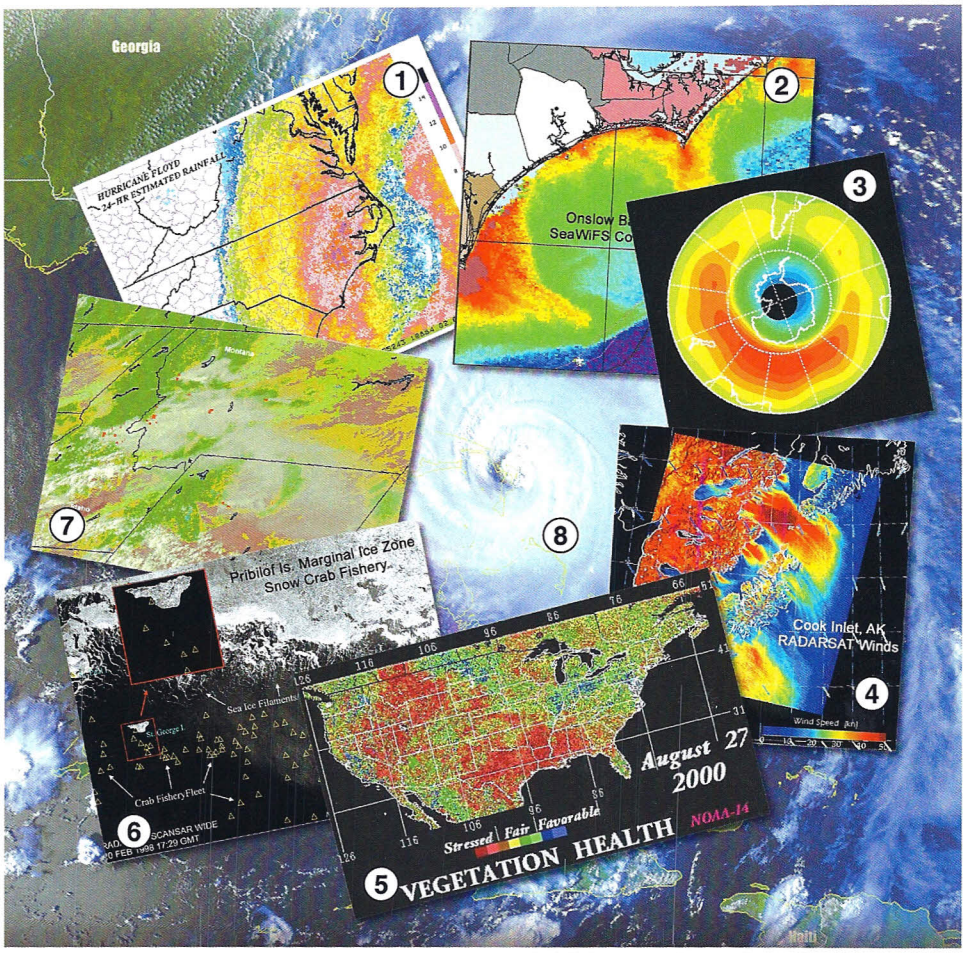
Office of Research and Applications

. . . in the year 2000 . . .



(1) Hurricane Floyd 24 hour auto-estimator rainfall estimates.

(2) SeaWiFS ocean chlorophyll image data displayed in ArcView" GIS application for Onslow Bay, NC near Wilmington, NC. GIS enables far wider quantitative use of satellite data than does the more complicated scientific data formats.

(3) This figure shows the October 1999 Southern Hemisphere (Antarctic) ozone hole measured by the Solar Backscatter Ultraviolet (SBUV/2) instrument. The ozone hole with total ozone values below 220 Dobson Units is shown in blue. The region of no SBUV/2 data over the south pole is shown in black.

(4) RADARSAT-1 synthetic aperture radar data processed for winds speed imagery showing high wind speed coastal jets flowing through mountain passes through Cook Inlet, AK.

(5) Following AVHRR-based estimate of vegetation health, intensive drought developed in western U.S. In addition to crop and pasture failure, drought caused large area intensive fires. Since May when drought started, millions of acres of forest have been burned.

(6) RADARSAT-1 synthetic aperture radar imagery of marginal ice zone near Pribilof Island during snow crab commercial fishing season. The high resolution of the image allows detection of many of the fishing vessels engaged in the fishery.

(7) GOES-8 composite visible and infrared image showing the smoke pall from fires in the western U.S. on August 8, 2000. The 650 mb streamlines analysis is superimposed on this image.

(8) Hurricane Floyd at category 4 intensity as it batters the Island of Great Abaco in the Bahamas on September 14, 1999. The storm turned to the northwest and hurricane warnings were raised for portions of the southeastern United States coast.

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EXECUTIVE SUMMARY

The Purpose of this NESDIS/ORA Review Document

On September 25, 1997, NOAA established a Science Advisory Board (SAB) to obtain independent advice on the scientific quality and relevance of its products and services. The SAB is responsible for advising the Under Secretary of Commerce for Oceans and Atmospheres on long- and short-range strategies for research, education, and application of science to NOAA's environmental stewardship and prediction mission. The SAB is constituted as an official Federal Advisory Committee and, as such, its establishment and operations comply with the Federal Advisory Committee Act and related regulations.

In 1999, NOAA asked the SAB to assist in the review of the quality and use of science in support of NOAA's mission. The SAB recommended that reviews should include considerations of the following themes: (1) quality and credibility, (2) timeliness and scale; (3) science/policy connection; (4) capacity building; (5) education, (6) efficiency, coordination, synergy and maximization of resources; (7) social science integration, and (8) diversity.

NESDIS' ORA agreed to hold its inaugural NOAA SAB review in September 2000. This document was prepared as overview material for that review and is organized as follows:

- The introduction provides motivation for our research (Section 1);
- The ORA personnel and partnership philosophy, including diversity, are reviewed (Section 2);
- Our staff, organization, and facilities are enumerated (Section 3);
- Justification for our work and place in NOAA's mission is described (Section 4);
- Major activities are defined in broad areas (Section 5);
- Significant activities are highlighted (Section 6);
- Our efforts at outreach and diversity are summarized (Section 7); and
- Explicit awards, recognition, visiting scientists, publications, and committee memberships are appended (Appendices).

1. INTRODUCTION

As early as 1948, pioneers in modern atmospheric science were paving the way for satellite meteorology with the first serious attempt to analyze the atmosphere from "space" using photographs taken from V2 Rockets. Nearly 12 years later, on April 1, 1960, the meteorological satellite era "officially" began with the launch of TIROS 1. The first TIROS television pictures presented numerous challenges before rectified, navigated, and calibrated images were realized; these same functions are still fundamental to correct utilization of satellite data today. The TIROS vidicon camera images were put to use almost immediately through image analysis and subsequent modification of synoptic weather maps.

From these early days when satellite images were uncalibrated photographs of clouds and the Earth, growth in remote sensing and computer technologies have led to the present day satellite high-resolution, multi-spectral digital renderings. Many countries, following the lead of the U.S., have engaged in free and open exchange of satellite data. As a result, operational meteorological satellites have become an essential source of data for weather forecasting to national weather services around the globe. Simultaneously, new instruments on research satellites have provided insights into future satellite system capabilities, so that fields like satellite oceanography are growing vigorously. From a meager start 40 years ago, meteorological and oceanographic satellites are now used for a variety of applications that span scales from nowcasting to climate, and include land, ocean, atmosphere, and ecological applications.

Yet with all of the advances in space technology over the past four decades, there remain significant challenges before maximum utilization of satellite data is achieved. Several important tenets demand consideration.

- Satellite data are an integral part of our weather forecast system and must be fully exploited. It is unrealistic to think that we will improve forecasting without improvements in NWP models and coincident improvements in the assimilation of satellite data and products (which include radiances, soundings, winds, precipitation, cloud, land and ocean properties). While satellite data have had a major positive impact in numerical weather prediction, satellite data remain greatly underutilized (for some systems less than 20% of the data are used). Improved assimilation requires that we address multiple issues such as inadequate computer capacity, incomplete data flow, and immature science.

- We should expect great strides forward with improvements to the global space-based observing system. The advancement to improved microwave sensors and hyper-spectral imaging and sounding is a *natural progression*, which provides exciting new opportunities and challenges with truly adaptive observing systems. In concert with these new capabilities, we must prepare for the predicted five orders of magnitude growth in data volume and content which will be available from systems such as AIRS, IASI, CrIS (major components of our future polar-orbiting satellite

constellations) and GIFTS (which promises to be a major part of our future geostationary observing platforms). In addition, updated and improved methods for preparing products for operational transition and distribution via the Internet and conventional communications must be developed in order to accommodate the rapid-paced development cycle that today's informed users now expect.

- Satellites have overlapping and finite life times. To achieve high cost-benefit ratios, we must optimize their utilization and long-term stability for both real-time and climatological applications and monitoring. Meeting both ends of the temporal spectrum requires careful calibration and validation of data sets, understanding of instruments, improved sensor accuracies, long-term archival and reanalysis capability. To this end, all countries involved in developing and providing environmental satellite data must be involved in the validation and assessment of those instruments, as well as their full exploitation.

- Satellite meteorology is a global enterprise that demands a coordinated, international science-based development. This type of collaboration must also extend to any new developing area, such as operational satellite oceanography. Maximum cooperation, benefit, and utilization of global satellite development are direct outcomes of focused working groups that transcend political boundaries, but are supported under the auspices of intergovernmental protocols.

We must move forward with a strong research component; a component grounded in solid understanding of remote sensing physics and awareness that *each spatial element in an image has a continuous spectrum that may be used to analyze the surface and atmosphere.* From strong scientific fundamentals, we develop the physical intuition that will guide our analyses and lead to insightful, timely applications required by our increasingly sophisticated satellite data user.

The Office of Research and Applications

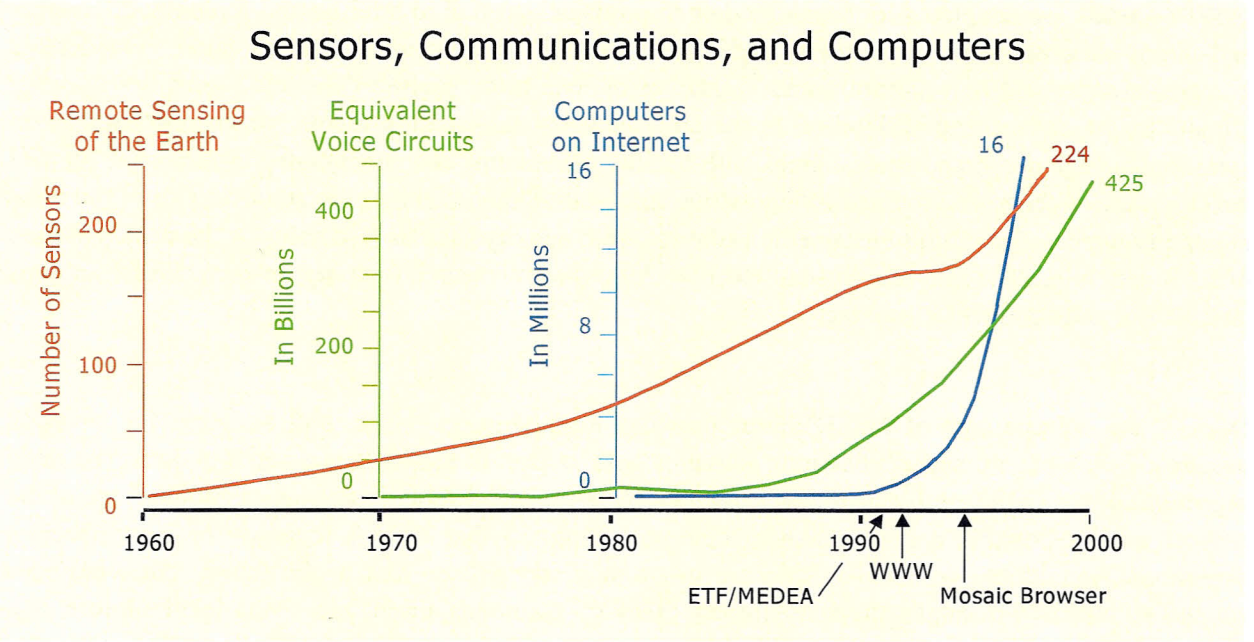
The Office of Research and Applications (ORA) supports the mission of the National Oceanic and Atmospheric Administration (NOAA) and the National Environmental Satellite, Data, and Information Service (NESDIS) to provide observations and information from environmental satellites to describe and predict changes in the Earth's environment, and conserve and manage wisely the Nation's coastal and marine resources to ensure sustainable economic opportunities. Activity within the ORA focuses on NOAA's strategic themes of **(1) environmental assessment and prediction and (2) environmental stewardship.** In the area of environmental assessment and prediction, ORA scientists focus on assuring current satellite data utilization is maximized as part of NOAA's integrated environmental observation, assessment, and forecast services directed toward enhancing public safety and the Nation's economic and environmental security. ORA scientists are actively engaged in three areas within that theme: (1a) Advance Short-Term Warning and Forecast Services where science is focused on achieving the goals of the U.S. Weather Research Program and on improving the utilization of satellite data for Numerical Weather Prediction; (1b) Implement Seasonal to Interannual Climate Forecasts, where atmospheric

(NWP) models are coupled with ocean models to produce seasonal to inter-annual forecasts of weather and ocean variables; and, (1c) Predict and Assess Decadal to Centennial Change where considerable energies are devoted to calibration and validation of long-term satellite data sets useful for studying climate trends and natural variability. In the environmental stewardship theme, which concentrates on maintaining U.S. ocean and coastal areas with healthy ecosystems and encouraging wise human use and development of ocean, coastal and living marine resources, ORA scientists are active in two of the three major focus areas: (2a) Build Sustainable Fisheries, with activity such as leadership in the demonstration of SAR data in Alaska; and (2b) Sustain Healthy Coasts, with research focusing on such diverse areas as ocean color and coral reef bleaching.

ORA is the science arm of NESDIS and provides leadership, guidance, and direction for NESDIS research, development, and applications activities with respect to satellites and satellite data. The main objectives of the ORA are to ensure that satellite remote sensing data and information products are of the highest quality possible and to enhance their utilization, so that NOAA missions of environmental assessment, prediction, and stewardship are met today, and will be met in the future. ORA provides counsel to NESDIS management to assure that NESDIS maintains a dynamic vision for the future, and through that vision helps assure the Nation maintains a state of the art, vibrant operational environmental satellite program that evolves based on sound scientific principles. Through its Divisions, ORA conducts oceanographic, land surface and atmospheric research on the use of satellite data for monitoring environmental characteristics and their change. ORA is responsible for developing applications of satellite data, as well as developing algorithms to produce satellite products, for uses relevant to NOAA's mission.

Meeting the Challenges

As the new millennium progresses, environmental remote sensing will undergo rapid changes brought on by the explosion in the number of sensors and telecommunications assets started in the last decade (figure shown). While the number of sensors grew nearly linearly until about 1992, their complexity has been increasing such that data volume can be expected to grow by five orders of magnitude in the next 10 years. During the 1990s, communications and computing capability also increased dramatically so that it is possible to partner with an international community of scientists working on improved data dissemination and better utilization. The ORA strategy for meeting the challenge of improving remote-sensing systems and their utilization is to (1) guide the NESDIS decision making process regarding systems, programs, and applications, (2) leverage resources by maintaining and enhancing outside links and collaborations, (3) foster strong working relationships with the entire user community both locally and globally, and (4) invest in the future through resource allocation to risk-managed, high payoff opportunities.



The number of sensors, voice and computer connections since the launch of the first Earth observing satellite in 1960 implying exponential growth in number of potential users.

Satellite Data Assimilation

As indicated earlier, satellite data remain underutilized in numerical weather prediction. Consider the example of the current Advanced Microwave Sounding Unit sensor on NOAA's polar orbiting satellite. In spite of its early successful assimilation, still less than 1/7th of the available data over oceans and almost none over land are being used by the most prominent NWP centers in the world. Considerable detail and information is not being assimilated.

Recognizing the need to improve the use of satellite data in NWP, NOAA's NWS National Centers for Environmental Prediction, OAR's Atmospheres Division, and NESDIS' ORA, together with NASA's Goddard Laboratory for Atmospheric Science, have formally joined together to maximize the utilization of satellite data to improve weather forecasts. At the focus of that activity is the formation of a Joint Center for Satellite Data Assimilation for NWP. The goal of this new synergism is to fully exploit satellite data for both research and operational purposes and has received strong endorsement by NOAA and NASA Associate Administrators. As a signatory, ORA has been involved in this activity from its inception and will continue to play a major role in achieving its goals.

We have also engaged our cooperative institutes to explore the impact of our data and products in the operational numerical weather forecast models. Working together with the NCEP scientists, we are making new strides in assimilating observations and products from the composite observing system comprised of land, ship, buoy, balloon, and aircraft in situ data and leo/geo satellite remote-sensing data.

Through Observing System Experiments, the impact of various components of the composite observing system are now being evaluated and possible reconfigurations within the U.S. and globally are being studied.

New Technology and Technology Transfer

ORA is preparing for and using increasingly fine resolution data in three domains—spectral, spatial, and temporal. This increased resolution is providing new observations of the physics of the atmosphere and of the physics and biology of the ocean on scales that we have not seen before and which we must prepare to fully exploit. ORA is enjoining an expanding community of national and international research partners in the efforts to explore the new science and to maximize the utilization of these enhanced remote-sensing assets. ORA has maintained active engagement in the NASA science teams that conduct field programs with ground and airborne instrumentation to prepare for new remote-sensing capabilities within the U.S. ORA scientists are members of the EOS MODIS, AIRS, and CERES science teams.

ORA faces an expanding user community which is being propelled by desktop, high-performance, low-cost computers that evolve to the next generation in an average of only 18 months. The processing power of small computers and the availability of sophisticated efficient software has changed the way ORA distributes data and products. Further, software and workstation commercial development is finally making it possible to now merge satellite data with demographic information through Geographic Information Systems. Through a Web-based virtual laboratory, more data users and research collaborators have been engaged in the task of improving remote-sensing products and services. The Virtual Lab has enabled meteorological data sharing, collaborative research, as well as education and training. ORA has installed many sites within the U.S. government and university community and has test sites outside the U.S. at the secretariat in the WMO, at the Regional Meteorological Training Center in Costa Rica, at the Met Office in Nairobi, at the CNR in Bologna, Italy, at the NSMC in Beijing, at the EUMETSAT and ECMWF in Europe, and at the JMA in Tokyo. The CoastWatch program is also an on-site workstation approach that delivers space-based oceanographic data to local users for fisheries management and coastal monitoring from eight regional nodes around the U.S. and Caribbean.

Environmental Satellites as a Global Enterprise

Through national and international science partnerships, ORA endeavors to try old approaches on new data (to create long-term monitoring data sets that enable the search for the fingerprint of climate change), to try new approaches on old data (as we learn from the new remote-sensing science we must reprocess pathfinder data sets), and to try new approaches on new data (to improve products and services in the weather forecasting arena).

ORA is leading the effort to evolve the national and international remote sensing capabilities. ORA scientists are chairing and participating in the NPOESS Operational Algorithm Teams that are preparing the next generation of polar orbiting satellites with NASA and DOD partners. ORA scientists are chairing

and participating in GOES Technical Advisory Committees that are evolving the geostationary imaging and sounding sensors and introducing new ocean sensors. ORA scientists are chairing and participating in the working group activities within the Coordinating Group for Meteorological Satellites where the international community of operational satellite partners sets communications formats, shares science algorithms, and prepares backup strategies to fill temporary gaps in the global observing system. On the international front, ORA scientists are chairing and participating in WMO Open Program Area Groups on the Global Observing System where research and operational systems are being combined into a future global observing system; ORA is active in both the Expert Team on Observational Data Requirements and Redesign of the Global Observing System and the Expert Team on Satellite Data Utilization.

ORA has fostered international partnerships with operational and research organizations: with the EUMETSAT in Europe (to prepare for METOP and evolve to MTG), with ESA in Europe (to engage in science with ENVISAT), with the JMA in Japan (to study data assimilation approaches), with the NASDA in Japan (to collaborate on ADEOS and GCOM), with the NSMC in China (to utilize FY1C and FY2B and to assist China in contributing to the global observing system), with the IMD in India (to enhance open INSAT and IRS data exchange and to coordinate Indian remote sensing contributions to the GOS), with the NRSA in India (to engage in land and ocean remote sensing collaborative research).

Conclusion

Recent developments in space technology have thrust NESDIS, thus ORA, into a new era of environmental satellites. As the research and development arm of the world's largest civil operational environmental satellite organization, ORA must adapt to realize the exciting potential offered by these new sensors. In addition, ORA must build on the heritage scientific approach and retain the corporate strengths of the existing weather satellite community. ORA aims to capitalize on the momentum of change to make the next 40 years of satellite meteorology and oceanography as progressive as the first, as evidenced by the examples given in this report.

2. PHILOSOPHY

The Office of Research and Applications is committed to building a scientific research environment that supports the well-being and continued development of the Office's individual members, establishes intellectual linkages with other research or operational partners, and extends these connections both to the global remote sensing and local user communities.

Our People

Personal Expression

Individuals are encouraged to express their independent views and offer diverging opinions on existing and emerging research areas. To maintain their scientific edge, ORA scientists are encouraged to submit external research proposals for support of work that enhances our base activities with different technical or technological approaches. This freedom promotes creativity, intellectual competition, and openness.

Motivation

As an applied research organization, ORA draws its near-term requirements from NESDIS' operational mission activities, and sets its longer-term research goals by evaluating and anticipating relevant scientific developments. These competing perspectives require long-lasting partnerships. Thus ORA fosters close working relationships with our operational and research counterparts, who are responsible for environmental satellite programs involving both U.S. and international agencies. The resulting scientific research program is both responsive in the short-term while also being forward-looking as we lay a firm foundation for future environmental satellite missions and data utilization.

Performance and Development

The Office places high priority on promoting and measuring the quality of its scientific research. We strive to ensure high quality in both research and operational mission support through a structured planning process in which each individual becomes a part of, and contributes to, the Office's five-year operating plan at the top level. Annual personal plans on the individual level then may be evaluated in terms of both the organization's goals as well as the individual's continuing professional development goals. To assist in the development of balanced personal, professional and organizational goals, our staff cooperatively has embraced specific professional performance metrics that help in the year-to-year guidance evaluation of research activities within established professional guidelines.

Diversity and Human Resources

The Office is committed to achieving balanced representation in the atmospheric, oceanographic and climate research sciences. With that balance, we can enjoy the full benefit of all the Nation's talent. To this end, the Office actively recruits qualified women and under-represented ethnic groups when hiring new scientists and technologists. The Office continues to make substantial efforts to engage young

students and attract new scientists to the fields of atmospheric, oceanographic and climate-change related sciences.

Our Partnerships

All of our partnerships are formulated on the premise of free and open data exchange and maximal utilization of global satellite data for the benefit of the local user.

With NESDIS

ORA research and development supports the entire temporal range of activities embodied by the NESDIS line offices. The Office supports the NESDIS Office of Satellite Operations through early-orbit assessment of instrument and geophysical data from new systems. The Office develops improved satellite data products and services from current systems for the NESDIS Office of Satellite Data Processing and Distribution to implement and deliver to NOAA's constituencies for support of weather, ocean, and climate forecasts and applications. The Office conducts feasibility studies and instrument evaluations for future systems being developed by the NESDIS Office of Systems Development and the National Polar-orbiting Operational Environmental Satellite System Integrated Program Office. The Office develops and monitors statistics on instruments and long-term satellite data sets required by the NESDIS Data Centers in the production of archival quality data.

With NOAA

ORA has formal agreements with the National Weather Service to improve the use of current and future satellite systems in weather forecasting, to develop innovative techniques for assimilating satellite data into numerical prediction models, and to understand the needs for new classes of observational sensors. ORA collaborates with the National Ocean and National Marine Fisheries Services to expand the use of environmental satellite data in coastal habitat, ecosystem, and fisheries applications. ORA collaborates with Oceanic and Atmospheric Research to produce satellite data sets appropriate for climatological or in-situ studies.

With the Local Community

The Office raises the public's awareness of atmospheric, oceanographic and climate-related remote sensing by making scientific data available to local Government or commerce, by supporting research grants to local and regional environmental entities, by presenting public lectures, by teaching, and by mentoring students and teachers in local school districts.

With the National Community

ORA has strong collaborative activities with other Federal agencies active in Earth remote sensing and in atmospheric and oceanic science. It works with NASA to transition new technology into operations. ORA participates with NASA, NSF, DoD, and other agencies to ensure the success of the US Weather Research Program and the US Global Change Research Program. ORA scientists support national field

programs to study atmospheric and oceanic processes. The office maintains direct contact with the USGS remote-sensing program by assigning an ORA scientist to the USGS Eros Data Center.

With the Global Community

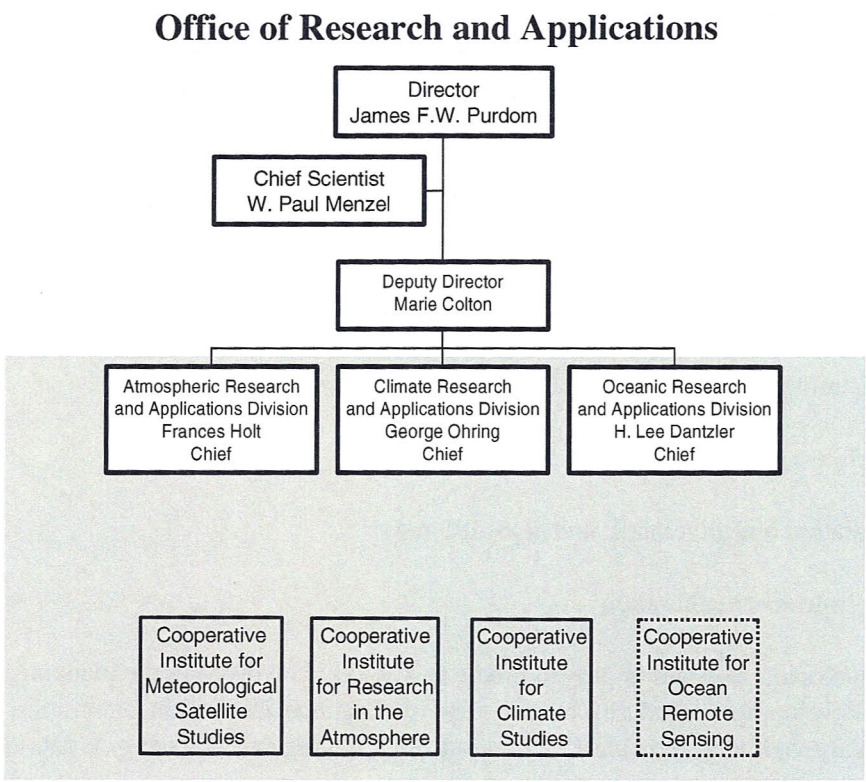
ORA scientists work within international atmosphere and ocean protocols established by the World Meteorological Organization or the United Nations/Intergovernmental Oceanographic Committee to participate in sanctioned studies and working groups that aim to produce global availability and uniformity of satellite data for beneficial environmental applications.

