Trenberth (1997) has provided an historical account of ENSO and the various geophysical indices used to represent these events. El Nino events have long been identified by anomalously warm ocean currents running southward along the coasts of Peru and Ecuador which alter the meteorological and ecological conditions in these regions. As *Trenberth* (1997) implies, it is difficult to define ENSO and there is really not one single universal ENSO index fully representing all the related complex physical oceanic and atmospheric conditions. Historically, there have been many indices defined to represent ENSO events. Two well known ENSO indices are based upon sea surface pressure differences at Tahiti and Darwin (dating from the 1880's) and the Nino 3.4 index based upon sea-surface temperature anomalies starting

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Correspondence to: J. R. Ziemke
(j. r. ziemke@nasa.gov)

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14. ABSTRACT

The 2010 Technical Highlights describes the efforts of all members of the Laboratory for Atmospheres. Their dedication to advancing Earth Science through conducting research, developing and running models, designing instruments, managing projects, running field campaigns, and numerous other activities, is highlighted in this report.

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