3. STAFF, ORGANIZATION, AND FACILITIES

Staff

The ORA staff consists of 78 full-time scientists, 4 part-time scientists, 7 technicians, 6 administrative support personnel, and 6 secretaries. The Federal staff is supplemented by 11 full-time, post-doctoral/ visiting scientists and 40 on-site contractors. Throughout the year, ORA hosts visiting scientists for periods ranging from one week to several months (Appendix 2).

Organization



Office of Research and Applications Organization Chart

Office of Research and Applications (ORA)

The NESDIS Office of Research and Applications (ORA) is structured to take maximum advantage of the various applications areas afforded by today's satellite systems. Through its divisions, ORA conducts atmospheric, climatological, and oceanographic research on the use of satellite data for monitoring environmental characteristics and their change. The Atmospheric Research and Applications Division (ARAD) optimizes the use of environmental satellite data as part of NOAA's modernization activity by conducting applied research and development, and technology transfer. The Climate Research and Applications Division (CRAD) develops products and applications of satellite observations for weather and climate monitoring and prediction. CRAD also develops calibration procedures for all NOAA

satellite sensors. The Oceanic Research and Applications Division (ORAD) of NESDIS/ORA provides the primary research and development support for oceanic remote sensing within NOAA. Scientific programs include sea surface temperature algorithms and analyses, ocean color, marine bio-optics, sea-surface wind measurements, satellite altimetry, oceanic rainfall measurements, Search And Rescue Satellite applications, and coastal monitoring tools in such programs as CoastWatch and the Coral Bleaching research. Ocean remote sensing is a major funding target in NOAA science. Scientists from all ORA Divisions help guide the development of new satellite instruments.

Division Descriptions

Climate Research and Applications Development (CRAD)

The Climate Research and Applications Division (CRAD), working mainly with polar orbiting satellites, develops products and applications to enable NOAA to achieve its strategic goals to Advance Short Term Warning and Forecast Services, Implement Seasonal to Interannual Climate Forecasts, and Predict and Assess Decadal to Centennial Change. The Division conducts an end-to-end program ranging from planning new satellite instruments to applying satellite data in NOAA's weather and climate analysis and prediction systems. Most of the Division's research and development falls in the following categories:

- Atmospheric temperature and moisture soundings;
- Ozone monitoring;
- Land surface variables;
- Earth radiation budget, clouds, and aerosols; and
- Satellite instrument calibration.

In addition to developing new and improved products, CRAD is involved in the planning of new satellite instruments, in developing procedures for pre- and post-launch instrument calibration and characterization, and in analysis of long-term satellite data sets for studying and assessing climate change.

To conduct its activities, CRAD has a vigorous visiting scientist program and an extensive task order contract support system, which provides scientists and software specialists to support the CRAD investigators. Its external partners include: NWS/NCEP/EMC, NWS/NCEP/CPC, NWS/OH/NOHRC, OAR/ETL, OAR/CMDL, NIST, NASA/GSFC, NASA/LRC, NASA/JPL, U. Maryland, USGS, and USDA. Its scientists also collaborate with colleagues both nationally and internationally. For additional information on CRAD activities, consult the World Wide Web (http://orbit-net.nesdis.noaa.gov/crad/index.html)

Atmospheric Research and Applications Division (ARAD)

The Atmospheric Research and Applications Division (ARAD) programs are primarily directed toward the utilization of satellite data to improve and advance operational weather forecasting. It serves as the

focal point within NESDIS and the external scientific community, both domestic and international, for development of satellite applications for improved analysis and forecasting of:

- Heavy rainfall and flash floods;
- Aviation hazards;
- Extratropical and tropical storms; and
- Regional, mesoscale and local weather including severe storms.

It is responsible for developing sounding products for use in numerical prediction models, and conducts data assimilation and impact studies on these models.

The Division provides the interface between research and operations. It conducts applied research, evaluating research results for operational utility. It develops, improves, specifies and implements new products, services, and techniques; develops test and pilot operations; turns over systems or components to the NESDIS Office of Satellite Data Processing and Distribution; and monitors products to assure quality and accuracy. Division staff also transfer new technology and applications to the field practitioner and research communities through classroom and Internet training sites. The Division also participates in the specification of new instruments and sensors with the Office of Systems Development. It conducts field experiments with experimental and prototype instruments, and evaluates field and simulated data to determine the feasibility of new satellite remote-sensing technology to improve measurement accuracies of the operational satellite programs. For additional information on ARAD activities, consult the World Wide Web (http://orbit-net.nesdis.noaa.gov/arad/index.html).

Oceanic Research and Applications Development (ORAD)

The Oceanic Research and Applications Division (ORAD) seeks to expand and improve the use of Earth satellite-observed oceanographic data by local, regional, state and Federal users. A priority area of our research and applications development efforts is oriented towards achieving a full utilization of both NOAA international, and (where appropriate) commercial ocean sensing-capable Earth satellites. Priority is given to those present and future satellite systems where the potential exists to provide sustained, useful coastal and open ocean data to end users. Particular attention is given to those areas where the satellite oceanographic sensor observations can provide the end-use data or information, such as ocean surface wind speed and direction, temperature, chlorophyll concentration, and sea height observations. The Division's scientific activities are organized thematically, into seven scientific areas:

- Ocean Surface Winds;
- Sea Surface Topography;
- Ocean Color Physics and Biology;
- Sea Surface Temperature;
- Synthetic Aperture Radar and Multi-purpose Imagery;
- Sea Ice and Polar Oceans; and
- Oceanic Rainfall.

Oceanic research and applications development in these areas is increasingly driven by the significant growth in both the number and capabilities of ocean remote-sensing capable satellites, and by the blurring distinction between operational and research missions. There are currently over twenty, operational Earth satellites now in orbit that have significant ocean and coastal remote-sensing capabilities. Of these, significant use is made of only about a third. Many of these satellites represent "old technologies." We see the promise of the future generation of ocean-capable satellites now here. In satellite altimetry we have established teams making important contributions to climate change sea level studies. In active and passive microwave remote sensing, new capabilities to observe ocean winds on a global scale at high resolution are now being demonstrated. Advances in processing and interpreting synthetic aperture radar are opening new vistas on our understanding of high latitude cyclogenesis. Ocean remote sensing is on the threshold of new operational capabilities for our coastal and oceanic constituencies. Our goal is to meet those challenges. For additional information on ORAD activities, consult the World Wide Web (http://orbit-net.nesdis.noaa.gov/orad/orad_index.html).

NESDIS' Cooperative Institutes

NESDIS has established three Cooperative Institutes to collaborate on research to advance the use of satellite technology in climate and weather forecasting. Plans are underway to establish a fourth Cooperative Institute that will focus on ocean remote sensing.

Cooperative Institute for Meteorological Satellite Studies (CIMSS)

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin, Madison, WI, was founded in 1980. The ARAD Advanced Satellite Products Team (ASPT) is co-located with CIMSS. ASPT and CIMSS scientists collaborate on meteorological satellite studies in weather forecasting and satellite data assimilation in models, clouds and radiation, and environmental monitoring. For additional information on CIMSS activities, consult the World Wide Web (http://cimss.ssec.wisc.edu).

Cooperative Institute for Research in the Atmosphere (CIRA)

The Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University, Ft. Collins, CO, also was established in 1980. The ARAD Regional and Mesoscale Meteorology Team (RAMMT) is co-located with CIRA. Together, RAMMT and CIRA scientists conduct research on tropical storms and regional and local weather including severe weather. CIRA, together with colleagues from all ARAD units and CIMSS, leads the effort to improve satellite data analysis and visualization techniques and to transfer research results to operational forecasters through workshops and interactive Internet training sessions. For additional information on CIRA activities, consult the World Wide Web (http://www.cira.colostate.edu).

Cooperative Institute for Climate Studies (CICS)

In 1983, the Cooperative Institute for Climate Studies (CICS) at the University of Maryland, College Park, MD, was established. Over the years, variabilities in the funding profile have impacted CICS. In the last year, a concerted effort has been made to reinvigorate CICS. A rebuilding effort is underway. A

research program in climate diagnostics, modeling, and prediction, and satellite climatology is being pursued. For additional information on CICS activities, consult the World Wide Web (http://www.meto.umd.edu/MISSIONS/cics.html).

Cooperative Institute for Ocean Remote Sensing (CIORS)

The Cooperative Institute for Ocean Remote Sensing (CIORS) is a proposed new cooperative institute that has a start-up date in early FY 2002. CIORS will serve to provide a focus for realizing the full potential of environmental satellites in coastal and ocean applications, and will be hosted in a university research environment to facilitate NESDIS staff interaction with the academic research community. The host university will be selected as a result of national, competitive search in FY 2001.

Computing Facilities

ORA Information Technology (IT) Environment

The ORA IT environment represents an increasing mixture of legacy and new computing systems and networks. The ORA IT environment currently includes a mix of more than 300 computers running a dozen operating systems. These include SGI, HP, Sun, IBM, and Compaq UNIX workstations, Windows 95, 98, NT and 2000 PCS, Linux workstations, Macintosh, and VAX/VMS hosts. The bulk of this environment is in the Camp Springs/Suitland area and is managed by the system administrators in ORA's Technical Support Team (TST). The remote sites (Silver Spring, Madison, Boulder) manage their own environments, with the ultimate responsibility resting with the TST and the ORA front office. The TST currently includes two Government and two contract system administrators, with an open Government system administrator vacancy.

Challenges include reducing the ratio of computers and operating systems. We are consolidating into an integrated environment of fewer, more powerful computers running Windows NT and Linux. We are tying into the NOAA-wide directory, messaging, and calendar services. We are reducing our system administration burden and cost by centralizing IT administration and application deployment using the strengths of UNIX and investigating NT solutions such as System Management Server, Terminal Services, Citrix, and Windows 2000. We are also investigating the use of outsourcing in general, and application service providers in particular. We plan to build upon our web-based Intranet and Internet. And we are implementing a reliable and intuitive remote access into our IT resources for our travelers.

Virtual Institute

The Virtual Institute, developed by the Regional and Mesoscale Meteorology Team (RAMMT) and CIRA, provides an opportunity for the Government and academic communities to access research quality, rapid scan (e.g., 1 or 5 minute interval), geostationary satellite data for pre-selected noteworthy events, e.g. severe storm or tornado outbreak. The purpose of this "facility" is to foster collaboration among other NOAA and academic scientists to further our understanding of the data and provide educational and training opportunities to the broad meteorological academic community through interactions with the

CIRA/RAMMT. Scientists can access this data through internet or file transfer protocol (FTP) at the CIRA homepage http://www.cira.colostate.edu.

Marine Optical Buoy (MOBY) Calibration Facility

MOBY, developed by ORA under NASA sponsorship, is the world's most sophisticated, continuously monitored in-situ marine optical buoy. MOBY provides calibrated, time-series bio-optical data for algorithm development supporting national and international satellite remote sensing of ocean color and color derivations. These algorithms translate variations in the ocean's visible surface-reflected light (ocean color) into the concentration abundances of microscopic marine plants (phytoplankton). Phytoplankton are critically important to the marine food chain, and influence the global balance of carbon dioxide in the atmosphere. MOBY data are the critical calibration reference for both U.S. ocean color satellites (e.g., SeaWifs) as well as the emerging international network of ocean color sensing satellites. Ocean color satellite calibration services (that MOBY provides) is critical at a time when understanding the global carbon cycle has become fundamental to climate change studies. MOBY is the Nation's internationally recognized standard in ocean optical measurements, and enables the growing global exploration from space of the world's marine resources.

4. OUR WORK AND ITS PLACE IN NOAA'S MISSION: CHALLENGES FOR ORA

NOAA's Strategic Goals

NOAA's overall program, as outlined in the agency's strategic plan, is composed of two missions:

- ***Environmental Assessment and Prediction*** in which NOAA envisions integrated environmental observation, assessment, and forecast services that enhance public safety and the Nation's economic and environmental security. These objectives are embodied in the following strategic goals:
  - Improve Advance Short-Term Warning and Forecast Services,
  - Implement Seasonal to Interannual Climate Forecasts,
  - Predict and Assess Decadal to Centennial Change, and
  - Promote Safe Navigation.
- ***Environmental Stewardship*** in which NOAA envisions U.S. ocean and coastal areas with healthy ecosystems and the wise human use and development of ocean, coastal and living marine resources. These objectives are embodied in the following strategic goals:
  - Build Sustainable Fisheries,
  - Recover Protected Species, and
  - Sustain Healthy Coasts.

The Office of Research and Applications concentrates primarily in five of the seven strategic goal areas: Improve Advanced Short-Term Warning and Forecasts, Implement Seasonal to Interannual Climate Forecasts, Predict and Assess Decadal to Centennial Change, Build Sustainable Fisheries, and Sustain Health Coasts. ORA is also a contributing partner with the other NOAA line offices in the remaining NOAA strategic goals. In this regard, ORA is unique within NOAA because of its broad application of satellite remote-sensing research and applications development across all of NOAA's strategic goals. ORA's scientific activities are structured into three broad research themes: weather, climate and oceans.

Improve Advanced Short-Term Warning and Forecast Services

NOAA's vision is to provide significantly improved short-term warning and forecast products and services that enhance public safety and the economic productivity of the Nation. Although we can do nothing to prevent natural disturbances, we must do everything possible to minimize their human impact. NOAA's strategic goal is to improve its observing systems, develop a better understanding of natural processes, and enhance predictive models and dissemination systems. Within this strategic goal, the Office of Research and Applications develops satellite-based products and applications for use by local forecasters and in operational models to improve warning and forecast services.

Implement Seasonal to Interannual Climate Forecasts

NOAA's vision is to work with academic and multi-national partners in order to provide one-year lead-time forecasts of known skill of global climate variability, especially El Niño and the consequent precipitation and surface temperature distributions. These forecasts will increase society's ability to mitigate economic losses and social disruption.

Within this strategic goal, ORA's scientific activities focus on developing satellite-based global data and information products to: provide the initial conditions needed to predict seasonal to interannual climate variations; verify seasonal to interannual predictions; and better characterize and understand these short-term climate variations.

Predict and Assess Decadal to Centennial Change

NOAA seeks to provide science-based options for decisions regarding decadal to centennial changes in the global environment, specifically for: climate change and greenhouse warming, ozone layer depletion, and air quality improvement. Our planet is naturally a place of change, often with severe impacts on humans. The challenge is to understand and foresee the natural and human-induced variations of approaching decades in order to make sound economic and social decisions. Within this strategic goal, ORA develops long-term global satellite data sets to monitor decadal changes in the Earth's climate and ozone layer.

Build Sustainable Fisheries

NOAA's vision for the next decade is to increase greatly the Nation's wealth and quality of life through sustainable fisheries that support fishing industry jobs, safe and wholesome seafood and recreational opportunities. Rebuilding and maintaining fisheries will promote the economic and biological sustainability of U.S. fishing resources, and assist the commercial fishing industry in becoming more competitive internationally. Uncertainty in scientific information makes management decisions difficult. Within this strategic goal ORA is focusing primarily on improving the access to environmental satellite data that is relevant to fisheries management activities by marine resources managers at the state and Federal levels.

Sustain Healthy Coasts

NOAA envisions the Nation's coasts to have more productive and diverse habitats for fish and wildlife, and cleaner coastal waters for recreation and the production of seafood. Coastal communities will have thriving, sustainable economies based on well-planned development and healthy coastal eco-system. This goal addresses the practical needs and concerns of resource managers, and strengthens the watershed and regional management frameworks used by state Coastal Zone Management programs. An integrated NOAA program of monitoring, process research, modeling, assessments and information dissemination will provide the scientific basis for measures designed to prevent harm to ecosystems while allowing sustainable development. Within this strategic goal ORA investigates the quantitative use of the broad range of available and future environmental satellite data by coastal and ocean resource managers, and how access to and use of those data can be facilitated. The ORA-managed CoastWatch Program is an integral part in these efforts to help increase the capacity of coastal and ocean constituents to realize the full potential of ocean observing-capable satellite systems in their daily activities.

Challenges for ORA

An Accelerating Pace in Technology Transition

The transition of research into operational applications has always been challenging, and there are few easy solutions. ORA is not insulated from this challenge. There is explosive growth projected in both the number of research and operational environmental satellite sensors in orbit, and in the increasing spectral and spatial resolutions of those sensors. Information technologies now allow the near instantaneous global exchange of data and information by users. Whetted by both the emerging satellite sensor capabilities and Internet, users are increasingly unwilling to wait for a structured development process to be fully completed before the "certified operational" product is made available. There are major implications to how research will be conducted in the future within ORA. For example, are the traditional relationships between NESDIS, NASA and industry still germane in the new information technology environment? What should be the balance between operational and experimental satellite senor data streams in our applications development? What is our continuing quality assurance role as experimental products and services become more widespread? How and how well ORA responds to these challenges will have major implications for our future.

Maximize Utilization of Satellite Data in Numerical Weather, Climate and Ocean Forecasts

Although much progress has been made in recent years, the fact remains that satellite data are underutilized in the NWS numerical prediction models. This situation will only be exacerbated as a new generation of advanced instruments with their finer spatial and spectral resolutions and orders of magnitude more data comes on line. Furthermore, while weather prediction has reaped remarkable benefits from satellite data, newly evolving climate and ocean prediction models are just beginning to exploit space observations. ORA must work more effectively with its NOAA, national, and international partners to capitalize on our nation's and the world's investments in space observations of the Earth. The operational prediction centers have built powerful infrastructures for assimilating satellite data into models. Further progress depends on close collaboration between remote-sensing scientists and specialists in data assimilation and numerical modeling. As a partial solution to this challenge, ORA is playing a major role in a new initiative to establish a joint NASA and NOAA Center for Satellite Data Assimilation.

Expanding Horizons in Coastal and Ocean Remote Sensing

A new generation of improved resolution, coastal and ocean remote-sensing capable satellites is rapidly emerging. Satellite spatial, spectral and temporal resolutions are improving to the point where we can now for the first time envision an operational coastal and ocean remote-sensing system, and be able to respond to burgeoning Federal, state and local needs in marine fisheries management, coastal planning, and environmental quality stewardship needs. There is much at stake. More than half of the Nation's population lives within 50 miles of the coast. Coastal recreation, tourism, and commerce comprise the second largest employment base in the Nation. There is and will continue to be an increasing tension between utilization, exploitation and stewardship considerations on our coasts and in the ocean. Unlike the atmospheric research and operational forecast constituencies that have a long history of partnerships with the satellite community, coastal and ocean constituencies are just beginning to understand the

potential benefits that operational satellite observations of our coastal and ocean waters may bring. There is a model that we can draw upon. The weather community has a well-established framework of national and international organizations that help guide capabilities development, data access, and product delivery. A similar framework and focus is needed for coastal and ocean remote-sensing services in order to help achieve full utilization of present satellite resources. ORA has a leading responsibility in helping to develop the scientific, development and global operational coastal and ocean remote-sensing capabilities that NOAA and the Nation need in order to be fully utilize environmental satellites on an operational basis.

Space-based Observations for Long-term Climate Monitoring

Climate services are becoming an integral and increasingly important part of NOAA's mission. The challenge for ORA is to insure that the potential contributions of satellite measurements to NOAA's expanding climate mission are fully realized.

Several recent National Academy of Science Reports raise concerns about the nations' ability to monitor climate variations and emphasize the need for a program of long term, sustained observations of the Earth's changing climate. No single agency has the responsibility for such sustained observations. NASA has the mandate of technological innovation and research, and developing the systems that would enable the operational agencies to do their jobs better. NOAA, with its operational in-situ and satellite observational systems for the atmosphere and oceans is clearly well positioned to carry out the needed sustained long-term observations. The NAS/NRC Pathways Report on the U.S. Global Change Research Program recognizes this fact by stating that the long-term environmental monitoring program must be built on the operational observing systems of NOAA, DoD, and their international partners. The report recommends that development of the next generation of weather satellites (e.g., NPOESS) be undertaken with the climate record clearly in mind.

A major challenge for ORA will be the development of the science capabilities needed for NOAA to take on the mission of sustained long-term monitoring of the Earth's climate from space. Several issues are involved.

- Insuring the required accuracy, continuity, calibration, stability, and documentation that are essential for climate change detection and attribution.
- Transitioning NASA developed technology, in the form of satellite climate instruments, instrument characterization and calibration science, and data processing systems, to NOAA. This will include measurements never made before by NOAA, but crucial for monitoring and understanding climate change.
- Establishing the partnerships with the climate user community to update observational requirements, provide feedback on products, and analyze the data.

5. MAJOR ACTIVITIES

In the previous section, we provided an overview of our role within NOAA's strategic goals. This section presents a more complete picture of our work in weather, climate, and oceans. In addition we will discuss the Office's contributions to current instrument calibration, future instrument planning, technology transfer, and scientific partnerships.

Weather

Overview

ORA's activities in weather, which support NOAA's strategic goal to Advance Short Term Warnings and Forecasts, are focused on the development of satellite data and information products for use in:

- Numerical Weather Prediction models, which are run on the computers of the NWS/NCEP/EMC and form the underlying basis for all weather predictions extending from a few hours to 10 days out into the future;

- Nowcasts and short term warnings and forecasts, which are made by NWS forecasters for their local areas and NWS/NCEP Centers responsible for severe storm, hurricane, and aviation warnings; and

- Monitoring natural environmental hazards, such as wild fires and volcanic eruptions.

ORA is also involved in two major interagency thrusts that cut across many of its major activities in weather research and applications:

- NASA/NOAA Joint Center for Satellite Data Assimilation; and

- U.S. Weather Research Program.

NASA/NOAA Joint Center for Satellite Data Assimilation

To accelerate the use of satellite data in NWP models and to prepare for assimilating the advanced and high volume data streams from the next generation of satellite instruments, NASA and NOAA are planning to establish a Joint Center for Satellite Data Assimilation. A virtual center will be formed consisting of the NASA/GSFC Data Assimilation Office and components of NOAA's NWS/NCEP/EMC, NESDIS ORA, and OAR. The center will coordinate the talents of NASA and NOAA scientists in data assimilation, numerical modeling, remote sensing, and satellite instruments. It will include NASA/NOAA science teams to incorporate polar and geostationary satellite data into NWS operational forecasting. The center will serve as a bridge between NASA and NOAA weather activities. It will maximize satellite data utilization in research, through its links to the USWRP, and operational forecasting. It will develop a community fast forward radiative transfer model for direct assimilation of satellite-measured radiances. The center will also establish a partnership with NSF for post-doc and graduate-level student participation

and associated research support. Both NASA and NOAA are redirecting current resources and developing new budget initiatives to develop a viable center.

U.S. Weather Research Program

ORA is a leader and active partner in the U.S Weather Research Program. The objectives of the U.S. Weather Research Program (USWRP), a joint program of NOAA (NESDIS, NWS and OAR), NASA, DoD, the National Science Foundation (NSF) and the university community, are to continue improvements in weather forecasting, lower costs of routinely disruptive weather, and mitigate the effects of weather disasters. Over the next five years, USWRP will focus on hurricanes, particularly land falling storms, heavy precipitation and flooding, Pacific sources of winter storms, and societal and economic impacts of weather.

ORA scientists participate in the planning of USWRP programs and are engaged in research in support of these goals. Research areas include: improved depiction of the hurricane surface wind field, intensity analyses and prediction, characterization of the upper-level hurricane environment using satellite data and the study of meso- and micro-scale structure during landfall. Research to improve quantitative precipitation estimates (QPEs) from satellite data and utilization of QPEs in hydrological and NWP models to improve mesoscale Quantitative Precipitation Forecasts (QPFs) are ongoing. Efforts to utilize cloud and precipitation observations and satellite sounding information over land; characterize/specify satellite observation errors, and conduct Observing System Simulation Experiments (OSSEs) to determine optimal observational mix and future satellite sensors, along with special rapid scan satellite imaging and data collection to support field campaigns round out the ORA contributions to USWRP.

Numerical Weather Prediction

ORA develops satellite-based products for initialization and verification of NWS numerical weather prediction models. To predict the weather more than a day or two in advance requires global observations. The conventional weather observing networks provide information primarily for the land areas of the Earth, leaving wide gaps over the oceans and uninhabited areas. Satellite observations fill in these gaps. Primarily as a result of satellite observations, weather predictions for the mostly-ocean Southern Hemisphere are now almost as accurate as those for the Northern Hemisphere. ORA has an ongoing program to improve existing products and develop new ones. ORA scientists also develop the radiative transfer models that are needed by the NWS to assimilate satellite observed radiances directly into the models.

> **Joint National Weather Service (NWS)/ORA Projects.** Over 80% of the data used to initialize NWS numerical weather prediction (NWP) models comes from satellite observations. However, this is only about 15% of the available satellite data. To accelerate the use of satellite data in the NWS NWP models, and to prepare for scheduled new satellite instruments, the NWS National Centers for Environmental Prediction (NCEP) and ORA have identified several joint satellite data assimilation projects and have started to work on a number of these.

Surface Emissivity Models. Satellite infrared and microwave soundings affected by land and sea ice surfaces are currently underutilized, for the good reason that the surface contributions may be grossly uncertain. This does not mean that there is only poor quality information over land, but instead that more effort is required to use it properly. Also it means that there is an opportunity to estimate surface properties.

Surface radiance depends on both the surface emissivity and skin temperature. What a satellite observes of the surface is further affected by atmospheric absorption/re-emission and transmission of the radiation. For spectral channels sensitive to radiation from layers high in the atmosphere, surface contributions are negligible, but for those sensitive to the lower atmosphere, surface contributions can be significant. Data from the higher peaking channels are currently assimilated into NWP models, while the observations of the lower ones are not. This means that satellite information on the temperature and humidity structure in the lower half of the atmosphere is not being used.

ORA is developing microwave and infrared surface emissivity models. The microwave emissivity models use input from the NCEP NWP models (e.g., on surface types, vegetation type, snow depth, soil moisture content, and sea ice concentration). The models will be computationally efficient and will be directly implemented into the NCEP forecasting models.

The infrared surface emissivity model will be based on databases prepared by the Surface and Radiation Budget group of the Clouds and the Earth's Radiant Energy System Science mission for NASA's EOS. These databases contain the geographic distribution of 18 land coverage types, combined with emissivities for each of these types as a function of wavelength. AVHRR vegetation index will be used to produce a real-time "greenness fraction." The final emissivity will be a weighted combination of the greenness fraction times the emissivity for the predominate vegetation type, plus the complement of the greenness fraction times the emissivity of the predominate background soil type. This can be extended to multiple vegetation and soil types if deemed necessary. The developed software will be computationally efficient to meet NWP production schedules.

Fast Radiative Transfer System. Direct assimilation of satellite radiance data in the NWS NWP models is critically dependent on accurate, fast forward models. Forward models are radiative transfer models for calculating what a satellite observes, based upon a given atmospheric temperature, humidity, and composition structure. In the NWP data assimilation system, satellite radiances computed from the background fields, which are based on 6-hour forecasts, are compared to observed radiances. Differences between the two are used, along with similar differences for other kinds of observations, in the correction scheme for the background fields. The corrected background fields are the initial conditions for the next cycle of forecasts.

The most accurate atmospheric radiative transfer models are based on calculations that resolve each absorption line. These are too computationally expensive (i.e., they take too much time to run) to be used in operational weather prediction. The line-by-line calculations are approximated by simpler models for the various instrumental spectral channels that are being assimilated. The current forward model used by NWS was developed by ORA. It has certain deficiencies which have been traced to the line-by-line model. ORA scientists are working with other scientists to

obtain the best line-by-line model for use in generating a new, improved fast model. ORA is also adding aerosol radiative transfer and reflection of solar radiation by the Earth's surface to the forward model. ORA is also improving the computing algorithm to make the forward model more computationally efficient.

Atmospheric Soundings from Satellites. The Advanced Microwave Sounding Unit (AMSU-A & -B) on the NOAA-15 polar satellite and the sounder on the GOES-8, -10 satellites provide atmospheric temperature and moisture information either as soundings or radiances to NWS NWP models. The new ORA developed Advanced TIROS Operational Vertical Sounder (ATOVS) operational processing system provides soundings for clear, cloudy and partly cloudy conditions globally. Other products such as Total Ozone, Cloud Top Temperature, Cloud Top Pressure, Cloud Amount, Clear Sky Outgoing Longwave Radiation and four Clear Sky Layer Cooling Rates are produced from the ATOVS system.

This information is supplemented by the GOES sounder data over North America and adjacent ocean areas with a higher temporal resolution but lower spatial and vertical resolution. GOES information is also limited to clear sky conditions. Since the GOES sounding processing relies on the Eta model first guess, it makes little improvement in temperature forecasts. GOES' major contribution is the improvement of the depiction of moisture. Three layers of GOES precipitable water are routinely used in the Eta. The GOES sounder also provides the supplemental cloud information, above 12,000 feet, for the hourly Automated Surface Observing System (ASOS). ORA scientists continue to improve the sounding algorithms, and are currently evaluating full resolution (10 km) soundings every hour. Additionally they have found that the Aviation forecast provides a better first guess for the GOES sounding processing. GOES soundings using the Eta and Aviation first guess continue to be evaluated.

Assimilation of Satellite Passive Microwave Precipitation. Satellite-derived precipitation observations are clearly an important data source for the initialization of precipitation in forecast/analysis systems and, in a larger sense, the overall analysis of moisture and cloudiness. Precipitation estimates from the passive microwave sensors represent an important data stream that should not be neglected. Preliminary studies carried out by a number of researchers have shown improvements in analyses and forecasts when microwave rain rates are used in the assimilation process. Effective utilization of the information from sensors like the SSM/I and AMSU requires an understanding not only of observation but also model errors, both of which are complex given that the precipitation process includes phase changes and has many different potential mechanisms for similar precipitation signals.

Rain estimates from the operational SSM/I and, in a second phase, the AMSU, as well as the algorithms themselves, will be incorporated into the NCEP Global Data Assimilation System (GDAS). Since NCEP already accesses the SSM/I and AMSU data streams, provision of the algorithms enables precipitation product generation within the GDAS. In addition to a one-way relationship between the microwave estimates and the GDAS, NCEP and ORA scientists will also investigate the potential utility of a coupled approach whereby the GDAS provides input to the microwave precipitation algorithms, which in turn is fed back into the GDAS. The possibility for more robust microwave precipitation estimates given atmospheric and surface information available in the GDAS will be explored in this study.

The foundation of both approaches will be a comparison study of the SSM/I estimates and the short-term (0–9 h) forecasts in order to optimize the usage of the SSM/I precipitation estimates within the GDAS, and possibly also to suggest appropriate data compression techniques.

Cloud Liquid Water. Clouds are currently not predicted in NCEP's global model; they are specified based on the model's forecast humidity field. NCEP scientists are developing a prognostic cloud scheme that is based upon simplified equations representing cloud formation/dissipation processes. Observations of cloud properties, especially cloud liquid water, are vital for evaluation and further development of the scheme. In this project, POES observations will be used to evaluate the cloud prediction model.

A comparison of SSM/I, AVHRR and AMSU cloud liquid water estimates is being conducted to evaluate the quality and degree of consistency among the various estimates. Microwave instruments provide good cloud liquid water data over the oceans, but cannot be used over land because of inadequate knowledge of surface emissivities. AVHRR provides good estimates over both land and ocean, but for thin clouds only. Correct interpretation of the differences requires an understanding of the retrieval algorithm errors, both in space and time. Following this intercomparison, POES-based cloud liquid water estimates will be used to evaluate the NCEP prognostic cloud scheme. Noted discrepancies between the retrieved and simulated cloud liquid water fields will provide useful feedback to both algorithm and model developers.

NCEP accesses the SSM/I and AMSU radiances. As part of the project, the ORA SSM/I and AMSU cloud liquid water algorithms will be incorporated into the NCEP global data assimilation system (GDAS) to evaluate algorithm performance in an operational environment. These cloud liquid water retrieval algorithms may benefit from atmospheric and surface information available in the GDAS. Since AVHRR brightness temperatures are not yet part of the operational NCEP data stream, this approach will not be followed with the AVHRR cloud liquid algorithm. Instead, AVHRR cloud liquid water products will be used.

Assimilating Clouds and Total Precipitable Water. Improved cloud initialization using mean cloud-top pressure retrieved from the GOES sounders is being tested at NCEP in the Eta and Rapid Update Cycle (RUC) models to improve the initial distribution of cloud water. Previously, the cloud water analysis used a mean cloud-top pressure. The newest approach uses maximum and minimum cloud-top pressures from the GOES sounders and assumes bi-modal distribution of clouds in the vertical to construct two cloud layers in each column. This better represents clouds in nature which tend toward a bimodal vertical distribution.

At the request of NCEP, ORA and Cooperative Institute scientists are working together to incorporate a new cloud condensation/evaporation scheme in the 48 km research version of the Eta model. It has previously been tested on the 80 km version of the Eta and resulted in the generation of a more stable cloud field.

Geostationary Winds Suite. ORA scientists continue to improve and add to the suite of geostationary wind products. These include cloud drift, water vapor, and sounder winds. Currently hourly low-level high-density visible winds are being generated experimentally. These, though limited to daylight hours, are most valuable in the coastal areas and for the definition of

circulation centers such as incipient tropical storms. Researchers at NOAA's Forecast Systems Laboratory are experimenting with the use of these winds in the RUC and local models. Winds from the 3.9 μm channel are also under experimental development to improve depiction of tropical storm circulation centers.

As a result of discussions at the International Winds Working Group, ORA scientists are operationally testing a unified EUMETSAT/NESDIS quality control approach for GOES winds. Since GOES winds are distributed and used at all major forecasting centers in the world, this will add consistency to the operational data sets.

Finally, improvements to targeting and the intervals used for cloud drift and water-vapor winds are being tested. Readiness activities for GOES-M that will include a carbon dioxide channel that will greatly assist in the challenging task of cloud height and tracer analysis is underway.

Real-Time Values of Fractional Green Vegetation. The amount of vegetation cover in each grid box of an NWP model is needed to correctly model the exchange of heat, moisture, and energy between the land surface and the atmosphere. Currently, NCEP uses an atlas of fractional green vegetation that ORA developed based on many years of AVHRR vegetation index observations. The atlas consists of monthly maps of the land surface showing the fraction of green vegetation in each grid box of the NCEP regional and global forecast models. A shortcoming of the atlas approach is that it is based on climatological values and does not contain information about the current state of the vegetation fraction. That is, whether the current vegetation is greener or less green than the atlas value because of excessive rain, drought, etc. This project is developing a satellite-based technique to adjust the atlas values to account for current vegetation conditions.

An experimental, routinely produced product at NESDIS, the Vegetation Condition Index (VCI), a measure of vegetation stress, will be used to modulate the atlas values of vegetation fraction. The VCI is used to detect and quantify drought, conditions of excess precipitation, and other events that affect vegetation health. The VCI is simply a scaling of the current Normalized Difference Vegetation Index (NDVI) according to the historically observed range of the NDVI for each location and time of year. We are defining from the GVI database at NESDIS and the long-term 1 km AVHRR data archive at USGS what the expected variation of vegetation fraction is at each grid box for each month or week of the year. When the VCI is below or above predetermined thresholds, the VCI value will be used to raise or lower the vegetation fraction by some proportion of its observed historical variance.

Surface Products for NWP. Numerical Weather Prediction (NWP) models have advanced to a stage of sophistication that they are quite sensitive and responsive to land surface boundary conditions. The surface physics packages in NWP models control the water and energy balance at the land surface and thereby specify the soil water balance and surface-to-air transfer of moisture and heat. This is critical for the models to correctly forecast near-surface temperature and humidity. The NCEP models specify surface albedo, vegetation type (IGBP class) and fractional green vegetation for each vegetation class. The models also use satellite-derived snowcover as an initial condition.

The first land surface characteristic created for NWP was green vegetation fraction derived from the Global Vegetation Index (GVI) product. This was a monthly climatology of vegetation fraction at a resolution of about 16 km at the equator. When this product was implemented into the NCEP regional NWP model, it made a significant improvement in the humidity and temperature forecasts. A monthly database of surface albedo was derived from the same data set (GVI) and at the same resolution. The albedo database is being tested in the NWP models now. For improved NWP models with more sophisticated surface schemes, a high resolution surface characteristics data set is being prepared from AVHRR global 1 km data archived at the EROS Data Center. This data set will be at about the same resolution as the original data sets, but will contain the three dominant vegetation classes in each map cell and the green vegetation fraction associated with each. Preparation of these data sets requires careful attention to remote-sensing problems like cloud screening, bidirectional correction and satellite calibration.

Snowcover is a surface product that varies much faster than vegetation or albedo. Daily interactive snow maps have been developed for initializing the models and similar maps of surface snowcover fraction are being developed.

GOES Products for a Land Data Assimilation System (LDAS). A set of GOES products is being developed and used to validate and force the land surface components of regional NWP models. A problem with NWP soil moisture fields is that they are typically forced by precipitation, radiation, handling atmospheric conditions generated by the models themselves. The models do a poor job of precipitation and clouds (and therefore radiation) and this causes the soil moisture carried by the model to depart from reality. Therefore, NCEP is implementing the LDAS which will be a surface and soil moisture model forced by real observations where possible. The GOES imager is used to estimate cloud cover, cloud fraction, cloud and surface brightnesses. These numbers are used to estimate incident solar radiation (insolation) at hourly intervals and at a resolution of 0.5° lat/long resolution. For clear scenes, a surface (skin) temperature is estimated using a split-window retrieval from the 11 and 12 μm bands of the imager.

The first use of the GOES insolation and surface temperature was to validate the radiation and surface physics schemes of the NCEP regional forecast model, the Eta model. Several changes were made after routine comparisons of the satellite and model results. Now the satellite insolation is being used as part of the forcing for an uncoupled land surface model. As mentioned, the model radiation and precipitation are not accurate so the model soil moisture has large errors. The uncoupled surface model is forced with real observations of insolation (from GOES) and precipitation (from gauges and radar) along with atmospheric variables from the model itself. This is expected to greatly improve the model soil moisture. In the future, experiments will begin with direct assimilation of surface temperature into the model.

Regional, Local, and Nowcast Forecasting

A substantial portion of the research and development effort in ORA is directed toward the improvement of local and short-term weather forecasts or Nowcasts. At the forefront are products produced from the GOES satellite imager and sounder channels that are developed for use by the NWS Forecast Offices. These range from requests for rapid scan operations to monitor severe weather to heavy precipitation

estimates to time-rate-change of atmospheric stability parameters such as Lifted Index or CAPE or moisture content.

The key to supporting the front-line forecasters and, in many cases, emergency management officials is to extract and present information from the satellite data quickly and in an easily understood and useful format. Today, much of this support is provided via Internet web pages. One of these is ORA's interactive distribution system, the RAMM Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS). It began as a method to distribute digital satellite data from the first of the GOES I-M satellites, (GOES-8) to NWS offices prior to the deployment of the Advanced Weather Information Display System (AWIPS). Today RAMSDIS-on-line continues this service of real-time data distribution, but to an even broader community such as support to fire fighting in Florida and, through partnerships of the World Meteorological Organization, weather forecasting efforts in Central America and the Caribbean. AWIPS currently delivers satellite data to forecasters and soon will provide many of the stability and precipitation products developed by ORA scientists. Work continues to refine these products adding critical parameters requested by forecasters and improving the display and visualization of this information for easier use.

Precipitation Estimates and Flash Flood Forecasting. Flash floods are among the most devastating of national weather events, claiming more lives and causing more property damage than lightning, hurricanes, or tornadoes. An average of more than 130 people are killed and more than $4.6 billion in property is damaged by heavy rain and flooding each year. More than 10 million U.S. households are located in high-risk flood areas.

The NESDIS Interactive Flash Flood Analyzer (IFFA) has, for nearly 20 years, been the basis for satellite precipitation estimates that are routinely disseminated to NWS Forecast Offices, and frequently are the basis for flash flood watches and warnings. In June 2000, the IFFA, a manually intensive and limited monitoring tool, was replaced with the ORA developed Auto-Estimator (AE) that allows analysts to monitor multiple rain events at more frequent (15 minute) intervals. Although the NWS has deployed Doppler radars throughout the U.S., satellite precipitation estimates are still critical to residents in mountainous or near-shore areas where radar beams are blocked or approaching precipitation is beyond coverage.

Work continues on improvements to the AE algorithm to account for warm-top clouds and rainfall, tropical rainfall and winter storms. Beyond that is the challenge of assimilating these and radar estimates into NWP and hydrological or river forecast models.

Tropical Storms and Severe Weather. Next to flash flooding, severe storms and tropical storms are the most devastating weather events in terms of lives lost and economic losses. ORA scientists are engaged in studies of tropical storm development and hurricane intensity and track forecasting, the primary focus of the multi-agency U.S. Weather Research Program, as well as the understanding of severe storm and tornadic cell development utilizing satellite data.

Critical to furthering the understanding of severe storm behavior and tornadic development is the collection of super rapid scan GOES data and the integration of that data with Doppler radar images. Features such as overshooting tops and Enhanced-V signatures have been identified with these events. Sounding products from the GOES satellite that provide hourly updates of

atmospheric stability and moisture content are proving to be critical in fine tuning placement of severe storm watches and warnings. Merging these fields with wind observations and assimilating GOES sounder data into local models are areas yet to be explored by ORA scientists.

Tracking and monitoring of tropical storms and hurricanes is a legacy application of satellite data. Techniques to estimate the strength of these storms were developed by ORA scientists more than 25 years ago and still are in use worldwide. In this past year, the technique has been automated and provided to the NESDIS Satellite Analysis Branch and the Tropical Prediction Center.

Rapid scan imagery provides the opportunity to compute high resolution winds around and over the storms; however, critical variables such as the radius of 60 kt winds and surface pressure cannot be determined in this fashion. ORA scientists today are focused on extracting environmental conditions using the new microwave data from NOAA-15 to measure the atmospheric mass field and calculate the three-dimensional pressure field, tangential wind, etc. that provides valuable information about the outer storm circulation and its vertical structure. Further research on the use of this data includes modeling of tropical storms that could be used to improve assimilation techniques and operational forecasts.

Aviation Products. Fog, low clouds, icing, clear air turbulence, and strong winds or microbursts are aviation hazards for aircraft on the ground and in the air. Any of these events can and have in recent years and months caused enormous delays in our air traffic system. Satellite-based techniques have been used to develop prototype, but limited, products to detect these hazards or conditions leading to the hazards.

Currently new fog and low-cloud ceiling products are being tested by NWS forecast offices serving the fog-prone airports of the West Coast. A downburst or microburst product called WINDEX that combines forecast information with GOES sounder data provides an estimate of the maximum wind gusts that may occur with thunderstorms. It is under evaluation with the Department of Defense at the Kennedy Space Center where winds are a critical factor for operations. Additionally, clear air turbulence and aircraft icing products are produced on ORA's experimental product web sites. The U.S. Navy, a longstanding partner with ORA, has incorporated several portions of the turbulence index into their operational flight support programs. Recently they have expressed an interest in adding the aircraft-icing product to their operations. Efforts will continue to validate and refine these experimental products in preparation for operational use including distribution over AWIPS.

Natural Hazard Monitoring

Costs of natural disasters are high and continue to rise. A wide range of economic sectors ranging from agriculture to local emergency managers need advance information to plan for potential response and mitigation activities. Recent events such as forest fires in western U.S., the high human toll exacted from prolonged extreme summer temperatures, the eruption of volcanoes in Mexico and the Caribbean all illustrate the need to develop new products and tools to protect the U.S. population and its businesses. Today's satellites provide enhanced observations and new information that can be developed into analyses, assessments, forecast guidance products, situational outlooks, and mitigation aides to address these natural hazards.

Monitoring Effects of Wildfires, Aerosols, and Biomass Burning. Over the past few months, wildfires in the western U.S. have dominated the national news. This is a continuing problem, brought on by drought conditions or summertime thunderstorms. Acres of forest, hundreds of homes and an untold number of lives have been affected. Although our focus is local, similar events around the world have been in the news for several years. Understanding the long-term effects of these events is also important.

The tools available for monitoring wildfires and smoke were developed by ORA scientists about 5 years ago to monitor the slash and burn activities in the tropical forests of Brazil. New wildfire detection algorithms that work with the cloudier weather in North America during the summer fire season, are under evaluation both in the U.S. and Canada.

Beyond the detection of the fires themselves are issues of air pollution in cities downwind and the effects of these aerosols on precipitation and severe storms. Longer term issues of global albedo, surface temperatures and climate have yet to be explored.

Volcanic Eruptions. Volcanic ash, even very thin layers, is very hazardous to cruising, ascending or descending jet aircraft. It can disable jet engines and scratch windshields and accompanying sulfuric acid emissions can cause etching and other damage. Eruptions also create lava flows, mudslides, flash floods and poor air quality. The primary focus in NESDIS is the detection and forecast of the ensuing ash cloud. Due to the unpredictability of volcanic eruptions, satellite-based detection and tracking techniques, products and services are essential in providing faster, more accurate and comprehensive volcanic ash warnings to pilots and dispatchers. Satellite remote sensing and warning of ash locations and accurate computer modeling of ash dispersion are cornerstones of an international program involving nine regional centers of expertise.

ORA scientists have developed several analytical techniques to detect volcanic eruptions and subsequent ash clouds. These are currently being used experimentally by the NESDIS Satellite Analysis Branch, a part of the Washington Volcanic Ash Advisory Center. This International Airways Volcano Watch program is coordinated by the International Civil Aviation Organization to help warn aircraft of the major hazards associated with volcanic ash. Data from GOES split window channel in combination with the infrared window channel is one the best methods currently available to detect and track volcanic ash during the day or night. However, the split window image channel will not be in the sensor suite on GOES-M, scheduled for launch in 2002. Thus ORA scientists are exploring other approaches to detecting volcanic eruptions to mitigate the loss of this channel.

Climate

Overview

ORA is constructing and studying long-term data records from operational satellite instruments. These data sets contribute to understanding seasonal to interannual and decadal to centennial climate changes. A number of challenges must be overcome in generating climate quality data sets from the operational

instruments. The operational sensors were designed mainly for observing the (relatively large) meteorological variations and not the smaller signals associated with climate change. Thus, they may not have the accuracies and stabilities needed for detecting global change. A particular challenge is overcoming the lack of on-board calibration of all the operational instruments observing sunlight reflected by the Earth to space. An additional complication is satellite-to-satellite intercalibration, since a climatic time series is constructed by stringing together data from a series of satellites, each with a slightly different version of the same instrument. And, finally, for NOAA's polar-orbiting satellites, the problem of dealing with satellite orbit drift. This causes the local time of observation to change slowly during the lifetime of each satellite and introduces diurnal effects into the long-term record. Procedures developed for construction of the long-term data sets also serve for near real time monitoring and prediction of climate-scale events such as regional droughts, ENSO phenomena, coral reef bleaching, and the life cycle of each annual Antarctic ozone hole.

ORA is currently generating the following climatic data sets:

- Atmospheric data sets for monitoring stratospheric ozone, temperature and moisture profiles, precipitation, clouds, aerosols, Earth radiation budget, and carbon dioxide distributions;
- Land data sets for determining the distribution of drought, fire danger, and wildfire occurrence; and
- Ocean surface temperature data set for monitoring trends in sea surface temperatures and coral bleaching events.

Ozone Monitoring

The continuous measurements of total and profile ozone from the Solar Backscatter Ultraviolet Spectral Radiometer, MOD 2 (SBUV/2) instruments aboard NOAA satellites have enabled the scientific community to study the Antarctic ozone hole and ozone depletion in the Arctic, and to perform ozone trend analysis on a long-term data set.

Scientists at NESDIS/ORA oversee the calibration and post-launch characterizations of the SBUV/2 instruments, and they also participate in the ozone retrieval algorithm development and testing activities. The information on the instrument changes is used at ORA to reprocess, validate, and analyze the SBUV/2 ozone products. Additional support to the operational SBUV/2 ozone products is provided through participation on the Ozone Product Oversight Panel (POP) and the NASA Ozone Processing Team (OPT).

Recently, the entire data record of NOAA-9 SBUV/2 from early 1985–1997 has been reprocessed using improved instrument characterization. The total ozone estimates from NOAA-9 were validated by comparing them with those made by ground-based Dobson instruments and those made by satellite instruments such as the Total Ozone Mapping Spectrometer (TOMS). The NOAA-11 (1989–1994, 1997–present) and NOAA-14 (1995–present) SBUV/2 total ozone data have also been reprocessed using improved instrument characterization. The NOAA-9 SBUV/2 total ozone data set is a reliable link in the 20-year SBUV/2 record. Work is currently in progress to use the combined 20-year data set to determine

trends in total and profile ozone. The reprocessed SBUV/2 data for NOAA-9, NOAA-11, and NOAA-14 are now available by anonymous ftp from orbit-net.nesdis.noaa.gov in pub/crad2 subdirectories.

We work closely with investigators at NWS/NCEP and NWS/CPC to study and apply the SBUV/2 ozone data. The SBUV/2 total and profile ozone data are used in numerical weather prediction models and UV index forecasts; analyses of the ozone estimates provide results for the bulletins on stratospheric ozone variations. Further validation of the SBUV/2 ozone profiles is obtained from comparisons to measurements from the NDSC.

Studies of the Antarctic ozone hole by the NWS/CPC show that the ozone hole in 1998 was the largest in its areal coverage (16.7 million square kilometers) and its duration (94 days). The average values of the areal coverage and duration of the ozone hole for the previous 10 years are nine million square kilometers and 90 days. The Antarctic ozone hole in 1999 was equally large with an areal coverage of 16.2 million square kilometers. The ozone depletion in the Arctic is not as large as that in the Antarctic but has been increasing; the SBUV/2 total ozone data show that the ozone depletion was the largest in its areal coverage in 1996 (11.8 million square kilometers). ORA scientists are also responsible for maintaining the ozone retrieval algorithms for the TOVS ozone products. They also provide results of validation and trend studies for these data products.

Atmospheric Temperature Trends

The long-term global records of measurements of the outgoing infrared and microwave radiation from the NOAA polar orbiters provide a unique data set for the study of variation of atmospheric temperature on climate time scales. ORA scientists have the primary responsibility for the calibration and post-launch characterization of the two primary atmospheric temperature-sounding instruments: The Microwave Sounding Unit (MSU) and the High Resolution Infrared Radiation Sounder (HIRS). The MSU has been replaced by the Advanced Microwave Sounding Unit (AMSU) on the current generation of satellites.

Both the AMSU and the HIRS are cross-track scanners. This means that each channel sees a different altitude of the atmosphere at each scan angle. For climate studies and certain operational applications this limb effect must be adjusted for. ORA scientists have developed techniques for adjusting radiances to a common view angle.

The above instruments were primarily designed and have been operated to improve weather forecasting and not for climate studies. Hence, for climate studies, it has been necessary to develop new methods and reprocess the data. Recently, the entire set of MSU measurements have been reprocessed using an improved calibration algorithm by a team of ORA scientists. These re-calibrated MSU measurements are more consistent from satellite to satellite and are thus more useful for climate studies. This data set is also being merged with the AMSU measurements, which requires the development of some new optimization techniques for using the infrared radiances to retrieve temperature. The raw satellite measurements give an average temperature over deep layers of the atmosphere. These deep layers are not optimal for the detection of climate trends. Using the same optimization procedures mentioned above, new deep-layer mean temperatures time series have been and are being produced. This is the case for both the MSU-AMSU data set and the HIRS data. ORA scientists collaborate with investigators at NWS/CPC in the application of the reprocessed data in climate studies of stratospheric temperatures.

AVHRR Atmosphere Pathfinder Data Set

As part of the NOAA/NASA Pathfinder Program, NOAA has reprocessed the archived AVHRR observations from all afternoon NOAA satellites from July 1981 through December 1999 into research-quality atmospheric data sets. State-of-the-art algorithms have been used to process the global observations into what fraction of the sky is cloud covered, the components of the Earth's radiation budget (infrared radiation emitted to space and the amount of the sun's energy that gets absorbed by the Earth and the atmosphere), and the amount of aerosols (dust and pollution) that exists over the oceans, including that emitted from volcanic eruptions. The Earth radiation components are determined for clear-sky and cloudy conditions. The data sets have many applications, some of which are used in studying the influence that clouds and aerosols have on the Earth's radiation, the interactions between clouds and aerosols, and the relationships between the surface temperature, the absorbed solar radiation, and the clouds. These data are available from the web site http://aries.nesdis.noaa.gov/. Another extremely useful site for visualizing and electronically accessing monthly mean data can be found on the NESDIS Satellite Active Archive (SAA) at http://saa.noaa.gov/.

Analyses of the 20-year time series are ongoing and may provide indicators of changes in regional or global climate. Time series of global cloud cover, cloud top brightness and aerosol optical depth are being prepared and evaluated.

Drought Detection and Fire Risk Diagnostics

Drought is a significant natural disaster, affecting and killing the largest number of people and damaging the environment. Unlike other natural calamities, drought starts unnoticeably, develops cumulatively and its impacts are not immediately identifiable from in situ data. Observations from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA polar-orbiting satellites detect drought quite well because measured radiances respond to changes in Earth surface conditions, including vegetation greenness, vigor, and health.

ORA has a project to develop global methods for early drought detection and assessment of fire risk from AVHRR measurements, calibrate and validate the assessments, distribute the assessments worldwide through a NOAA web site, and provide technology transfer to other countries and users.

The AVHRR drought detection method is based on estimation of vegetation stress (reduced greenness and vigor). Unlike a two-spectral channel approach used in the past, the new numerical method developed at NESDIS is based on a three-spectral channel combination: visible, near infrared, and 10.3–11.3 m infrared. These bands account for changes in the amount of leaf chlorophyll, moisture content, and thermal condition of vegetative surface. Fire risk is calculated as an integral of intensive vegetation stress.

Three major users of the drought products are the NWS' Climate Prediction Center, the U.S. Department of Agriculture, and the International Drought Mitigation Center (University of Nebraska). Other users include Government institutions, universities, and the private sector in the U.S. and in nearly 30 countries, including all large producers of agricultural commodities. The products can be found at: http://orbit-net.nesdis.noaa.gov/crad/sat/surf/vci/index.html

Aerosol Monitoring

The goal of the aerosol project is better knowledge of the global aerosol distribution via satellite instruments and the application of that knowledge to related remote-sensing problems. This will allow higher accuracy in other NOAA/NESDIS products that are affected by aerosols, such as sea surface temperatures (SST) and vegetation indices. Researchers are developing and improving retrieval algorithms for the Advanced Very High Resolution Radiometer (AVHRR) as well as the Visible InfraRed Scanner (VIRS) for use over oceans. The current operational aerosol retrieval algorithm retrieves aerosol optical depth (AOD, the column amount of aerosol). Improvements are being made to increase the accuracy of this retrieval by improving a radiative transfer model, using a better simulation of the ocean surface reflectance and a better estimate of the aerosol properties which define how the aerosol particles scatter light. Further improvements will allow the retrieval of these aerosol properties in addition to the AOD.

The operational AVHRR algorithm has already been applied to a reprocessed AVHRR data set, yielding a 20-year climatology of aerosol amount over the world's oceans. This climatology is being used to develop an aerosol-robust SST retrieval algorithm which corrects for the cold-bias and random errors caused by volcanic aerosols (e.g., Mt. Pinatubo in 1991). Further research will extend this algorithm to tropospheric aerosols.

Although this research—and most satellite aerosol retrieval in general—has previously been limited to oceanic areas, the PATMOS data set is currently being investigated to determine the amount of aerosol signal over land. This research will help identify possible sources of aerosols (e.g., biomass burning areas) and likely improve vegetation index estimates. An aerosol signal has been found, but it is strongly affected by the surface bidirectional reflectance. Research is ongoing in an attempt to separate these effects. Preliminary results are suggesting that this can be performed for some regions of the Earth.

Development of a Fire Climatology

ORA is participating in a 3-year, multi-agency research project aimed at developing time series and climatology of North American wildfires from the existing ~15 years of 1 km AVHRR data record. The project is funded by the NASA Land Cover Land Use Change program. The other participants are USDA Forest Service, University of California at Berkeley, and Canada Center for Remote Sensing (CCRS). The project includes the extraction of all existing daytime 1 km AVHRR scenes over North America from the NOAA data archives, production of daily 1 km resolution georeferenced maps, running an AVHRR fire detection algorithm, and estimating gaseous and particulate matter emissions. The expected results from the project are time series and climatology of active fires, burned areas and emissions, particularly a quantitative estimate of the role of North American wildfires in the Earth's CO_2 budget. ORA's contribution will be the collection of the AVHRR database and development and validation of AVHRR fire detection algorithms applicable for NOAA satellites at various observational conditions due to the satellite orbital drift.

In support of the algorithm development and validation efforts, an experimental real-time automated AVHRR fire detection and monitoring system has been implemented at ORA (http://orbit-net.nesdis.noaa.gov/crad/sat/surf/fire/fireim.html). The accuracy of the fire detection algorithm is

being validated by visual inspection of AVHRR imagery, comparison with the results of other fire monitoring systems and with available ground-truth data.

Carbon Dioxide Studies

The carbon dioxide retrieval study is designed to determine the feasibility of using current and past sounding data to determine the sources and sinks for carbon dioxide. The first phase has been completed and used simulation studies to determine the sensitivity of the accuracy of the measurement of total column carbon dioxide to various instrument combinations. Combinations using past instruments such as (HIRS + AMSU) and (HIRS + MSU) show an ability to retrieve monthly mean values of carbon dioxide to slightly over 2 ppm while new high resolution instruments such as AIRS will be able to retrieve mean monthly values to within 1 ppm. In the next phase, the retrieval algorithms will be applied to stored data sets to determine local variations.

Oceans

Overview

Coastal and ocean remote-sensing services are expanding. The rapid pace of information and computing technologies now puts data processing and analysis capabilities on user desktops that were previously only available through access to large, mainframe computing. The Internet is revolutionizing data access, and users' expectations. In the Oceans research area, we focus on accelerating the operational transition of satellite data, information and services to the Nation's (and in some areas, international) coastal and ocean forecast, marine resource management, and public user communities. Several critical issues frame our research activities:

- Coastal and ocean remote sensing is dependent on having access to a mix of operational, research, and commercial satellite remote-sensing systems;
- While satellites do provide global coverage, many of our coastal and ocean user data needs are region or problem specific;
- In spite of the Internet and the advantages it brings, access by users to coastal and ocean satellite data is still a critical concern; and
- The coastal and ocean constituencies are new user groups to NESDIS. We have only just begun to learn who they are and what their operational needs are.

We are committed to understanding the regional implications of our national responsibilities, and thereby guide our research towards the development of services to ensure that the end user is appropriately served. We strive to make those differences arising from heterogeneous data sources (operational, research or commercial) transparent to the end user. We seek to provide scientific leadership in framing future activities in the national and international coastal and ocean remote sensing areas. What began in the 1960s as primarily a national domestic weather satellite system is now becoming an environmental

satellite system. We see expanding applications for our coasts and oceans to improve the future use and stewardship of our coastal resources, economy, and fragile ecosystems.

NESDIS Ocean Remote Sensing Program

The Office of Research and Applications manages NESDIS' Ocean Remote Sensing Program. This program is a funded activity of NESDIS, and sponsors ocean remote sensing-related research and applications development in three principal activity elements: 1) NOAA CoastWatch; 2) A peer-reviewed, external research program; and 3) NESDIS-relevant research and applications development. NOAA CoastWatch receives its operations and applications development resources from the Ocean Remote Sensing Program. Additional details on NOAA CoastWatch activities are provided separately below. The Ocean Remote Sensing Program's external research program seeks to expand the research base in ocean and coastal remote sensing. It encourages public and private universities, state governments, commercial, and not-for-profit organizations to undertake research in areas relevant to NESDIS' contributions to NOAA's missions that might be addressed through ocean remote sensing. Proposals are solicited annually through public notice in the Federal Register, and awards are selected through an independent peer-review process. The third element in the Ocean Remote Sensing Program provides resources to support selected NESDIS-relevant research in ocean remote sensing that has the potential for significant NESDIS payoff. Many of the activities described below receive support in varying degrees from this program. The program also sponsors major demonstrations of promising ocean remote-sensing research in coastal regions where potential end-users are brought in as partners. These demonstrations allow an early evaluation of promising research and help ORA scientists understand how the research might be applied by the users.

NOAA CoastWatch

ORA serves as the program manager for NOAA's CoastWatch Program and provides the major share of funding for its activities. CoastWatch is a national network of eight regional offices that serves to provide assistance and satellite data to coastal managers, forecasters, and researchers. In many regards CoastWatch serves an "ocean remote-sensing extension service" role for marine resource managers perhaps similar in principle to the Department of Agriculture's Agricultural Extension Service. By virtue of the CoastWatch regional offices being located "on-site" across the U.S. coast, we have intimate contact with our users and their resource management issues. CoastWatch helps users to become more aware of and enables them to be able to make use of satellite data in coastal and ocean resource management activities. In parallel to the remote-sensing extension service that CoastWatch provides, CoastWatch also helps develop and operate a high-resolution, near real-time environmental satellite data distribution system for the coastal ocean of the United States in support of governmental operational requirements, education and research. It also is involved in partnership activities with the National Ocean Service to address some of the longstanding satellite data access issues that coastal operational users. A major activity is the application of innovative geographic information systems (GIS) technologies to facilitate the assimilation of coastal and ocean remotely sensed satellite data in routine marine resource management activities. CoastWatch is a primary contributor to NOAA's Environmental Stewardship mission to Sustain Healthy Coasts, Recover Protected Species, and Build Sustainable Fisheries strategic goals. For additional information, please see http://coastwatch.noaa.gov.

Ocean Surface Winds

NOAA and NESDIS face two critical challenges in ocean surface winds research and applications development: full utilization of present sensors and active/passive sensing tradeoffs for future NOAA satellites. There is an increasing ocean surface winds observing capability (both active and passive) that is now being employed on a succession of satellite missions. Remotely sensed wind speed and direction data are critically important to improving coastal and open ocean storm forecasts, as well as to climate change studies. The National Polar-orbiting Operational Environmental Satellite System Program is moving forward to realize a converged U.S.-European polar-orbiting satellite system environment. There are critical sensor selection and risk reduction efforts that are required. This research activity addresses a broad range of existing deficiencies in NESDIS research and applications development support in ocean surface winds observations and their use, and has as its goals: to make full use of the present and planned winds observation satellite missions, including the NPOESS risk reduction mission Coriolis/WindSAT; to conduct exploratory product development, sensor calibration and validation experiments; and to accelerate the transition of experimental high-resolution ocean vector winds products to user communities. Additional research is being conducted to improve winds speed and direction estimates in high wind speed regions. This activity is a primary contributor to NOAA's Environmental Assessment and Prediction Mission to Improve Advanced Short-Term Warning and Forecast Services, Implement Seasonal to Interannual Climate Forecasts, and Predict and Assess Decadal to Centennial Change. For additional information, please see http://orbit-net.nesdis.noaa.gov/orad/.

Sea Surface Topography

The focus of our activities here is to develop capabilities to make full use of sea surface topography from satellite radar altimeters for NOAA operations and related research in global climate change and geophysics research. Operations include near-real-time processing and assimilation of satellite altimetry data into ocean models used for forecasting El Niño/La Niña, coastal ocean circulation, and hurricane intensity forecasts. Research topics include the North Atlantic oscillation, Pacific-decadal oscillation, global sea level change, bathymetric and gravimetric mapping, crustal dynamics, and polar ice mass balance. This activity is a primary contributor to NOAA's Environmental Assessment and Prediction Mission through the following strategic goals to Implement Seasonal to Interannual Climate Change, to Advance Short-Term Warning and Forecast Services, and to Predict and Assess Decadal to Centennial Change. For additional information, please see http://ibis.grdl.noaa.gov/SAT/SAT.html.

Ocean Color Physics and Biology—Biology

ORA is developing capabilities for users to make full and quantitative use of ocean color observing satellite systems. Areas of focus include the ocean's biological parameters (in particular the quantity and productivity of phytoplankton present), important geochemical and coastal sediment transport processes, and understanding the effect of human activities along the coast. Ongoing work includes efforts to implement NOAA's Ocean Color Validation System for SeaWiFS data; to develop methods to detect and predict the occurrence of noxious marine organisms in coastal waters (such as of sea nettles in the Chesapeake Bay); and to detect the occurrence of algal blooms (such as *Emiliania huxleyi*) that may have characteristic spectral signatures. This activity is a primary contributor to NOAA's Environmental Stewardship Mission to Sustain Healthy Coasts, Recover Protected Species, and to Build Sustainable Fisheries. It is a secondary contributor to NOAA's Environmental Assessment and Prediction Mission

through the Predict and Assess Decadal to Centennial Change strategic goal. For additional information, please see http://orbit-net.nesdis.noaa.gov/orad2/doc/ocp.html.

Ocean Color Physics and Biology—Physics

ORA manages a major NASA marine optical properties characterization and satellite sensor calibration program. Through this program, ORA has developed and now deploys on a continuous operational basis the Marine Optical Buoy (MOBY) system in the Pacific off Hawaii. MOBY serves as the single national and international standard for marine optical properties for both NASA's and industry's ocean color satellites. Capabilities to make full use of ocean color observing satellite systems to provide quantitative information relating to the ocean's biological parameters (in particular the quantity of phytoplankton present, important geochemical processes, and the state and magnitude of human activities in the ocean and along the coast) are now widely recognized as playing a critical role in understanding the biological and geochemical processes in the ocean. FY 2000 saw the successful launch of the NASA Terra (EOS AM-1) and Aqua (EOS PM-1) satellites. The satellites carry the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument that provides high spectral resolution of the ocean's surface every 1 to 2 days. Scientists and engineers in ORA are providing the data and analyses to calibrate and initialize the MODIS instrument for research and operational use. This activity is a primary contributor to NOAA's Environmental Stewardship mission to Sustain Healthy Coasts, Recover Protected Species, and Build Sustainable Fisheries. There are secondary contributions to NOAA's strategic goal to Predict and Assess Decadal to Centennial Change through improved understanding of the ocean's global biological and geochemical role in the carbon cycle.

Sea Surface Temperature—Coral Reef Bleaching

ORA has as its goal to realize the full utilization of space-based observations to monitor for early indications of climate change-induced coral reef bleaching on a global basis. A major objective is to be able to understand the relationship between the magnitude and persistence of anomalously high sea surface temperatures in coral reef areas and the subsequent reef mortality risks. The NESDIS Office of Research and Applications has established a vigorous research program that now provides coral reef "Hot Spot" and "Degree Heating Week" analysis charts weekly over the Internet on a global basis; has established a joint "virtual laboratory" with the Australian Institute of Marine Science, and the Great Barrier Reef Marine Park Authority in order to utilize existing in-situ reef research efforts in the Australian Great Barrier Reefs as a source of satellite in-situ validation data; and provides experimental "early-warnings" for coral reef bleaching based on satellite data derived ocean heating indices. These efforts are fully coordinated with the U.S. Coral Reef Task Forces exploring improved techniques and are anticipated to lead to a global network of in-situ calibration and monitoring sensors in coral reef areas that will be used with satellite data in order to improve the monitoring of critical coral reef ecosystems. This activity directly supports NOAA's Environmental Assessment and Prediction Mission through the Advance Short-Term Warning and Forecast and Implement Seasonal to Interannual Climatic Forecasts strategic goals. It also supports NOAA's Environmental Stewardship Mission through the Recover Protected Ocean Species and the Sustain Healthy Coastal Ecosystems strategic goals. For additional information, please see http://orbit-net.nesdis.noaa.gov/orad/coral_bleaching_index.html.

Sea Surface Temperature—GOES Sea Surface Temperature Evaluation and Data Assimilation

The office is developing the capabilities to provide calibrated Geostationary Operational Environmental Satellite temperatures for monitoring the time dependent changes along sea surface temperature fronts associated with oceanic currents, eddies and upwelling in order to allow monitoring of the oceanic environment along the coast as well as offshore. This activity is a primary contributor to NOAA's environmental stewardship missions to Sustain Healthy Coasts, Recover Protected Species, and Build Sustainable Fisheries. It is a secondary contributor to NOAA's mission of Environmental Assessment and Prediction Mission through the Predict and Assess Decadal to Centennial Change strategic goals through improved understanding of the observed changes in ocean currents, eddies and upwelling.

Sea Surface Temperature—Calibration and Validation

This research activity is focused on enhancing the satellite-derived sea surface temperature calibration and validation infrastructure within NESDIS in order to provide accurate quantitative data derived from different satellite platforms and instrumentation. Using in-situ sea surface temperature observations obtained in near-real time on a global basis from instrumented buoys (both fixed and drifting), data processing algorithms are developed and evaluated on a continuing basis. These algorithms are then incorporated into NESDIS' operational satellite data processing infrastructure to support the accurate derivation of SSTs from 1) NOAA's current polar operational satellites and future operational polar satellites; 2) NOAA's operational geostationary satellites; and 3) from non-NOAA satellites. These efforts contribute primarily to NOAA's Environmental Assessment and Prediction Mission.

Synthetic Aperture Radar and Multi-Purpose Imagery

In many areas of the world, especially in high latitudes, persistent cloudiness limits the operational usefulness of passive radiometric satellite sensors. Active microwave sensors such as synthetic aperture radar offer viable alternatives, and significant research has demonstrated that SAR can provide important data and information about the surface winds, sea ice, and sea state over the ocean. Until recently, operational use of SAR has been significantly limited by the associated heavy data processing and high bandwidth communications requirements required by the high data volumes associated with SAR. These limitations are now mitigated by the significant growth in computing and networked data communications capabilities. ORA has a major research effort to develop and demonstrate practical applications of synthetic aperture radar (SAR) imagery to be used in synergy with other satellite sensor data, in situ and model data, and human analysts' products. These applications include high-resolution ocean-surface winds and ice location for safety of life and property at sea, vessel positions for fishing enforcement, and oil spill, harmful algal bloom and flood mapping for hazard response. Users and collaborators include the CoastWatch Nodes, the National Weather Service Forecast Offices, the National Ocean Service, the National Marine Fisheries Service, the U.S. Coast Guard, the Alaska Department of Fish and Game, and the U.S. Air Force. This activity directly supports NOAA's Environmental Assessment and Prediction Mission through the Advance Short-Term Warning and Forecast Services strategic goal, and the Environmental Stewardship Mission through the Sustain Healthy Coasts, Build Sustainable Fisheries, and Promote Safe Navigation strategic goals. For additional information, please see http://orbit-net.nesdis.noaa.gov/orad/sar/index.html.

Sea Ice and Polar Oceans

In this activity ORA is working with the National Ice Center (a joint NOAA, Navy, and Coast Guard office) to develop capabilities to make full use of satellite observing systems and numerical models in order to provide quantitative information relating to the sea ice and polar ocean parameters. The long-term goal is to develop an automated daily, global 10 km resolution sea ice concentration product. This activity is a primary contributor to NOAA's Environmental Stewardship Mission through the Sustain Healthy Coasts strategic goal, and the Environmental Assessment and Prediction Mission through the Implement Seasonal to Interannual Forecasts, Promote Safe Navigation, and the Predict and Assess Decadal to Centennial Change strategic goals.

Oceanic Rainfall

ORA is developing the capability to improve the quantitative estimation of surface rainfall over the ocean. We anticipate that these efforts will yield improved insight for the development and operational deployment of satellite-derived, over-ocean precipitation estimates produced by NESDIS, GPCP, and TRMM. Such capabilities are important to climate change studies and to severe ocean/coastal storms prediction. This effort supports strengthening observing and prediction systems to advance short-term warning and forecasting services. This activity supports NOAA's Environmental Assessment and Prediction Mission in the Advance Short-Term Warning and Forecast Services strategic goal.

Instrument Calibration

Overview

Calibration of a satellite radiometer is defined as the process of determining the relationship between the instrument's response and the incoming radiation. This relationship is often inferred by looking at a source of radiation whose output can be varied in discrete, known steps. The relationship thus developed is used to determine the radiation sensed by the radiometer when it views an Earth scene. The importance of accurate determination of the Earth-scene radiation to ensure the quality of the derived geophysical product can hardly be exaggerated. Hence, a very comprehensive program of calibration of satellite radiometers in both the pre- and post-launch environments is presently underway in ORA to ensure that the operational products generated in ORA are of the highest quality. The following paragraphs briefly describe the calibration of the various sensors on NOAA's polar-orbiting and geostationary spacecraft, with emphasis on the visible and infrared radiometers.

Polar-orbiting Operational Environmental Satellites

The instruments flown on NOAA's Polar-orbiting Operational Environmental Satellites (POES) for the past 40 years have been an invaluable source of long-term geophysical records which have proven to be an essential component of studies of sea surface temperature, ozone, atmospheric temperature and humidity, aerosols, climate change, and the feasibility of drought and fire monitoring, to name a few. Since the usefulness of the satellite-derived geophysical products is essentially defined by the accuracy of the radiation measurements made at the top of the atmosphere, considerable effort is devoted to the calibration and characterization of the in-orbit performance of the instruments after launch.

The various sensors on POES measure radiation emerging at the top of the atmosphere in the ultraviolet, visible, infrared and microwave regions of the spectrum to derive surface and atmospheric variables. A typical payload, flown on the present POES, is made up of the: (1) Advanced Very High Resolution Radiometer (AVHRR); (2) High Resolution Infrared Radiation Sounder (HIRS); (3) Solar Backscatter Ultraviolet Spectral Radiometer-2 (SBUV-2); and (4) Advanced Microwave Sensors A/B (AMSU A/B). ORA scientists have developed improved vicarious techniques, using terrestrial targets with constant reflectance (e.g., deserts; snow fields of Greenland and Antarctica) for the calibration of the visible and near-infrared channels of the AVHRR and HIRS which do not have onboard calibration devices, and for the characterization of the in-orbit performance of onboard calibrators when they are present (e.g., the Along-Track Scanning Radiometer; SBUV/2). Simple methods to account for the non-linear response of thermal and microwave instruments (AVHRR, Microwave Sounding Unit (MSU), AMSU) have been established, and these are finding wide application in the reprocessing and rehabilitation of the relevant long-term geophysical records (e.g., the NOAA/NASA Pathfinder Program). In particular, the reprocessing of the pre-launch calibration data for the MSU flight models flown on TIROS-N, NOAA-7 through NOAA-12, and NOAA-14 will be central to the analysis and interpretation of MSU-derived atmospheric temperature records.

We are presently investigating how best to improve calibration accuracies with the different instruments. We are actively participating in the design and development of optimum sensors for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). We are also involved in the development of techniques for the characterization of the in-orbit performance of radiometers to be flown on ENVISAT, a European platform. Present plans call for active collaboration with the National Institute of Standards and Technology (NIST) in the definition and establishment of protocols for the pre- and post-launch calibration of radiometers to be flown on NOAA's POES and NPOESS platforms. The feasibility of using the International Space Station as a platform for NIST-traceable, retrievable, reference radiometers to calibrate the POES sensors is under study.

Geostationary Operational Environmental Satellites

The meteorological payload on the present Geostationary Operational Environmental Satellite (GOES) is made up of a 5-channel imager, patterned after the AVHRR, and a 19-channel (18 infrared and one visible) sounder patterned after the HIRS. The imager is primarily used to obtain Earth images under clear skies and to study clouds and upper tropospheric moisture. The measurements by the sounder of the infrared radiation at the top of the atmosphere are used in the derivation of atmospheric temperature and moisture, winds over the oceans, and in the study of rapidly evolving mesoscale phenomena. Thus, the imager and sounder measurements together provide invaluable tools to study weather.

The procedures for the real-time calibration of the GOES Imager and Sounder in the ground-system were developed, and continue to be maintained, by ORA scientists. The calibration accounts for non-linearities in the response of the infrared channels, which use onboard calibration devices. In addition, methods were developed to account for the directional dependence of the reflectances of the instruments' scan mirrors in the infrared, a phenomenon that was first observed after GOES-8, the first of the current series, became operational. Active collaboration has been established with the National Institute of Standards and Technology (NIST) to improve the accuracy of the laboratory blackbody calibration sources on which the in-orbit calibration is based. (We plan to extend this collaboration to include the laboratory sources for future polar satellite radiometers.)

The visible channel of the GOES Imager has no onboard calibration device. We have developed a vicarious technique to calibrate this channel on orbit, using the visible channel of the AVHRR as a calibration reference. In addition, the relative degradation in orbit is estimated from long-term observations of stars, which serve as stable sources of illumination.

Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS is the key instrument aboard the Terra (EOS AM-1) satellite. The MODIS instrument will view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands. These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS will play a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment. Through its Marine Optical Buoy observations, ORA provides the ocean optical calibration data on which the MODIS sensor is calibrated. Of particular importance is the development of coastal turbid water calibration data to improve the quantitative use of MODIS data in coastal regions. For additional information, please see http://modis-ocean.gsfc.nasa.gov/.

TOPEX/POSEIDON Altimeter

The joint NASA/CNES satellite altimeter, TOPEX/POSEIDON, has been operating since September 1992. It is the most accurate altimeter system flown to date, with an absolute accuracy of about 4 cm. ORA is assisting in the calibration of the TOPEX/POSEIDON altimeter through an ongoing analysis of the altimeter data records with ocean tide gauges that are distributed across the Pacific Ocean. In this effort TOPEX/POSEIDON altimeter data are processed as collinear differences and sea level time series are averaged by longitude and latitude for each month. The monthly altimeter deviations are then compared with similar averages from Pacific island tide gauges (corrected for the inverse barometer effect). ORA also provides analyses that estimate along-track sea level deviations, gridded sea level deviations, and gridded sea level anomalies, all of which are used in the TOPEX/POSEIDON calibration effort. For additional information, please see http://ibis.grdl.noaa.gov/SAT/hist/index.html.

Geosat Follow-On (GFO) Altimeter

Geosat Follow-On is a U.S. Navy altimeter mission that was launched on February 1998. ORA works together with the Naval Oceanographic Office (NAVOCEANO) to process the altimeter data and will provide geophysical data records (GDRs) to the scientific research community. All of this processed data will be unclassified. As part of the Calibration/Validation effort for GFO, ORA is actively analyzing both the Sensor Data Records (SDRs) and NAVOCEANO Interim Geophysical Data Records (GDRs). This is part of our effort to perform the geophysical validation of the final NOAA GDRs. For additional information, please see http:// ibis.grdl.noaa.gov/SAT/gdrs/gfo.html.

Future Instrument Planning

Overview

A major focus of ORA's activities is preparing for new instruments and planning future instruments for its polar and geostationary satellites. To transition from the current NOAA series of polar orbiting satellites (POES) to the converged military-civilian NPOESS at the end of this decade, ORA is leveraging the polar satellite programs of NASA, DoD, and international agencies. These agencies are and will be flying NPOESS-like instruments prior to NPOESS. For each NPOESS instrument there are pre-cursor instruments with similar capabilities on NASA's Earth Observing System (EOS), DoD's DMSP, and European Organization for the Exploitation of Meteorological Satellites' (EUMETSAT) METOP satellites. The joint NASA/IPO NPOESS Preparatory Project will fly the first versions of three of the planned NPOESS instruments as early as 2005. ORA, working with the NESDIS Office of Satellite Data Processing and Distribution (OSDPD), is accessing the data from, and developing prototype product processing systems for, key pre-cursor instruments. These systems are building on the science and processing paths developed by the NASA instrument teams, the other space agencies, and NPOESS instrument contractors. Participation by ORA scientists on the instrument teams of these non-NOAA satellites has given ORA a head start on the utilization of the data from these instruments. ORA scientists are adapting the algorithms, or developing new ones, to meet NOAA's operational requirements. They are evaluating whether these NPOESS-like instruments meet the NPOESS operational requirements. ORA works with the NOAA user community to evaluate the products and demonstrate their benefits in NOAA operations. A major objective of these activities is risk reduction for NPOESS and early demonstration of NPOESS capabilities and benefits.

Ocean Observer Mission Planning

The Ocean Observer Mission study is addressing requirements for high-resolution ocean observations from space. These requirements may form the basis for a limited set of Earth satellite missions in advance of the NPOESS Block 2 upgrade. Of particular interest are ocean surface winds, sea level, and all-weather multi-purpose high-resolution imagery. ORA leads the inter-agency user requirements panel in the Ocean Observer Mission study.

NPOESS Emulation Using the Moderate Resolution Imaging Spectro-Radiometer (MODIS)

The NASA Earth Observing System satellite, Terra, launched in December 1999, carries five sensors to collect data on Earth's atmosphere, biosphere, hydrosphere, land surface, and radiant energy. Terra's key instrument is MODIS which images the Earth's surface every 1 to 2 days and obtains data from land, oceans, and the lower atmosphere in 36 visible and infrared spectral bands at band dependent resolutions of 250 and 500 m and 1 km. NESDIS will produce selected MODIS products in near realtime, less than 180 minutes after data ingest, and deliver the products to customers in operations and research for use and assessment. The analysis, evaluation, and use of MODIS experimental products will significantly mitigate the risk related to the performance of the VIIRS instrument to be carried on NPP and NPOESS. To process these MODIS products for North America and surrounding coastal oceans, NESDIS installed a computer system at the Goddard DAAC. The products will be delivered to NESDIS in Suitland,

Maryland. The NESDIS server at GSFC uses NASA software with algorithms developed by the MODIS Science Teams. The selected MODIS Level 1 and 2 products are: Level 1A, Geolocation, Level 1B, cloud masks/profiles, clouds, snowcover, sea ice, ocean color, and sea surface temperature. ORA will also produce products from MODIS using VIIRS algorithms and our own techniques (CLAVR) to evaluate and characterize products expected from NPP/VIIRS.

Special Sensor Microwave Imager Sounder (SSM/IS) Calibration and Validation

The SSM/IS, which is scheduled to be launched in December 2000, is the first microwave instrument with collocated temperature and moisture sounding channels. These channels are also collocated with the imaging channels. The instrument is mounted on the anti-Earth side of the spacecraft, and a large rotating antenna directs Earth-emitting radiation into a set of feedhorns and the associated electronics. The potential exists for more accurate retrieval products from this viewing configuration than from present satellites where the different channels are distributed among different instruments. However, there are challenges to be met in order for the SSM/IS to be successful, not the least of which is the calibration function. This function establishes a relationship between the observed scene temperature and the instrument measurements. Traditionally this is done by the instrument viewing an internal target of known temperature and deep space, which has a temperature of about 2.7 K. Because the SSM/IS is a conically scanning instrument, the warm target is viewed only by the feedhorns, not by the main antenna, and deep space is viewed by the feedhorns only through a secondary reflector. In order for the calibration to be successful, great care must be taken to characterize the reflectivity of the reflectors and of the other components of the system. Validation of the SSM/IS products involves comparing those products with other measurements of known quality—for example, comparing the SSM/IS derived temperature profile with that measured from rawinsonde that is collocated in time and space. Examples of other sources of validation data include aircraft (ACARS), and other satellite retrievals (e.g. NOAA, DMSP). The Naval Research Laboratory has funded ORA to perform validation and to assist in the calibration of the SSM/IS retrieved atmospheric temperature and moisture profiles. This activity is expected to be completed approximately 12–18 months after launch. The focus of this work is for risk reduction for NPOESS, which will fly a much more advanced version of the SSM/IS called the Conically scanning Microwave Imager/Sounder (CMIS) in about 2008.

Atmospheric Infrared Sounder

ORA scientists are directly involved in the development of new procedures for the operational processing of high spectral resolution infrared data. The new generation of infrared sounders including the Atmospheric Infrared Sounder (AIRS), the NPOESS CrIS (Cross-track Infrared Sounder), and the Infrared Atmospheric Sounding Interferometer (IASI) will introduce many new developments in the use of infrared measurements in operational forecasting and climate studies. These new instruments will provide atmospheric temperature profiles with an accuracy of 1 K over 1-km layers and atmospheric moisture profiles with an accuracy of 15% in 2-km layers, which are expected to lead to improvements in numerical weather forecasts. These instruments will also have the capability to measure the concentration of trace gases such as ozone and carbon monoxide. The enormous volume and the new characteristics of the measurements from these instruments will provide new challenges in producing accurate atmospheric profiles within operational time constraints. New techniques for computing limb adjustments and transmittances will be required. ORA scientists are working on retrieval techniques to allow the efficient

use of a large number of predictors as well as new techniques for cloud clearing. ORA is a world center for addressing these issues. The AIRS data will be processed operationally at NESDIS and will be used in EMC's numerical weather forecast as a prototype for the future infrared sounding instruments. This will require the close collaboration between scientists at ORA and NWS/NCEP. There will also be collaboration with investigators from NASA/Goddard Space Flight Center's Data Assimilation Office (DAO) and the UK Meteorological Office (UKMO).

Global Ozone Monitoring Experiment

GOME-2 (Global Ozone Monitoring Experiment) will be part of the instrument suite on the European Meteorological Operational Platform (METOP). ORA scientists are participating in the development of the GOME-2 instrument and algorithms through formal and informal arrangements. An ORA scientist is on the Instrument Functional Chain Team (IFCT) for GOME-2 and provides reviews of GOME-2 plans. On an informal level, research results from ORA studies of GOME profile retrievals are provided to GOME and GOME-2 calibration and algorithm researchers.

GPS Occultation Sensor (GPSOS) and Doppler Wind Lidar (DWL)

NESDIS/ORA has supported the selection and design reviews for the NPOESS GPSOS, the first of which will be deployed in 2008. However, operational data of this type will become available as early as 2003 from the METOP GPS Radio Atmospheric Sounder (GRAS) and from the international Constellation Observing Satellites for Meteorology, Ionosphere, and Climate (COSMIC). ORA scientists will participate in the validation of these observations by comparing them to those from conventional sounders, making certain that they are of suitable quality for use in the weather forecasting system. To prepare for operational use of GPSOS observations, ORA and NCEP/EMC have applied a ray tracing "forward model" to facilitate ingestion of GPS bending angles into NCEP's global data assimilation system. ORA organized and hosted an international workshop on the GPS Radio Occultation technique in May 2000 to assess the state of GPS/RO science and technology, to discuss means for mitigating certain shortcomings of the GPS/MET demonstration sensor, and to document progress and problems encountered in preparing for operational use of the data for weather prediction and climate monitoring. Directly sensed global tropospheric wind observations are widely thought to have the potential to improve numerical weather forecasting significantly, and Doppler Wind Lidar (DWL) is the prime candidate sensor to provide these data. Although the cost and risk posed by an operational space-based DWL are considerable, so is the anticipated payoff. ORA scientists have worked to support such an instrument. ORA's efforts include participating in design reviews of a novel ground-based DWL instrument that may prove suitable for scaling to a space-based wind sensor. They have guided efforts by the DWL developers to plan a demonstration campaign that will allow its performance to be evaluated under varying atmospheric conditions and its wind measurements to be compared to those provided by radiosondes and NOAA/ETL Doppler radar and lidar. In addition, ORA scientists have been involved in the design and execution of Observation System Simulation Experiment (OSSE) to quantify the marginal improvement that DWL data might provide to NCEP's numerical weather forecast. Finally, ORA scientists are working with NASA to develop a validation/verification plan for future space-based DWL observations.

Observing Systems Simulation Experiments

ORA is engaged in an Observing Systems Simulation Experiment (OSSE) in collaboration with the NWS Environmental Modeling Center and NASA's Data Assimilation Office. The focus of this OSSE is the Doppler Wind Lidar (DWL). The question to be addressed is, "What incremental improvement might a DWL make on the numerical weather forecast over the present and near future observing system?" To answer this question, a "nature run" first must be established. The nature run is a long-term numerical forecast made by a forecast system other than the one to be used in the OSSE. Our 30-day nature run from early February to early March 1993 was provided by the European Centre for Medium Range Weather Forecasting in Reading, England. All present day observing systems (e.g., weather balloons, surface observations, satellite radiances) are simulated from the nature run. These simulated data are then assimilated into the EMC analysis model to assess the accuracy of the simulations and to validate the methodology. The next step is to simulate future instruments that are likely to be on orbit with a DWL. The Atmospheric Infrared Sounder (AIRS) to be flown on the next NASA EOS satellite is an example of such an instrument.

To date, ORA has produced simulated radiances for the High resolution InfraRed Sounder and the Microwave Sounding Unit for both NOAA-11 and NOAA-12 for the entire period of the nature run. Generation of simulated radiances for the Advanced Microwave Sounding Unit-A (AMSU-A) for these satellites is in progress and should be completed by the end of FY 2000. The AMSU-A simulation proved to be challenging because its scan pattern is different from that of other instruments, and because it did not fly until NOAA-15 was launched in June 1998. A method of scan pattern simulation was included with the rest of the software development. AIRS will require similar scan pattern simulation, as well as extensive modification to the radiative transfer software in order to compute the nearly 2,400 high spectral resolution channels. AIRS simulation production is expected to occupy all of FY 2001.

ORA has also played an advisory role in the generation of simulated DWL line-of-sight velocities for the OSSE. Because the specific nature of the DWL remains undetermined, a series of DWL observations of varying coverage and accuracy are being simulated. These will enable a set of technology-neutral, "bracketing" OSSEs to be run and multiple performance benchmarks to be established. It is anticipated that these benchmarks will help determine the data requirements for an operational DWL. New simulations may be made and new additional OSSEs run based on specific DWL concepts or designs proposed in the future.

ORA is also investigating the impact of possible improvements to the satellite remote-sensing capabilities on mesoscale numerical weather prediction (NWP). In collaboration with the CIMSS and FSL, ORA has designed and implemented a software system that enables quantitative assessment of the value of different atmospheric measurements to operational mesoscale numerical forecasts. Using the construct of an Observing System Experiment (OSE), where existing operational observing systems are assimilated into an analysis/forecast system and quantitatively assessed in a controlled-software environment, the ORA/CIMSS software system has been extended to include proposed observing systems. These assessments are performed as Observing System Simulation Experiments (OSSEs), where future-observing systems can be compared to existing systems to determine their relative potential for improving forecast skill.

Geostationary Advanced Baseline Imager and Advanced Baseline Sounder

To keep pace with the growing needs for GOES data and products, NOAA is evolving its geostationary remote sensing capabilities. Both the Advanced Baseline Imager (ABI) and the Advanced Baseline Sounder (ABS) enhance current capabilities and address unmet requirements of the NWS. Proposed for GOES Q in 2008, ABI has a minimum of 8 to a maximum of 12 channels representing an increase of 3 to 7 channels over the current GOES imager channel complement. ABI will improve the detection of volcanic ash clouds, delineate water and ice clouds, detect thin cirrus, and improve SST estimates. ABI will have more in common with satellites flown by NASA and our international partners and thus enhance the exchange of research algorithms and the generation of global products. ABI will also have higher spatial resolution in the visible and IR channels to enable detection of small-scale features and ABI will employ a faster scanning scheme to reduce the conflict between full disk and Continental U.S. (CONUS) coverage.

Design of the ABS is still underway. Today's GOES sounder has 19 spectral channels that provide limited vertical resolution inadequate for current NWP models. ABS will be an interferometer with hyper-spectral capabilities with over 1500 narrow spectral channels; this will improve vertical resolution and provide much cleaner atmospheric window channels. The ABS will also have faster scanning capabilities that will enable sounding of the full disk or more frequent sounding of the CONUS. It is planned for GOES R in the 2010 timeframe.

Technology Transfer

Transitioning Research Into Operational Utilization

Transfer of technology from ORA is accomplished through two pathways: 1) directly, to NESDIS operations as algorithms or products, and 2) to academic and international scientists and field forecasters through Internet web sites, publications, workshops, and professional conference and meeting participation. Technology transfer consists of research, algorithm development, software transfer, test and evaluation, distribution, and training. The objective of this effort is to maximize the use of satellite data and products in weather monitoring and prediction.

Nearly all the 200 plus operational products produced by NESDIS were developed by ORA scientists. Work continues to improve the science and algorithms that serve as the basis of these products. Long before these become operational they are evaluated by the user community, primarily the NWS, through access from various web sites and through formalized programs such as the NWS GOES Sounder Product Assessment and the Auto (precipitation) Estimator Demo conducted in 1999.

The next step in ORA's technology transfer program is training the users in the interpretation and utilization or application of the products to their assessment, analysis, or forecast challenge. ORA scientists have developed numerous avenues to achieve this step. The most recent approaches, recognized by a NOAA Bronze medal in 1999, are through classroom and computer-based training modules of the Cooperative Program for Operational Meteorology, Education and Training (COMET) and a joint NESDIS/NWS and Cooperative Institute (CIRA and CIMSS) program called VISIT.

Since 1996 ORA staff have presented over 85 lectures at workshops held at the COMET facility. Attendees are primarily NWS personnel, although representatives from other agencies (for example, Department of Defense forecasters, university faculty and students, etc.) also participate. This year two new computer-based learning (CD-ROM) modules: microwave satellite data interpretation and polar satellite products for forecasters have been completed. In total ORA scientists have been lead authors or contributed to at least a dozen CBL modules. These are developed primarily for use off-site at NWS forecast offices.

Most recently, this Team has developed an interactive "virtual" classroom instruction tool called Virtual Institute for Satellite Integration Training (VISITVIEW). The VISITVIEW program uses Internet technology to provide distance learning that allows interaction between students and instructors similar to a classroom situation. VISITVIEW provides concurrent instruction to multiple sites. In FY 00, 97 VISIT training sessions were conducted reaching 375 NWS and NESDIS offices and providing training to an estimated 1,900 students.

In addition to the VISIT interactive classroom, ORA maintains, through its web pages, a Virtual Institute with satellite tutorials, and a wide assortment of case studies, and technical information and documents for users to peruse and use.

This concept of remote training is expanding well beyond the U.S. Through the auspices of the World Meteorological Organization, ORA and CIRA scientists are bringing real-time geostationary data and interpretative assistance to Central and South America and the Caribbean Regional and Meteorological Training Centers. On the horizon are plans to expand collaboration and training programs to Europe, Africa, and Asia.

In addition to classroom efforts, ORA scientists participate in traditional workshops, professional conferences and publish extensively. The list of meetings and workshops can be found in Appendices 6, 7, 8, 10 and 11.

NOAA CoastWatch

NOAA CoastWatch is a national network of eight regional offices that serves to provide assistance and satellite data to coastal managers, forecasters, and researchers. Each office is located within an appropriate NOAA line office activity in the region (for example, National Marine Fisheries Laboratory, National Weather Service Regional Office, etc.). By virtue of the CoastWatch regional offices being located "on-site" along the U.S. coast, we have intimate contact with our users and their resource management issues. CoastWatch helps users to become more aware of and enables them to be able to make use of satellite data in local and regional coastal and ocean resource management activities.

Penobscot Bay, Maine, Marine Resources Collaborative

This Collaborative, sponsored by ORA, has as its objective the integration and near-real time electronic dissemination of remotely sensed environmental data to regional resource managers. Using the Penobscot Bay ecosystem as the demonstration focus for important regional marine resource management issues, the Collaborative seeks to: 1) bring ocean remote-sensing observations tools to the characterization of the

region; 2) build an integrated, multi-disciplinary team among the Federal, state, academic, and private partners; 3) provide for timely data access for state users by augmenting the State of Maine's geographic information system (GIS) infrastructure for use in supporting marine resource management decisions; and 4) foster expanded and lasting relationships among the partners, especially through the develop-ment of post-demonstration funding resources. For additional information, please see http://apollo.ogis.state.me.us/projects/penobay/penobay.htm.

Scientific Partnerships

NOAA Partnerships

National Centers for Environmental Prediction. ORA has strong partnerships with the NOAA/NWS National Centers for Environmental Prediction Environmental Modeling Center, Tropical Prediction Center, and Climate Prediction Center. ORA and EMC are conducting a number of joint projects to accelerate the use of satellite data in NWP. ORA and TPC scientists are exploring the optimum utilization of satellite-derived temperatures and winds in hurricane intensity investigations. ORA ozone scientists work very closely with CPC scientists responsible for monitoring the stratosphere and are collaborating on several tropical storm research projects with TPC.

Office of Oceanic and Atmospheric Research. NOAA's Office of Atmospheric Research is a co-investigator with ORA in a number of GOES model impact studies and field collaborations. Model impacts include studies with high spectral resolution infrared sounders and GPS meteorological profilers. Field collaborations include the NAURU Island ocean and atmospheric experiment. In addition, a scientist from the National Severe Storms Laboratory is stationed half time at the CIMSS, where joint studies on using GOES Imager and Sounder data in field nowcasting and forecasting are being pursued.

National Marine Fisheries Service. The National Marine Fisheries Service (NMFS) is a key partner in our effort to apply remote sensing technologies to fisheries management. NMFS also is host to four of the eight CoastWatch regional offices.

National Ocean Service. ORA is collaborating with the National Ocean Service in efforts to develop valid data processing algorithms for observations of ocean color (chlorophyll) in coastal waters. If successful, these algorithms will allow the quantitative use of satellite-observed chlorophyll in sediment-rich, coastal waters where current open-ocean algorithms fail. ORA also sponsors four full-time positions at the National Ocean Service's Coastal Service Center in Charleston, SC, in developing new coastal applications and information technologies in remote sensing.

QuikSCAT Ocean Winds and the National Weather Service. ORA has established a cooperative program with the National Weather Service's Alaska, Western, and Tropical Forecast Centers in order to evaluate the application of near-real-time QuikSCAT ocean surface wind observations to the forecasting of coastal storms. QuikSCAT is the first high-resolution ocean wind vector observing satellite, and greatly supplements the sparse in-water buoy observations data.

National Partnerships

NASA Goddard SpaceFlight Center. In a NASA/NOAA partnership, ORA and NASA GSFC scientists work jointly on NESDIS SBUV/2 ozone measurements. NASA is largely responsible for characterizing the instrument and supplying the algorithm for measuring the total amount and vertical distribution of the ozone from the instrumental observations. In addition, ORA scientists are members of the MODIS Science Team, coordinated by GSFC.

NASA Langley Research Center. ORA and NASA LaRC scientists are working together to investigate new science possibilities with interferometer measurements from geostationary orbit. Collaboration on GIFTS algorithm development is part of that effort.

Department of Defense. The Department of Defense is a strong partner of ORA particularly in its support of the development of satellite winds. Other programs such as Shared Processing are also vehicles for collaboration on algorithm development for DMSP products. Throughout the years, ORA has collaborated on a number of aviation products, especially in the testing and validation phases. More recently, ORA is providing fire products for assimilation in the Navy NAAPS model to diagnose and predict biomass emissions and transport in real time.

EROS Data Center. An ORA scientist is stationed permanently at the EROS Data Center (EDC) in Sioux Falls, SD, to collaborate in the large land surface remote-sensing activities there. EDC is the archive for Landsat data, the global 1-km AVHRR data set and is the Land DAAC for the NASA EOS program. The ORA scientist uses these land remote-sensing data sets to provide boundary data sets for NWP.

International Partnerships

U.S.-China Protocol. ORA participates in the U.S./China Agreement on Cooperation in Atmospheric Science by hosting long-term visits by scientists from the Chinese National Satellite Meteorological Center and sending ORA scientists to China for lecture series on satellite remote sensing and applications.

U.S.-India Protocol. In 1998, the U.S./NOAA/NASA signed an agreement with India for the exchange of data and products from the INSAT geostationary satellite. ORA scientists are participating in the science projects with the India Meteorological Department and the National Remote Sensing Agency that are part of this agreement.

Japanese Meteorological Agency (JMA). ORA has a scientific collaboration plan that it follows jointly with scientists from JMA in pursuit of improved utilization of remote-sensing data in NWP.

National Space Development Agency of Japan (NASDA). ORA has a scientific collaboration plan that it follows jointly with scientists from the Japanese NASDA to exchange data sets from our respective remote-sensing assets and to pursue joint science projects with those data.

European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). ORA has a scientific collaboration plan that it follows jointly with scientists from EUMETSAT to exchange data sets from our respective remote-sensing assets and to pursue joint science projects with those data.

World Meteorological Organization (WMO). ORA also participates in WMO activities through membership on committees and through its technology transfer efforts at Regional Meteorological Training Centers around the world.

Coordinating Group for Meteorological Satellites (CGMS). ORA participates in CGMS annual meetings, providing science input in the committees on satellite imagery, winds, and soundings. ORA also is active in the International Winds Working Group and the International TOVS Working Group meetings; both working groups report to CGMS.

Curtin University of Technology (CUT). ORA has a Memorandum of Understanding with CUT in Western Australia to pursue remote-sensing research and to exchange personnel as appropriate. Ground based interferometry and calibration/validation of polar-orbiting radiometers have been recent efforts.

Instituto Nacional de Pesquisas Espaciais (INPE). ORA is engaged in joint studies of biomass burning, aerosol transport, and data assimilation with scientists from INPE in Brazil.

Environment Canada. ORA is assessing the utility of GOES imager fire detection and monitoring capabilities in remote regions at high latitudes with Environment Canada in the Quebec region.

International Drought Monitoring. ORA has cooperative activities in drought monitoring with the following agencies: National Weather Service (NWS), United States Department of Agriculture (USDA), International Drought Mitigation Center/University of Nebraska, and Remote Sensing Institutions of Poland, Argentina, Morocco, Kazakhstan, Russia, Zimbabwe, Brazil, India, Mexico and fire monitoring activities with U.S. AID, Department of State, Brazil, Canada, U.S. Forest Service, Department of the Interior, and various state emergency management offices. Under these activities, we transfer technology, provide in-house training, supply processed data, validate and calibrate satellite-derived products, expand activities in other areas of the environment, do research and development based on users requests.

Rutherford Appleton Laboratory, U.K. An ORA scientist is collaborating with investigators in the Rutherford Appleton Laboratory, Didcot, United Kingdom, in the development of vicarious techniques for the in-orbit characterization of onboard calibrators; a detailed survey of sites suitable for use in the vicarious calibration of satellite sensors is also underway.

French Space Agency (CNES). The TOPEX/POSEIDON satellite was launched on August 10, 1992, with the objective of observing and understanding the ocean circulation. A joint project between NASA, the U.S. space agency, and CNES, the French space agency, it carries two radar altimeters and precise orbit determination systems, including the DORIS system. ORA is a partner in this effort, and provides near real-time processing and interpretation of the TOPEX/POSEIDON sea level data.

International Ocean Color Coordinating Group (IOCCG). ORA is the NOAA representative on the IOCC, an international organization dedicated to the development of quantitative applications of ocean color observations from Earth satellites.

Integrated Global Observing Strategy (IGOS). ORA is a member of the IGOS-sponsored, international Ocean Theme Panel that is developing the statement of needs and priorities for global ocean observations from space.

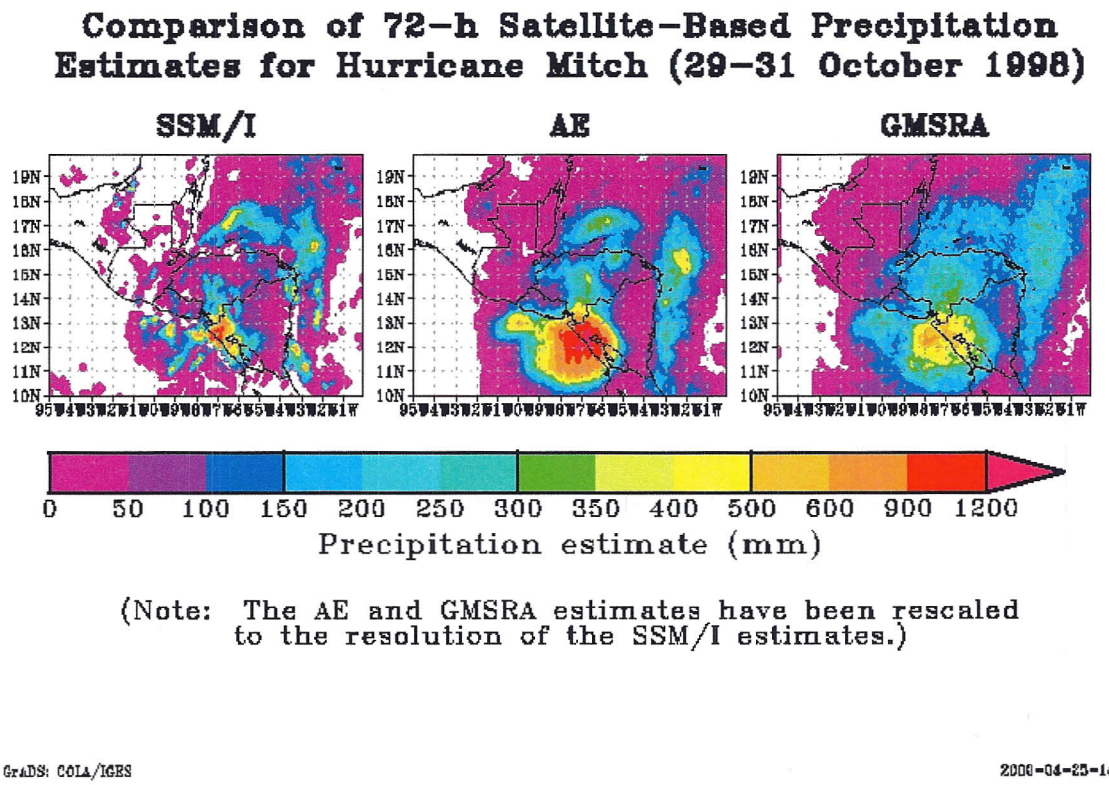
Irish Marine Institute (IMI). ORA is collaborating with the Irish Marine Institute in a cooperative program to assist in the incorporation of satellite observations into marine fisheries management in Irish waters. The focus is on transitioning ORA's synthetic aperture radar (SAR) processing technologies to the IMI. SAR is particularly relevant in the northeast Atlantic due to the persistently cloudy conditions that prevail there.

6. HIGHLIGHTS

Weather

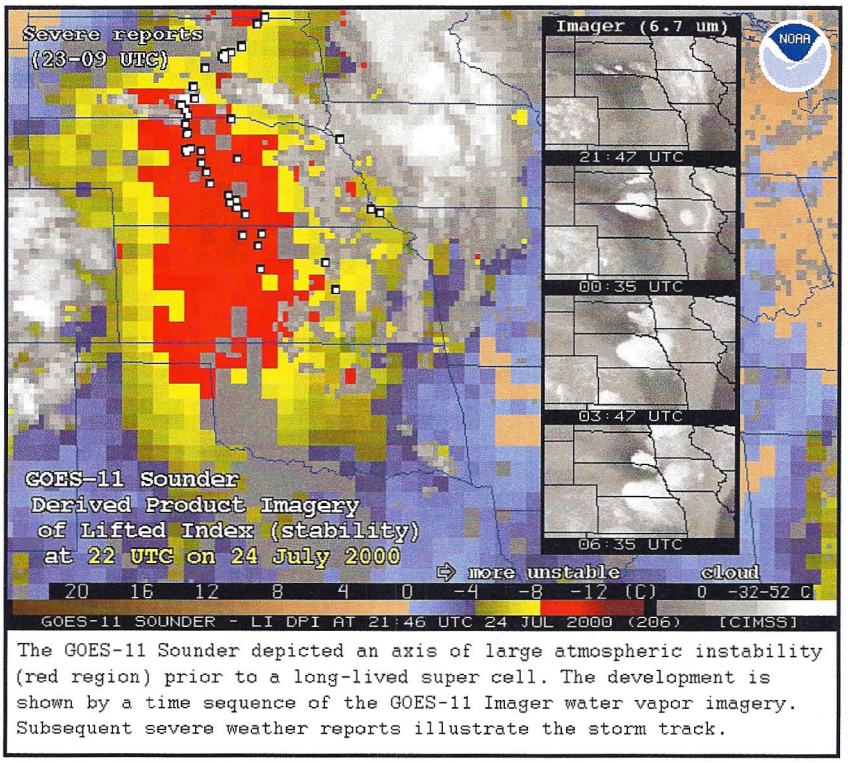
Geostationary Auto-Estimator and Multispectral Precipitation Algorithms

The Auto-Estimator (AE), an infrared technique to estimate rainfall amounts, became operational in June 2000, replacing the labor and time intensive Interactive Flash Flood Analyzer (IFFA) that had been in use since 1978. Not only labor intensive, the IFFA could only monitor one storm system at a time. The new AE expands the analyst's ability to monitor the entire continental U.S. at 15 minute intervals. The AE estimates are based on the cloud top temperature, changes and gradients in this temperature. Enhancements to the estimates are made for cloud mergers and orography. The analyst can also adjust environmental conditions, such as precipitable water and temperature based on the soundings to accommodate tropical systems and warm-topped convection. The new AE reduces the time to compute estimates by 60%. Estimates are provided to NWS forecast offices and the Heavy Precipitation Unit of NCEP as guidance for flash flood watches and warnings. Infrared precipitation techniques, such as the AE, tend to overestimate precipitation especially in the anvil area of convection. Various approaches have been tried to reduce the overestimation problem. One such approach is the GOES Multi-spectral Rainfall Algorithm (GMSRA) that employs all channels of the GOES imagers. It uses the effective cloud droplet radius to determine precipitating and non-precipitating clouds. The instantaneous rain rate is computed using a precalibrated probability of rain and a mean rain rate for the cloud top brightness temperature. Other techniques including satellite microwave (SSM/I) and real-time doppler radar reports are being used to improve the satellite rainfall estimates.



Comparison of 72-hour precipitation estimates from the AE, GMSRA, and SSM/I techniques for Hurricane Mitch.

GOES Sounder Derived Products for NWS Forecast Offices



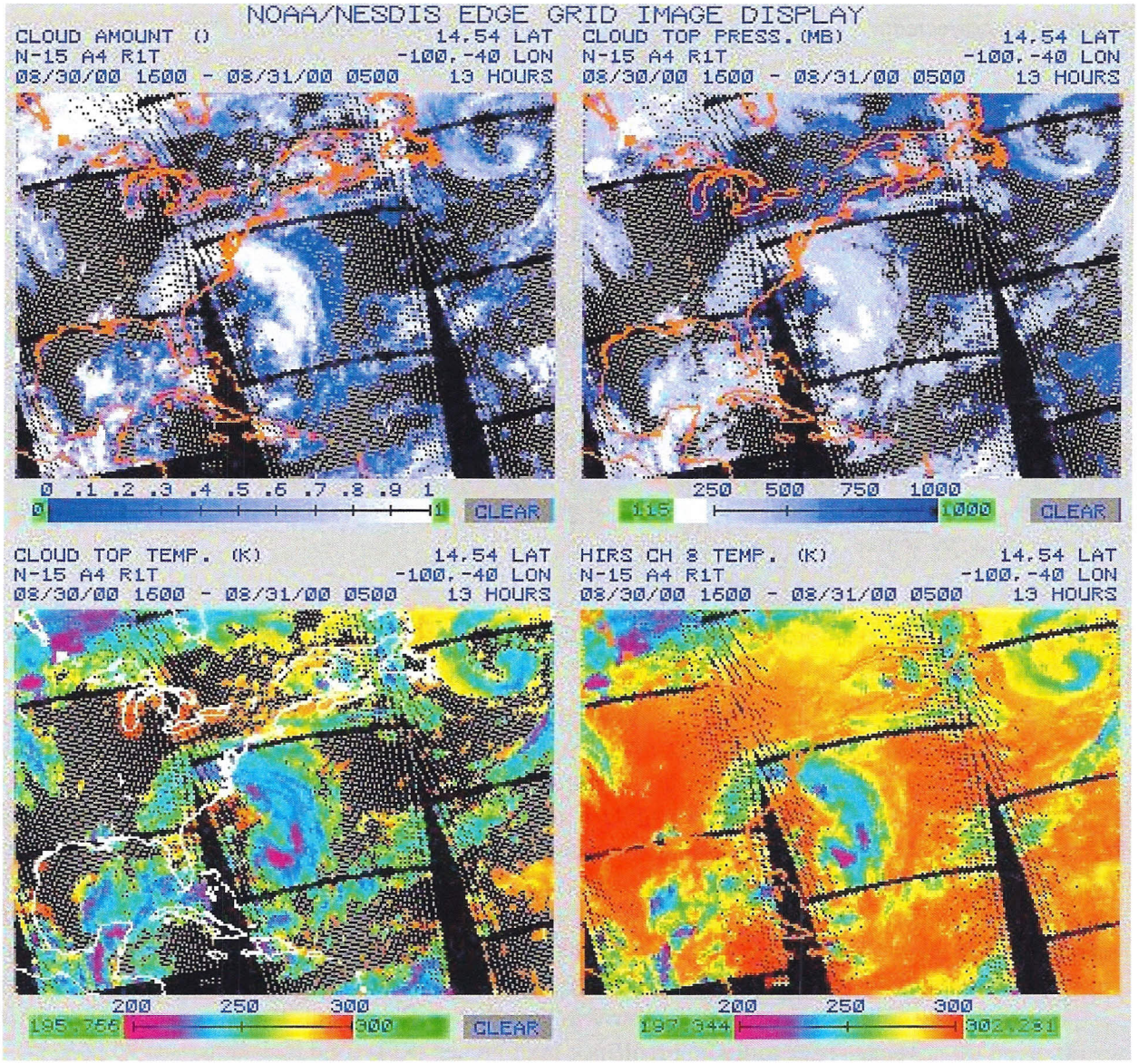
GOES Sounder Lifted Index Derived Product Image successfully diagnoses an axis of large atmospheric instability prior to long-lived super cell.

ORA is generating hourly GOES Sounder derived product images (DPI) and distributing them to the NWS Forecast Offices. They include moisture and atmospheric stability values such as Lifted Index (LI), Precipitable Water (PW), and Convective Available Potential Entergy (CAPE). In a 1999 NWS survey, forecasters indicated that they used the sounder products as tools to evaluate the potential of a wide variety of weather events, including tornadoes, severe thunderstorms, monsoon precipitation, and flash flood events. Responses showed that in over 79% of all non-benign weather situations, the use of GOES sounder products led to improved forecasts and the issuance of improved forecast products. Overall, forecasters found the sounder products to be valuable operational tools, providing information on the vertical structure of the atmosphere, especially the moisture distribution, with a temporal and spatial resolution not available from any other source. Several web-based approaches for display and access are evolving from experience with the VISITVIEW (Virtual Institute for Satellite Integration and Training viewer) efforts. One tool allows users to interactively select locations within a displayed image and observe the weather changes (http//cimss.ssec.wisc.edu/goes/realtime/gdpiviewer.html). Another capability allows web users to simultaneously collaborate on examination of real-time GOES sounder DPI with other web users (http//www.ssec.wisc.edu/visit/dpi.html). An example GOES-11 Lifted Index product is shown in figure above where the GOES Sounder successfully diagnosed an axis of large atmospheric instability prior to long-lived super cell.

Advanced TOVS Global Sounding Products

ORA scientists have successfully developed and implemented derived-product software systems in support of the Advanced TIROS Operational Vertical Sounder (ATOVS) sounding products from NOAA-15. ATOVS sounders introduced the new 15-channel Advanced Microwave Sounder Unit (AMSU), which replaces the previous 4-channel Microwave Sounding Unit (MSU). These together with the High-resolution Infrared Radiation Sounder (HIRS) are used to derive contiguous temperature and moisture sounding products on a global scale. The new ATOVS system has been developed and deployed on a test basis almost a year ahead of schedule, resulting in accelerated preparations for operational implementation, which occurred in April 1999. The ATOVS products represent a significant improvement in global atmospheric thermal measurements of the troposphere and stratosphere,

particularly concerning their reliability, accuracy and overall meteorological information content. Their use in numerical weather prediction forecasts, and as tools for climate research, represents a significant advancement over existing data.



ATOVS products montage for 1600 UTC August 30 to 0500 UTC August 31, 2000: upper left—cloud amount; upper right—cloud top pressure; lower left—cloud top temperature; lower right—HIRS Channel 8 temperature.

The ATOVS system utilizes data from HIRS/3, AVHRR/3, and AMSU-A to generate 16 operational products and 15 operational demonstration products. Many of these products are for multiple pressure levels or layers of the atmosphere. It is imperative that when a new spacecraft is launched that all of the necessary pre-flight preparation is completed well in advance (generation of HIRS/3 filter functions and generation of atmospheric transmittance coefficients for all instruments). This is currently underway for the September 2000 launch of NOAA-L. Following the launch of all spacecraft is a period when instrument engineers examine the health and well-being of each instrument and ORA scientists evaluate

the in-flight performance and validate the ATOVS product processing system. Since October 1978, with the launch of TIROS-N, two spacecraft (out of 11) have been launched without any problems. During the post-launch instrument evaluation and processing validation, for NOAA-15, the following problems were detected and corrected:

1) Calibration problems with the HIRS/3 and AVHRR/3;

2) Mis-location problems with AMSU-A;

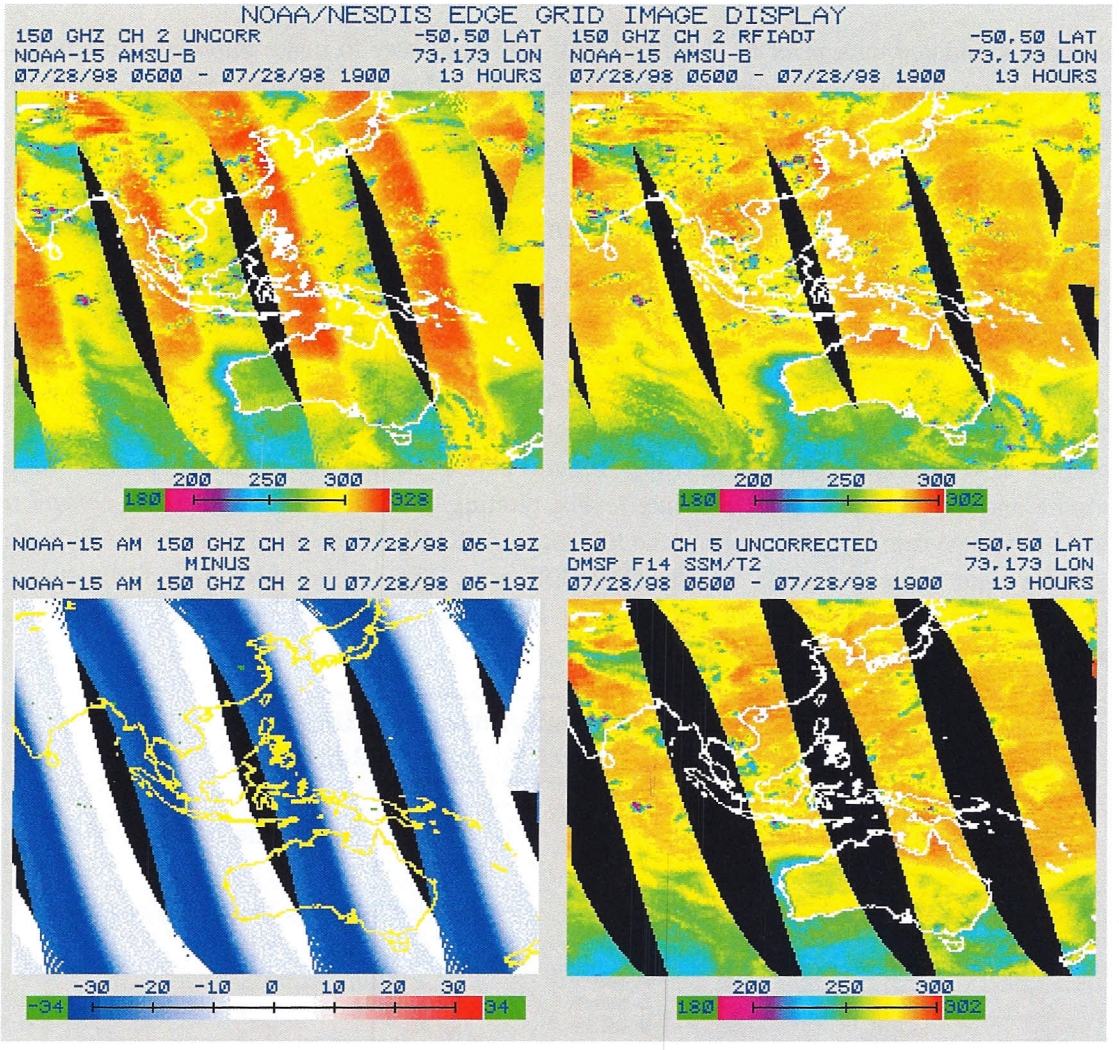
3) Channels #7 and #15 were swapped onboard the spacecraft; and

4) Mis-registration of AMSU-A relative to HIRS/3.

ATOVS product processing validation initially centered on the generation of temperature and moisture soundings but eventually included the other products which depend upon an accurate knowledge of the atmospheric temperature structure. These other products include Total Ozone, Cloud Top Temperature, Cloud Top Pressure, Cloud Amount, CLEAR-SKY Outgoing Longwave Radiation, and four CLEAR-SKY Layer Cooling Rates. Upgrades have been made to all of these products so as to take full advantage of both the new instrumentation as well as the development of new science. Vertical statistics, with radiosondes, confirm that the ATOVS system is generating the most accurate and reliable soundings available from any source.

Advanced Microwave Sounding Unit-B (AMSU-B) Global Moisture Sounding Products

ORA has successfully developed and has implemented into operations (April 2000) a new derived-product software system, fortunately split off from the ATOVS system during the development phase prior to the launch, using data from the high-resolution Advanced Microwave Sounding Unit-B (AMSU-B) on NOAA-15. Data from the AMSU-B consists of five moisture sounding channels at 16 km horizontal resolution. These provide contiguous moisture sounding products on a global scale. The new AMSU-B system has been developed and deployed on a test basis almost 6 months ahead of schedule, resulting in accelerated preparations for operational implementation. The products represent a significant improvement in global atmospheric water vapor measurements in the troposphere. Their potential for impact in numerical weather prediction forecasts and climate research is high. A highlight in the development of the AMSU-B processing system was the creation of a process to remove contamination in the observed measurements due to Radio Frequency Interference (RFI) from transmitters on NOAA-15. The un-anticipated contamination of this instrument originated from multiple sources (STX1, STX2, STX3, and SARR), each of which was a function of scan angle and channel frequency. ORA determined that a bias correction could be calculated and applied to the data so as to remove this contamination. Because the contamination was so large, it was necessary to remove this effect prior to the validation of product processing. The RFI characteristics of each antenna were observed to dramatically change because the cooling and heating cycle of the spacecraft caused the antenna leads (four per antenna) to flex and then fully or partially separate or re-contact. It was then determined that in order to stabilize the RFI, the use of the STX1, STX2 and STX3 antennas would have to be discontinued. STX2-Omni and STX4 were then substituted and a procedure to measure and monitor the RFI every 2 months was implemented. The current and most accurate method for determination of the RFI is to run two tests (one over Australia and the other over the south Pacific Ocean) in areas where the SARR could be turned off. These tests



Shows NOAA-15 AMSU-B channel 2 (150 GHz) before and after RFI correction. The quadrants contain the following data:

Upper left—uncorrected AMSU-B channel 2 (150 GHz)

Upper right—RFI corrected AMSU-B channel 2 (150 GHz)

Lower left—RFI corrected minus uncorrected AMSU-B channel 2 (the differences were made with the temperature scales set to identical limits)

Lower right—DMSP SSM/T2 channel 5 (150 GHz)

The SSM/T2 image was included as "ground truth" against which to compare the RFI corrected AMSU-B channel with the same frequency (150 GHz).

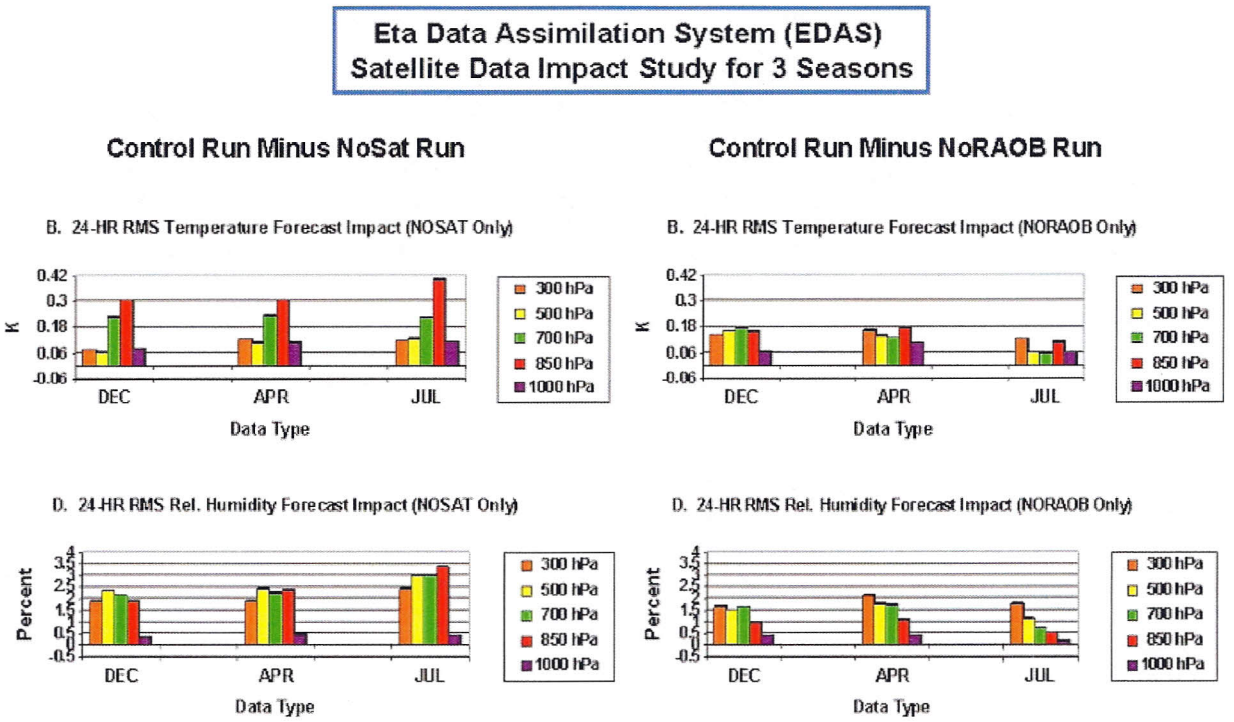
Quadrant 3 shows the correction applied to quadrant 1 to arrive at quadrant 2.

would then cycle (at regular intervals) through the antennas currently being used so as to measure the effect over a constant surface temperature for both land and sea. These test results are then analyzed, at the UKMO, with the RFI corrections generated and transmitted to NESDIS for operational implementation. These correction tables are then interpolated to the full 90 beam positions and uploaded to our web site for user access. Fresh AMSU-B data is then collected for 5 days so that new limb adjustment coefficients may be generated. The new RFI correction tables are then implemented into the NESDIS front-end calibration process while the new limb adjustments are implemented into AMSU-B product processing system. Since this system was cloned from the SSM/T2 processing system and

checked with simulated data prior to launch, it was only necessary to make minimal corrections to this processing system prior to operational implementation, other than the massive effort necessary to adjust the data for RFI contamination.

Impact of GOES Sounder Moisture Information on the Eta Model Forecasts

A data impact study was conducted using the Eta Data Assimilation System (EDAS) to test the impact of including satellite products versus conventional RAOB information in a forecast model. Ten day periods in each summer, winter and spring seasons were evaluated. The control run of the EDAS was produced using the numerous usual inputs (34 data types) which include satellite derived products and radiosonde observations (RAOBs). A second run was performed omitting satellite input only (NoSAT run); a third run omitted RAOBS only (NoRAOB run). Figure below shows the 24-hour forecast results for temperature and moisture at various pressure levels, plotting the difference between the control run and the denied data type run. The two plots on the left show the RMS differences for the NoSAT runs and the plots on the right show the same for the NoRAOB runs. The results seem to indicate that overall, removing the satellite data (NoSAT) has a bigger impact on the model forecasts of temperature and moisture than removing conventional RAOB data.



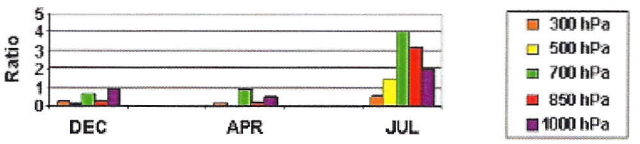
24-hour Eta forecast results for temperature and moisture showing the rms differences between the control run using all data types and the run denying satellite data (NoSat on the left) or the run denying RAOB data (NoRAOB on the right). Results for three seasons have been averaged.

Isolating the impact of the GOES Sounder moisture information, the following figure shows the relative impact of GOES sounder precipitable water vapor retrievals over the oceans versus the radiosonde temperature and moisture profile observations on the 24-hr forecast averaged for the three seasons. Both data types have positive impact on the foreacast in all seasons. However, in the summer season the GOES moisture information has up to five times more impact.

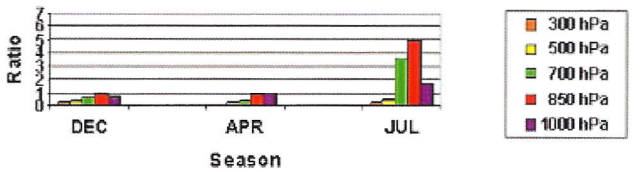
Eta Data Assimilation System
Satellite Data Impact Study for 3 Seasons

$$\text{Ratio} = \frac{\text{Positive Impact due to GOES sounder PW (marine)}}{\text{Positive Impact due to Radiosonde (T and moisture)}}$$

A Ratio greater than 1 means the satellite improved the forecast more than the radiosondes over the entire domain (land and marine)



24-hr forecast for Temperature



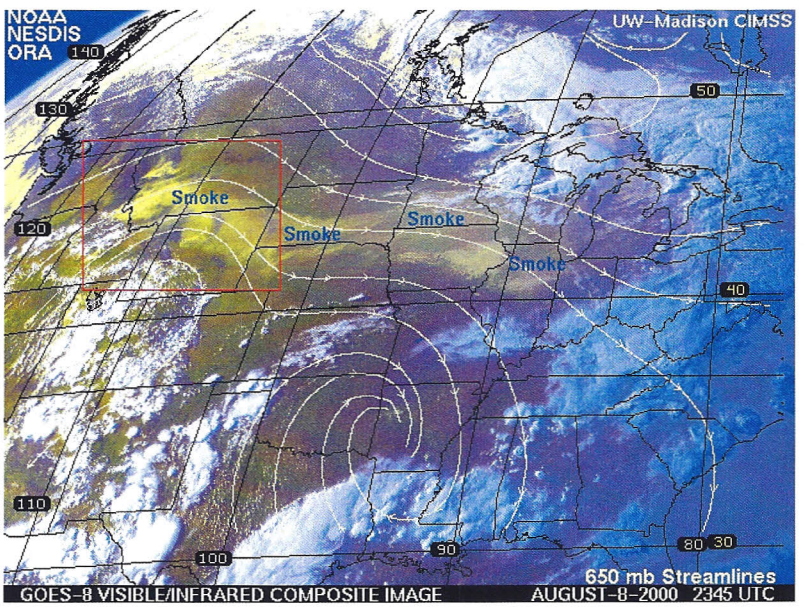
24-hr forecast for Relative Humidity

Ratio of the impact on the Eta 24-hr forecast (measured by rms differences) of removing GOES sounder precipitable water vapor retrievals over the oceans versus removing the radiosonde temperature and moisture profile observations over land. Results for three seasons have been averaged.

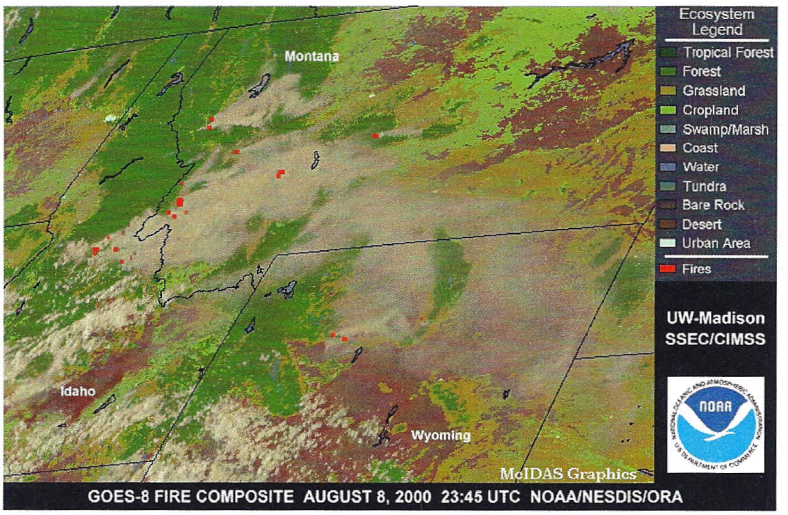
Biomass Burning and Real-time Fire Monitoring

Two algorithms, the Automated Biomass Burning Algorithm (ABBA) and the Automated Smoke and Aerosol Detection Algorithm (ASADA), developed to monitor the tropical forest burning in South America, are being modified for application to North America. In South America fires are primarily anthropogentic in origin and are often ignited in clear-sky conditions. In North America persistent cloud cover makes it more challenging to identify lightning-induced fires.

Known as the Wildfire ABBA, this algorithm is being tested in Canada and the U.S. To compensate for cloud problems, and for early identification of wildfires the Wildfire ABBA is being run at half-hourly intervals instead of the 3-hourly intervals of the South American product. Regional modifications to the ABBA and ASADA are being developed in preparation for a global geostationary fire monitoring product.



GOES-8 composite visible and infrared image showing the smoke pall from fires in the western U.S. on August 8, 2000. The 650 mb streamlines analysis is superimposed on this image.



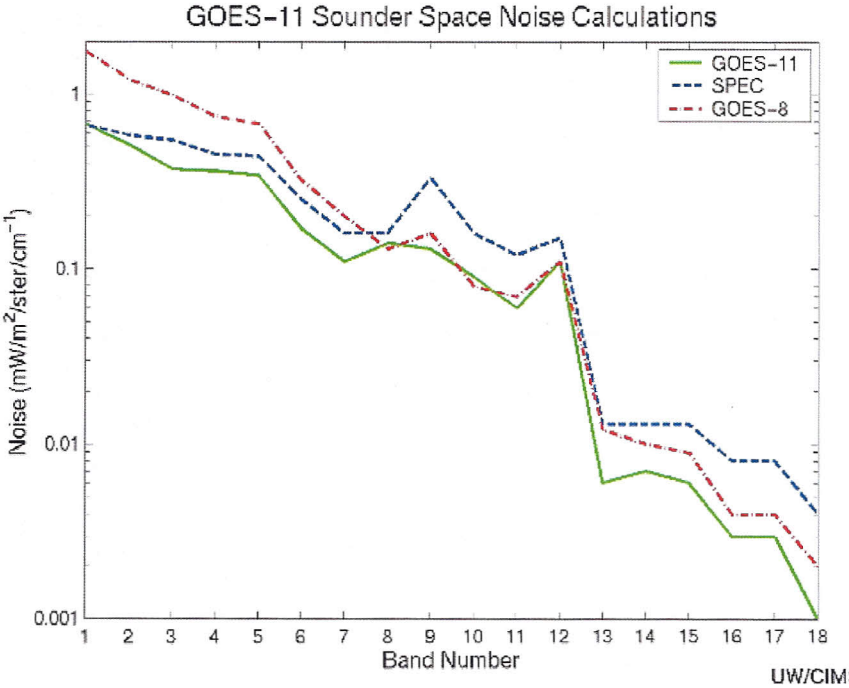
Composite multi-spectral GOES-8 image and 1 km land cover map from AVHRR showing the active fires (red areas) on August 8, 2000.

Preliminary results from Environment Canada indicate the utility and "profitability" of using high-temporal GOES-8 ABBA products at high latitudes for early identification of large rapidly growing fires that account for a large percentage of areas burned each year. The ABBA fire product is being used in smoke transport modeling efforts by the U.S. Navy and Brazil while the University of Sao Paulo is utilizing ASADA results to evaluate the contribution of smoke from Brazil's biomass burning activity to the air pollution problems in Sao Paulo's large metropolitan area.

Smoke palls reach great distances as seen here with recent wildfires in the western U.S. where smoke plumes were observed well into the mid-western states (first figure). The location of the active fires can be seen in second figure. In addition to concerns about air pollution and health, the impact of biomass burning is becoming an important issue in climate modeling.

GOES-11 Test

GOES-L, successfully launched on May 3, 2000, became GOES-11 in early May. After engineering check-out and prior to in-space storage, scientists from ORA coordinated two special data collection periods from June to early August. During that time, the imager was commanded into rapid scan (5 minute) and super rapid scan (1 minute) modes during severe weather over the Plains. A wide range of events was monitored during the test including a volcanic eruption of Tunguraha in Southern Ecuador and Tropical Storm Bud off the Baja coast. Data from the GOES-11 test can be

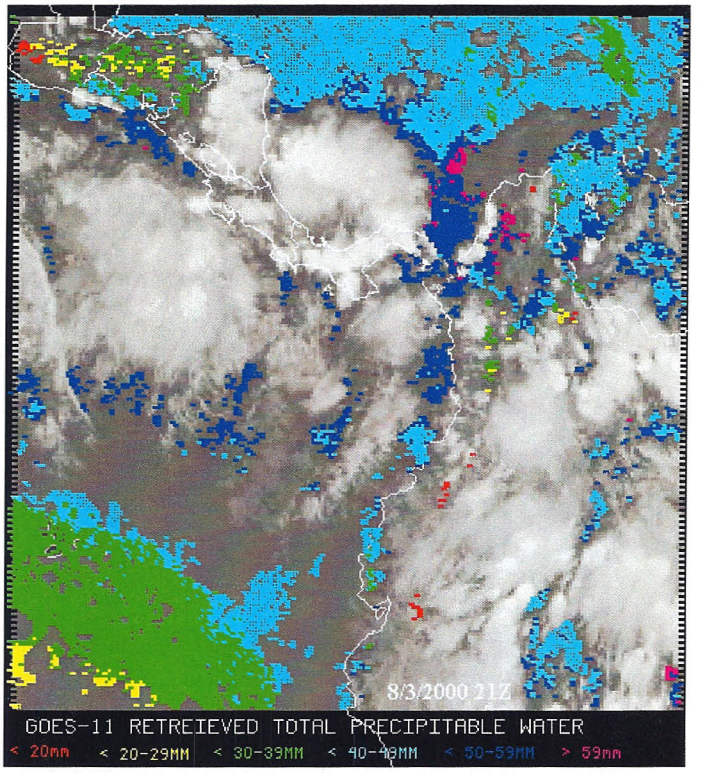


Comparison of noise in the GOES-11 sounder channels with GOES-8 and the instrument specifications.

found on several web sites including: http://cimss.ssec.wisc.edu/goes/realtime/g11 and http://orbit-net.nesdis.noaa.gov/goes/goes11test/goes11.html.

The position of GOES-11 allowed instrument performance comparisons to be conducted with coincident GOES-8 and GOES-10 data. Results show GOES-11 with excellent performance. Comparison of sounder channels show less noise than GOES-8 and that performance clearly meets or exceeds instrument specifications (upper figure). A report on this study is posted at http://cimss.ssec.wisc.edu/goes/g11_report/index.html.

During the GOES-11 test, the sounder which operationally is limited to North America, was in operation over Central and South America to collect data for a future forecast experiment. Lower figure shows GOES-11 derived product image of precipitable water which is thought to be the first ever produced for this area.



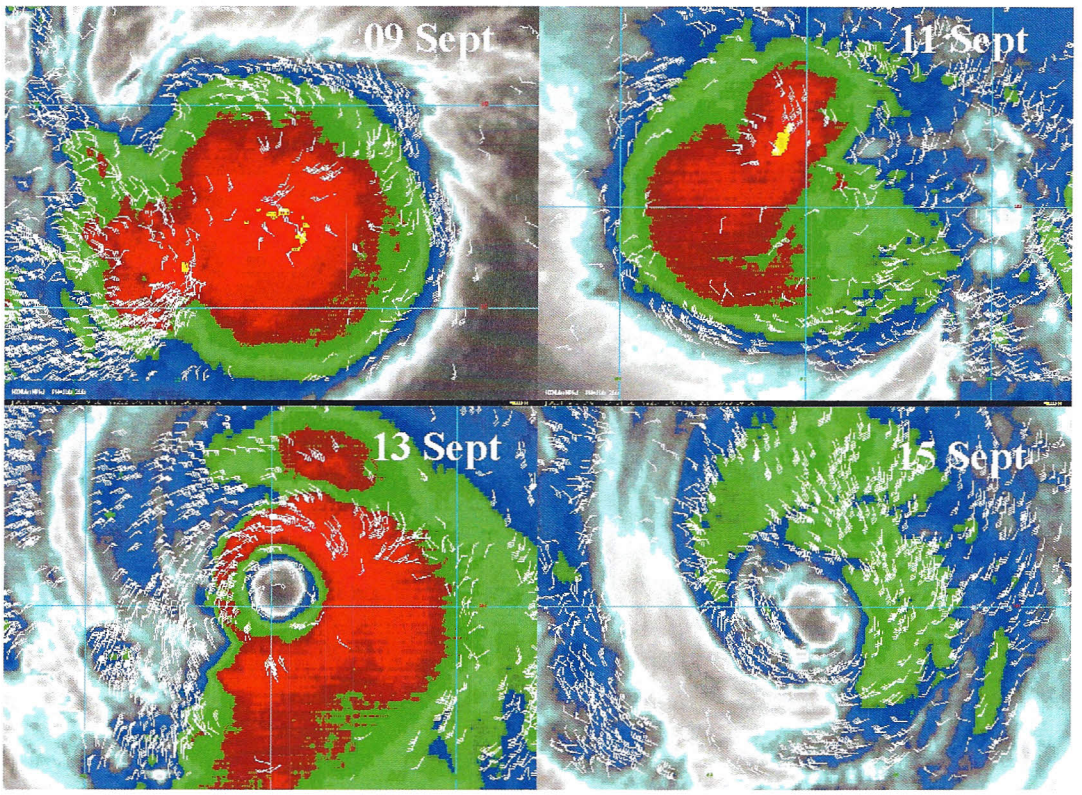
Precipitable water (PW) product from GOES-11 over Central and South America. Computation of PW is limited to cloud-free areas and is shown in color; clouds are depicted as dark gray to white.

Estimating Tropical Cyclone Winds from Satellites: Direct Methods and Balance Approximations

One of the challenging aspects of forecasting tropical cyclones is the lack of observations over the open oceans. In ongoing RAMM team research, several satellite techniques are being used to determine the wind fields of tropical cyclones and their environments. Three approaches are described which include the following: 1) Trajectory methods, where features are tracked to estimate winds, 2) Ocean surface wind methods, where the dependence of the emissivity (passive) or backscatter (active) of microwave radiation on the wind-induced ocean roughness is used to estimate wind, and 3) Balance wind methods, where soundings from the Advanced Microwave Sounder Unit (AMSU) are used to measure the atmospheric mass field, and an appropriate dynamical balance condition is used to measure the wind field. The eventual goal of this work is to combine the information from multiple satellite platforms with in-situ data to provide a complete analysis of tropical cyclone wind fields.

One of the earliest methods for determining winds from satellites is to track features in time sequences of imagery and then estimate the speed and direction from the feature trajectories. Extensive operational algorithms have been developed using multi-spectral GOES data. One of the new capabilities of the current generation of GOES satellites is to collect data at very rapid time intervals (up to 30 seconds).

Due to the very high winds and strong curvature of tropical cyclones, this high-temporal resolution has proved to be very important for determining winds over the tops of storms. During Hurricane Floyd of 1999, 1-minute imagery was collected over about 2-hour periods over 8 consecutive days (Super-Rapid



Examples of storm top winds for hurricane Floyd determined from GOES-8 super-rapid scan operations (SRSO) during September of 1999.

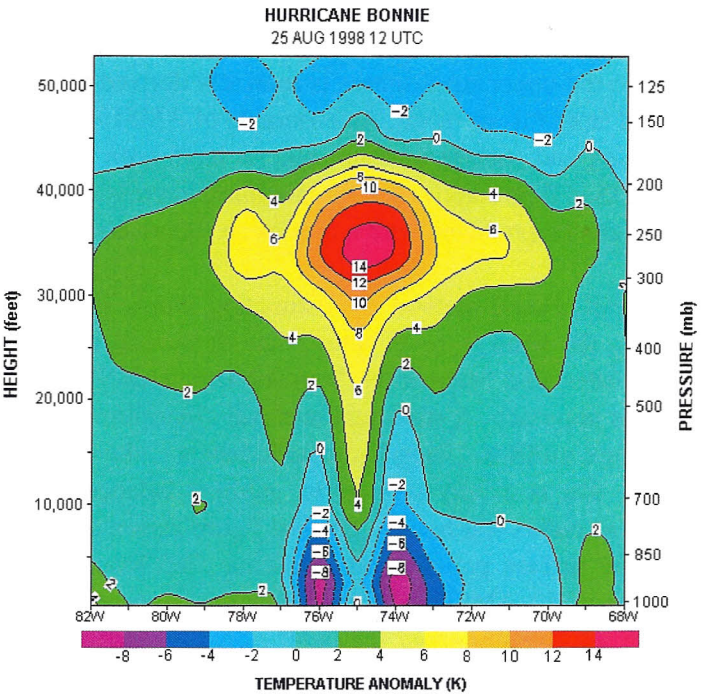
Scan Operations, SRSO). In cooperation with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in Wisconsin, the operational wind algorithms were modified to accommodate this new data. The figure shows an example of the type of wind data that is possible with the high time resolution data. These analyses are providing new insight into the relationships between the upper-level storm circulation and rapid intensification.

Hurricane Characterization with Data from AMSU-A

The AMSU-A is NOAA's new generation microwave sounder. It has improved spatial resolution and more channels than the older MSU sounders. The AMSU-A measures outgoing microwave thermal emission in 11 spectral intervals in the 50 to 60 GHz oxygen band, with a horizontal resolution at nadir of 29.8 miles. These spectral intervals (channels) are used to derive vertical profiles of atmospheric temperature from the surface to an altitude of approximately 160,000 feet. Each channel measures temperature from a different portion of the atmosphere between the lower troposphere and the upper stratosphere. As opposed to infrared temperature sounders, which are not sensitive to temperatures within and below clouds, the AMSU-A can "see" through clouds. It is this capability, together with its relatively

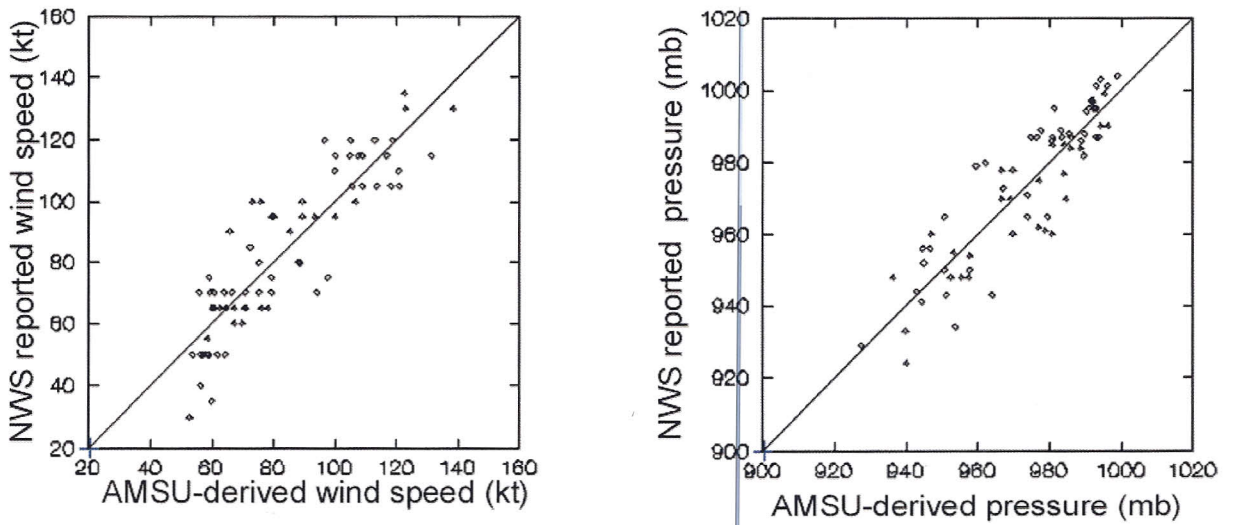
good horizontal and vertical resolution, that enables the AMSU-A to provide new and unique observations of the three-dimensional thermal structure of hurricanes.

An example of the warm core for Hurricane Bonnie is given in the figure to the right. The thermal pattern shown in the image is a vertical cross-section of Hurricane Bonnie's temperature anomaly, i.e, the difference between the temperature within the hurricane and that of the surrounding atmosphere. The cross-section extends from 82 to 68 degrees west longitude with a vertical extent of approximately 50,000 feet. The central location of Bonnie was near 29 degrees North and 75 degrees West at 12:30 Greenwich Mean Time (GMT) on August 25, 1998. The cross-section clearly shows the warm core of the hurricane at an elevation of about 35,000 feet. Contamination due to precipitation results in erroneous negative temperature anomalies near the eye-wall of the hurricane. The largest negative anomalies are associated with areas of the heaviest precipitation.



Vertical cross-section of temperature anomaly through Hurricane Bonnie.

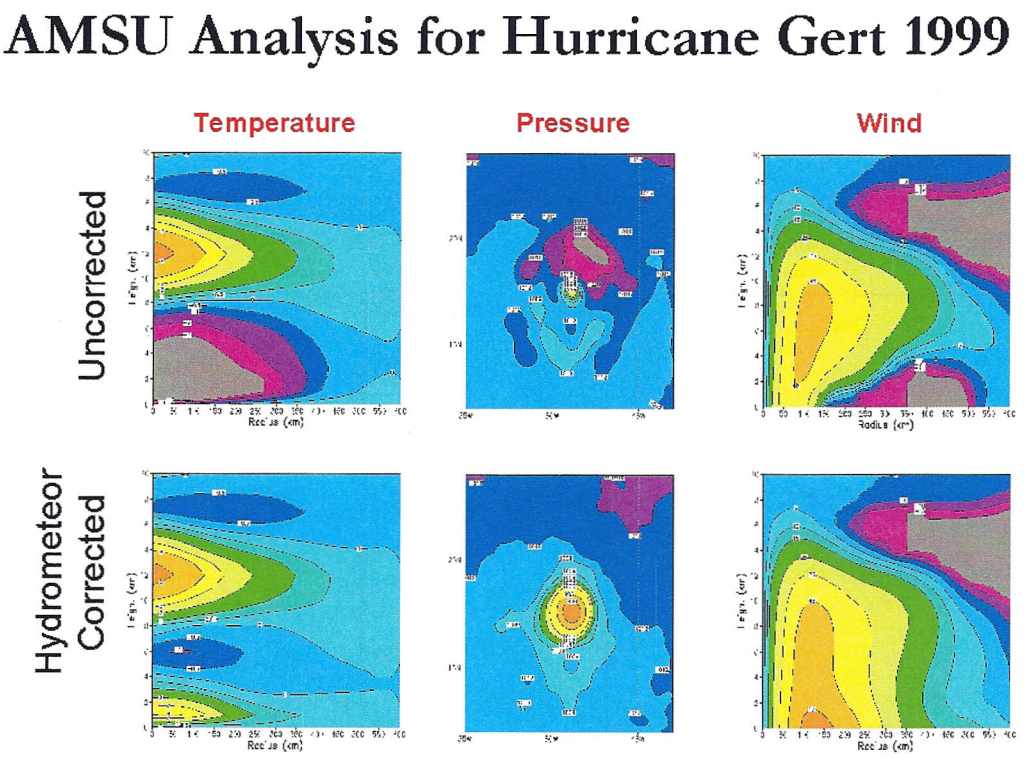
The intensity of a hurricane's warm core is an indicator of its strength, i.e., wind speed and central surface pressure drop. Since the condensation level in a mature hurricane is below the maximum warm core, a



Scatter diagrams of actual and AMSU predicted wind speed and surface pressure, respectively.

very good estimate of the warm core temperature can be determined. A temperature retrieval from the surface to the upper stratosphere is routinely derived from AMSU-A data. The warm core temperature is extracted from this retrieval. An ensemble of AMSU-derived warm core temperatures and NWS reported wind speed and surface pressure reports have been collected for hurricanes during the 1998 and 1999 seasons. (See figure above.) A simple linear regression on these data shows that wind speed and surface pressure can be predicted with a root mean square error of about 12 knots and 10 mb, respectively.

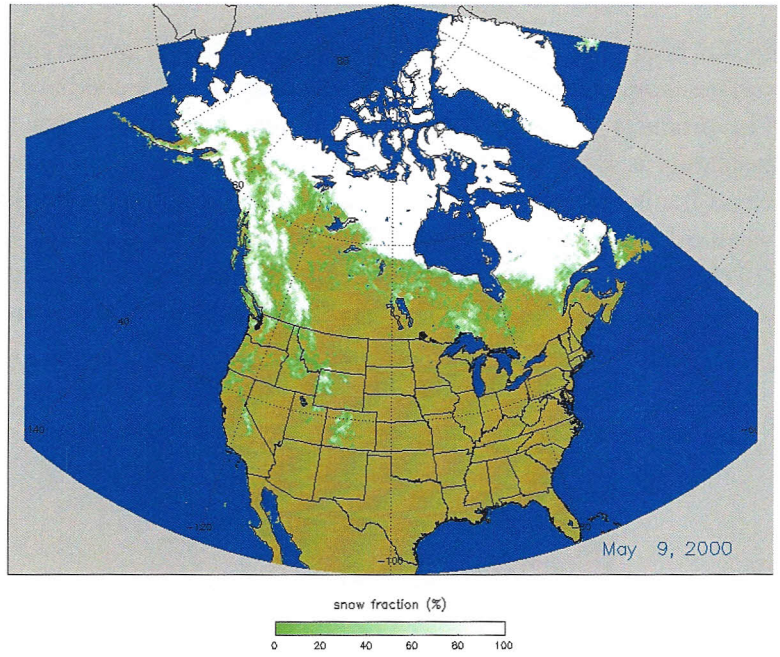
A physically-based method for estimating winds is to measure the atmospheric mass field and then determine the wind from an appropriate dynamical balance constraint. Methods are being developed to use the Advanced Microwave Sounder Unit (AMSU) on NOAA-15 to obtain tropical cyclone winds using this approach. A statistical retrieval algorithm is applied to the AMSU radiances to obtain vertical temperature profiles. Using hydrostatic balance, the three-dimensional pressure field can be determined. For flow that is axially symmetric, gradient balance provides an estimate of the tangential wind as a function of radius and height. The last figure shows an example of the perturbation temperature, gradient winds and surface pressure for Hurricane Gert from the 1999 Atlantic hurricane season. Although the resolution of the AMSU data is not adequate to capture the inner core of the storm, the method provides valuable information about the outer storm circulation and the vertical structure. This method is being generalized to provide the three-dimensional wind field by replacing the gradient wind equation with the nonlinear balance equation.



Radial-height temperature anomaly and gradient wind, and horizontal analysis of surface pressure for Hurricane Gert, 1999, determined from AMSU data. The top row is the analysis prior to the application of an algorithm to correct for microwave attenuation by cloud liquid water. The bottom row shows the fields after the application of the correction algorithm.

Snowcover Products for Numerical Weather Prediction

Data on snowcover distribution are primary inputs to numerical weather prediction (NWP) and hydrological models. Currently, regional NWP models use snowcover data with a yes/no indicator for each model grid cell. Such representation of snow is crude, and does not account for possible subgrid heterogeneity of the snowcover. To realistically represent snow within atmospheric models used to simulate weather, climate and hydrological processes, the fractional snow-covered area within each grid cell should be known. However, the resolution of the existing operational snowcover products is not sufficient to determine the horizontal variability of snowcover distribution at spatial scales compatible with current regional NWP models.



Experimental North American snowcover fraction map.

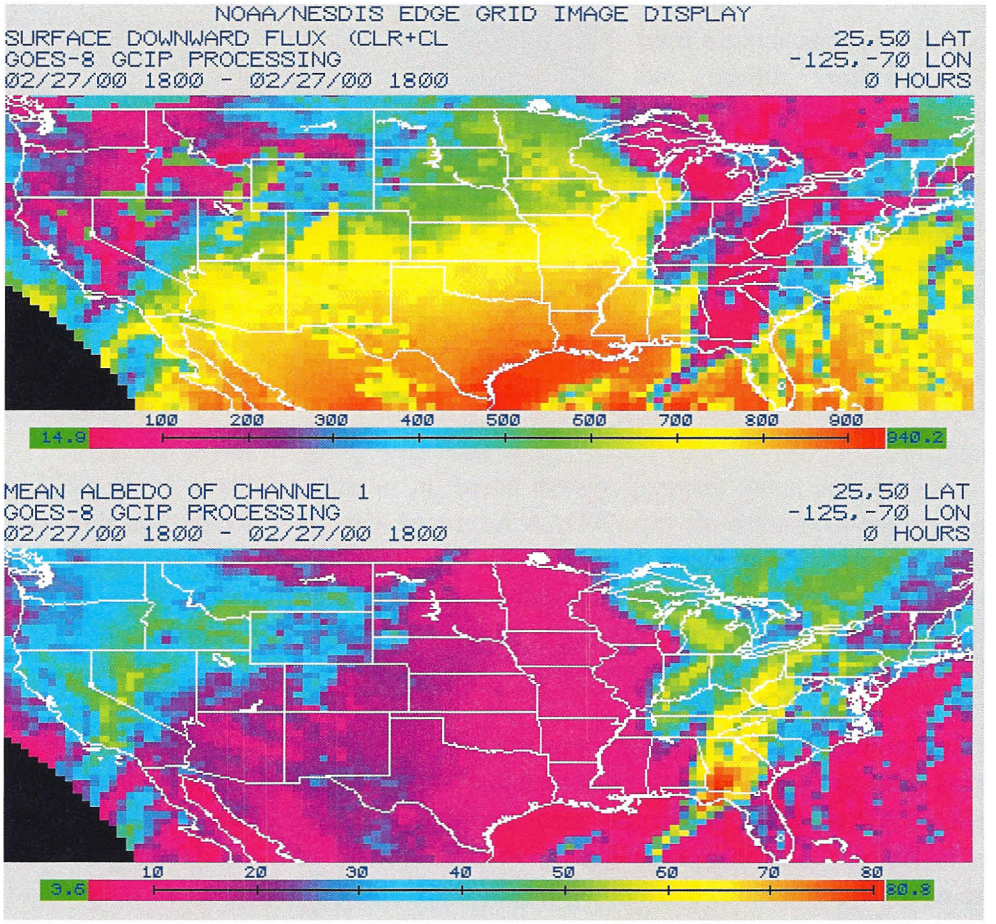
Recently an automated snow mapping system based on satellite data was developed in ORA. It uses visible and infrared measurements from NOAA Advanced Very High Resolution Radiometer (AVHRR) and the Imager instrument onboard Geostationary Operational Environmental Satellite (GOES) along with microwave measurements from the Special Sensor Microwave/Imager (SSM/I) onboard the DMSP satellite to produce daily maps of snowcover extent over the North American continent. The spatial resolution of the automated snow maps is 4 km.

This year studies were begun to retrieve snow fraction at several spatial scales from the automated snow maps. A map-cell count approach was employed to estimate snow fraction at a resolution typical to global and regional NWP models (~30 to 100 km). Feasibility of a pixel-level approach, where fractional snowcover is determined for each individual pixel was tested for a finer-scale snow fraction retrieval. Due to a coarse resolution of microwave measurements, the latter study was carried out only with visible and infrared data.

The automated snow mapping system is being validated with NOAA interactive snowcover maps, NOAA AVHRR 1 km resolution data and with snow fraction estimates obtained from surface observations. For three sites with dense ground observations, the mean difference between retrieved snow fraction and the ground estimates was about 0.08 with a scatter of about 0.25.

GOES Insolation for Numerical Weather Prediction

GOES hourly estimates of cloud cover, insolation, photosynthetically active radiation, and clear sky surface temperature are being made routinely in ORA and have recently become operational at NESDIS. The products are produced at 0.5° lat/long resolution from the GOES East and West imager data. Insolation is from an algorithm that requires for each hour and each target clear and cloudy radiance, cloud fraction, precipitable water, snowcover, and composite clear radiance, that is the surface radiance when there is no aerosol burden. This product is being used to force the Land Data Assimilation System (LDAS). Several land surface schemes are being tested using this product. They include techniques developed at NCEP, GSFC (Data Assimilation Office), and Princeton University.

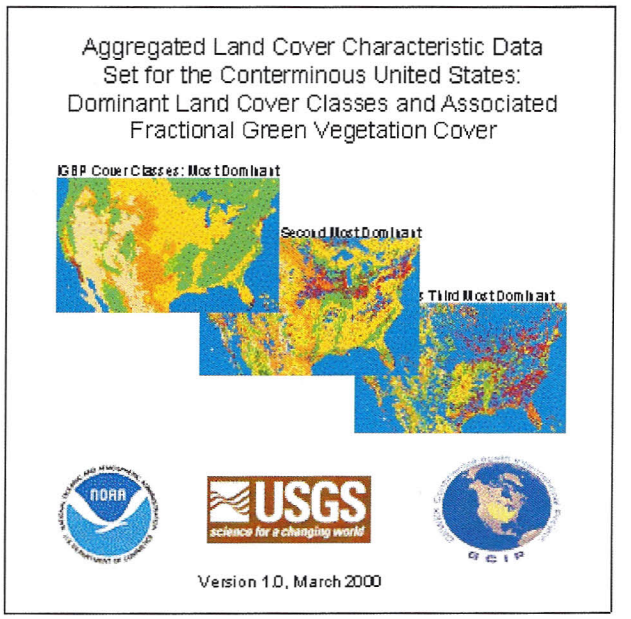


The top image shows the insolation (watts/m^2) for 18Z (approximately noon at 90° W) on February 27, 2000. The bottom image is the albedo for the same time and shows the cloud cover.

High-Resolution Land Cover Data Sets for Numerical Weather Prediction

Numerical weather prediction models have reached a level of sophistication that requires much more detailed quantification of land surface characteristics. The NCEP regional forecast model is moving towards specifying multiple vegetation classes, the fractional coverage of each, the fractional green vegetation associated with each class, the albedo of each class, and more, in each model grid cell. Surface physics packages in the global medium-range forecast models are moving in the same direction.

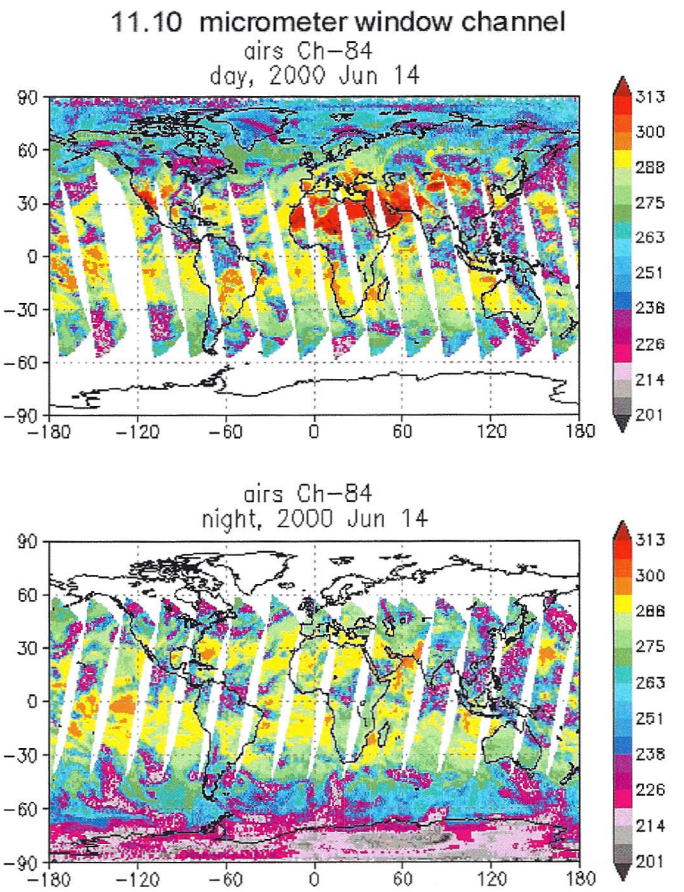
A CD-ROM has been produced that includes land cover and fractional green vegetation (fgreen) data for the Coterminous U.S. and GEWEX Continental-scale International Project (GCIP) region. The land cover data were analyzed to produce a 20 km resolution-gridded data set that includes the three most dominant land cover classes within each 20 km grid cell. Additionally, the fractional area associated with each of the three most dominant land cover classes as well as the area covered by water, was computed for each 20 km grid cell. The fgreen associated with each of the three most dominant land cover classes per grid cell was computed on a monthly basis. The fgreen was derived from monthly 5-year (1993, 1995–98) means of the normalized difference vegetation index, derived from 1 km resolution NOAA-AVHRR data. The land cover and fgreen information will be evaluated in land-atmosphere models by individuals within NCEP. It is also being provided to NWP modelers in other centers.



CD-ROM containing the three primary vegetation types and green vegetation fraction for each for the conterminous United States.

Preparing for Near-Real-Time Processing of Data from Advanced Sounders

The Office of Research and Applications (ORA) and the Office of Satellite Data Processing and Distribution (OSDPD) are developing an experimental processing system that will provide data from NASA's Atmospheric InfraRed Sounder (AIRS) to the National Centers for Environmental Prediction (NCEP) and other numerical weather prediction (NWP) centers around the world within the normal near-real-time requirement of 3 hours. AIRS will provide measurements in nearly 2,400 narrow spectral intervals (channels) in the important infrared region of the spectrum, primarily between 650 and 2,700 cm-1. The combination of many more channels and greatly improved spectral resolution (compared with the capabilities of current sounders) will permit the retrieval of



Brightness temperature fields of the AIRS 11.10-μm window channel for day and night.

tropospheric temperature and moisture products with a vertical resolution approaching 1 km, temperature accuracies of less than 1.0 K in 1 km layers, and moisture accuracies of 15% in 2 km layers. In contrast, the current operational infrared sounder, the High-resolution InfraRed Sounder (HIRS), measures outgoing infrared radiation in only 19 channels with relatively poor spectral resolution. The combination of poor spectral resolution and relatively few channels results in relatively poor vertical resolution (3–5 km in the troposphere) in the retrieved temperature and moisture soundings. Temperature accuracy from HIRS in 1 km layers within the troposphere is approximately 1.6 K, while moisture accuracy in 2 km layers is about 25%. It is anticipated that improvements of temperature and moisture information from AIRS, CrIS (Cross-track Infrared Sounder) and IASI (Infrared Atmospheric Sounding Interferometer) will result in appreciable positive improvements in weather forecasting skills.

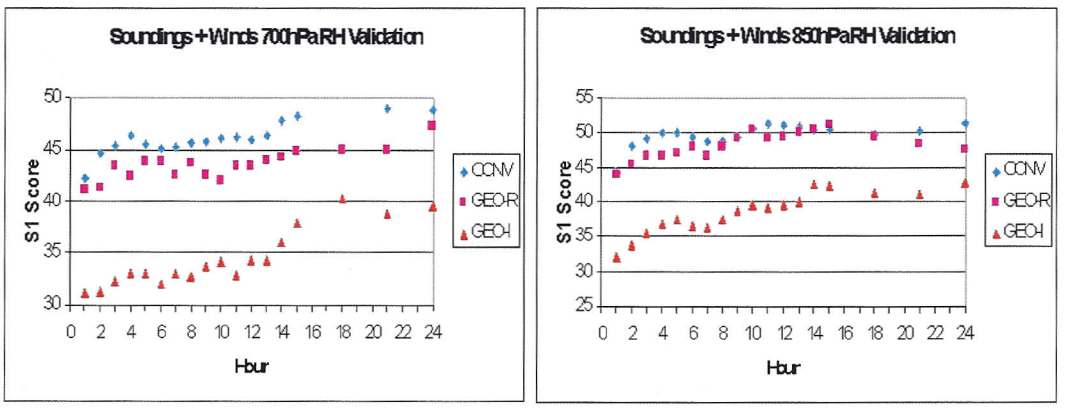
A 24 hours x 7 days near-real-time simulation of AIRS measurements was implemented, with the NCEP forecast used to specify the atmospheric state (temperature, moisture, clouds). The simulations are being used in the development, implementation, and validation of the entire processing system. The accompanying figure above is a display of brightness-temperature data simulated for the AIRS 11.10 μm window channel. Note the influence of clouds (low temperatures) and hot surfaces over the deserts. This AIRS processing system has been designed so that it can also be used to process data from CrIS and IASI.

Observing System Simulation Experiment to Estimate the Forecast Impact of a Geosationary Interferometer

An Observing System Simulation Experiment (OSSE) was conducted to assess the potential benefit of a geostationary-based interferometer on numerical weather forecasts generated by the Rapid Update Cycle (RUC) forecast model. The information and potential forecast impact from the geostationary interferometer (GEO-I) derived temperature, moisture, and winds is compared to that of the current operational filter radiometer (GEO-R) onboard the Geostationary Operational Environmental Satellite (GOES). The impact is measured with a robust conventional observing network (CONV) of radiosondes, surface observations, aircraft reports, and profiler measurements already in place. Observations were

Sounding Profile Observing System Simulation Experiment (OSSE) Results

UW-Madison/CIMSS **NOAA/NESDIS/ORA/ARAD/ASPT**



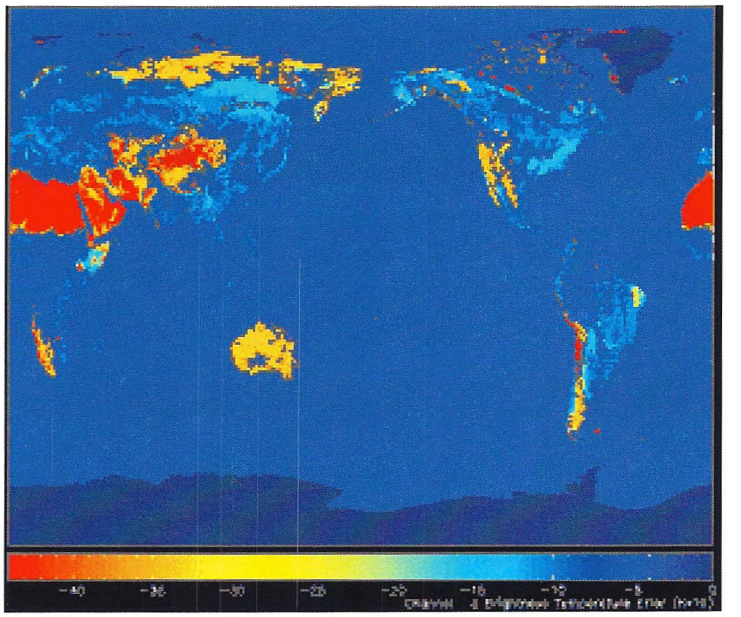
OSSE 12 hr assimilation followed by 12 hr forecast

Forecast Skill Score of the Rapid Update Cycle using conventional data (CONV), conventional plus GOES Sounder data (GEO-R), and conventional plus geostaionary interferometer data (GEO-I) for 850 hPa and 700 hPa relative humidity (RH%). Hours 0 to 12 comprise the assimilation cycle and hours 13 to 24 are the forecast for 1 out to 12 hours.

simulated by superimposing estimated observation errors on the "true" profiles generated by a "nature" forecast which defines "truth". All simulated observations are assimilated at characteristic temporal and spatial resolutions. Figure above shows the forecast Skill Score for 850 hPa and 700 hPa relative humidity (RH%). Hours 0 to 12 comprise the assimilation cycle and hours 13 to 24 are the forecast for 1 out to 12 hours. The GEO-I results show a marked improvement over the GEO-R at both levels. The impact of GEO-I was strong at 850 hPa, while GEO-R had little impact compared to CONV. This is due to the ability of the interferometer to penetrate deeper into the troposphere and detect moisture gradients.

Improved Emissivity in Calculations for Atmospheric Soundings and Brightness Temperature Assimilation into NWP Models

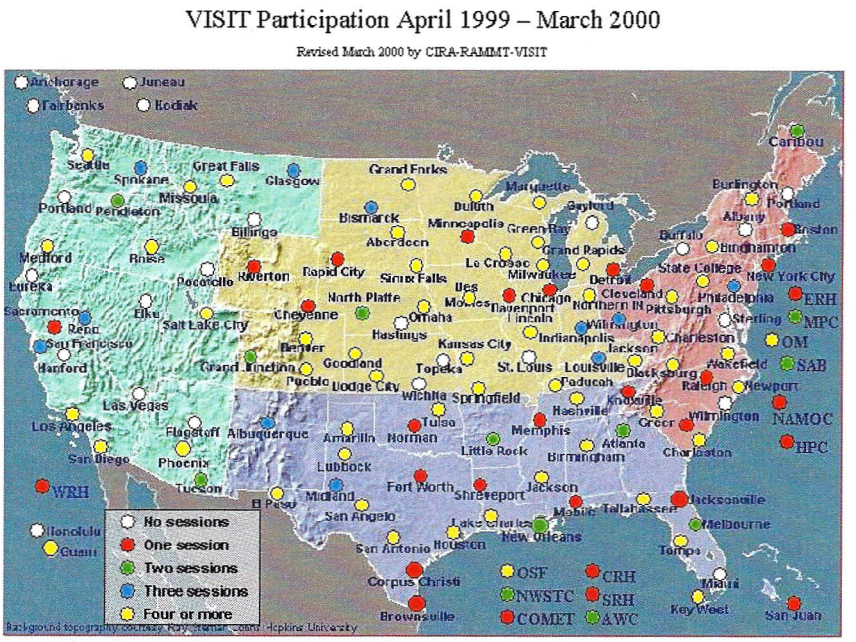
The direct assimilation of satellite brightness temperatures in numerical weather prediction models and the need for enhanced accuracy in atmospheric soundings place stringent requirements on the accuracy of calculations of outgoing atmospheric brightness temperatures. In particular, the small errors incurred by the neglect of land surface emissivity in radiative transfer calculations, which previously could be ignored with impunity, are now significant. Up to now our calculations have assumed that the emissivity of the land surface is unity everywhere. In fact, however, the emissivity varies with surface conditions. This has prevented NCEP/EMC from assimilating satellite-observed brightness temperatures over land in surface-sensing channels. (By comparison, ocean surface emissivity is relatively well characterized.) The accompanying figure demonstrates the effect of assuming unit land emissivity for HIRS channel 8 (11 μm). Displayed is the difference in computed brightness temperature between using an accurate emissivity estimate (provided by the NASA CERES project office), which varies with location, and that from using a unit emissivity everywhere. The colors represent –4 K in red to 0 K in deep blue. ORA is developing methodology to incorporate such accurate land emissivity estimates that will vary in location and time.



The effect of assuming fixed unit land emissivity in computing HIRS channel 8 brightness temperatures.

Virtual Institute for Satellite Integration Training (VISIT)

CIRA and CIMSS, together with ORA staff, have developed an interactive "virtual" classroom instruction program called Virtual Institute for Satellite Integration Training (VISIT). VISIT uses Internet technology to provide distance learning which allows interaction between students and instructors similar to a classroom situation. This program provides concurrent instruction to multiple sites. In FY 00, 97 VISIT

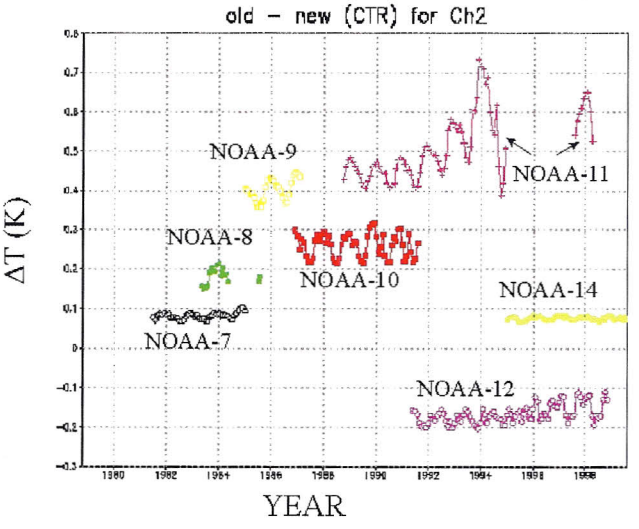


training sessions were conducted reaching 375 NWS and NESDIS offices and providing training to an estimated 1,900 "students." The figure on the left shows the distribution of sites that received training and the number of courses held from April 1999 through March 2000.

This map shows the distribution and number of VISIT training sessions conducted from April 1999 to March 2000.

Climate

Recalibration of MSUs and Reconstruction of Twenty-Year Tropospheric Temperature Data Set

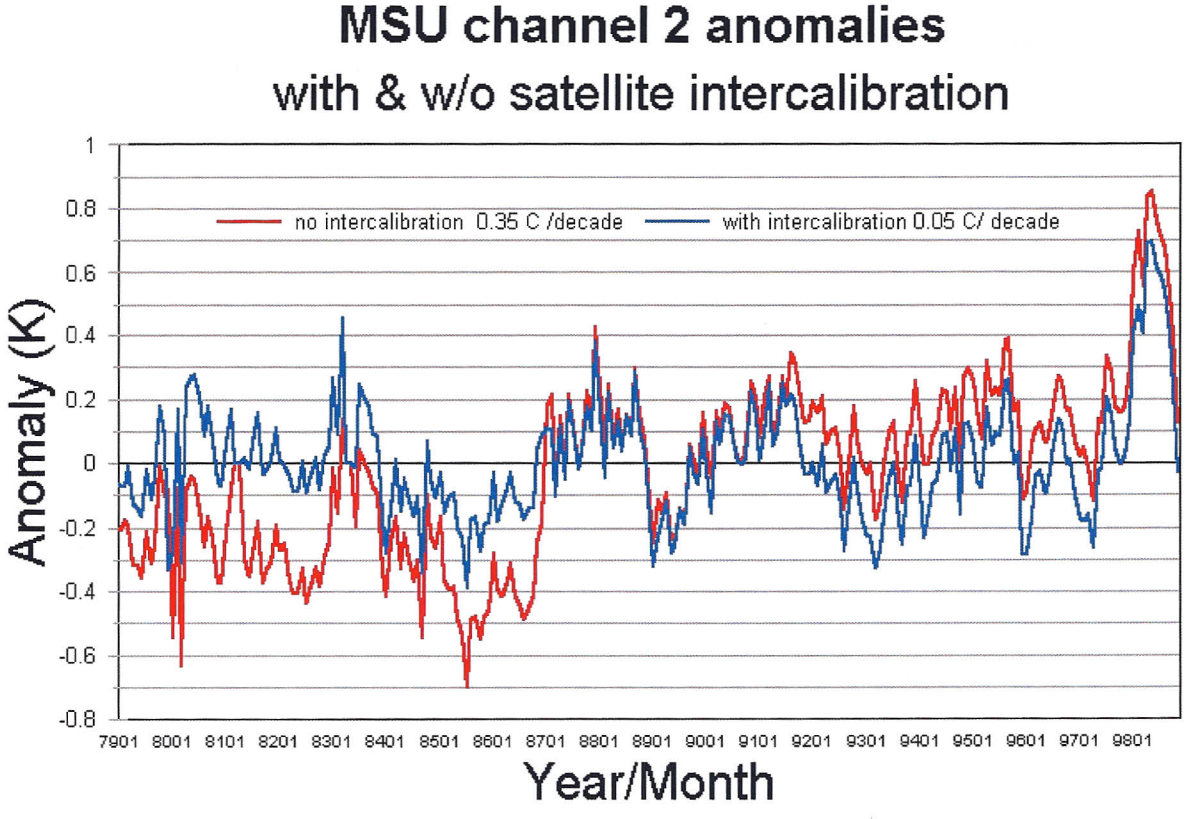


Difference in global-averaged brightness temperatures obtained from old and new calibration (old minus new) of MSU channel 2.

The Microwave Sounding Units (MSU) have been flown on the NOAA series of polar-orbiting satellites from 1978 through the present. The observations in channel 2 of the MSU represent a deep-layer mean temperature in the troposphere and lower stratosphere and can be used to determine trends of tropospheric temperatures. Spencer and Christy have carried out pioneering work on the use of these data for climate studies. However, the National Research Council has recommended that independent groups investigate and evaluate these data. It has also recommended that the scientific community perform a more comprehensive analysis of the uncertainties inherent in the satellite data sets. ORA scientists have accepted this challenge.

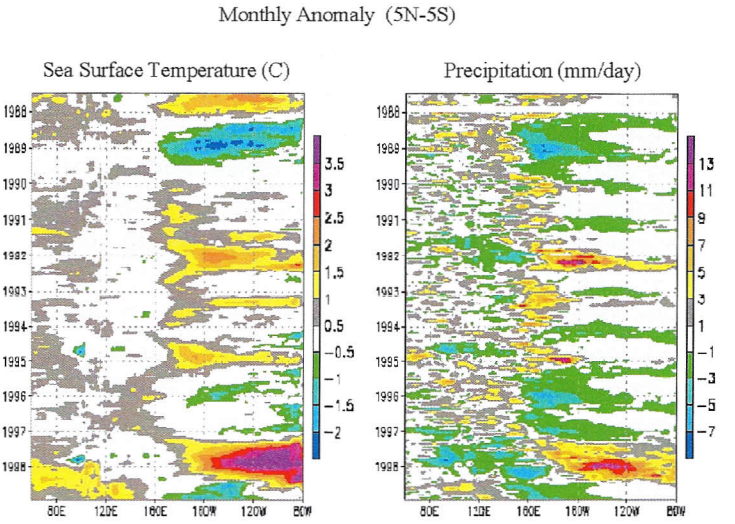
The calibration of the MSUs was recently found to be inadequate in its treatment of the non-linearities in instrument response, leading to scene-temperature dependent observation errors as large as 0.7 K. Unless accounted for, such errors will degrade climate trends inferred from MSU data. In FY 2000 we recalibrated the MSUs with an algorithm improved to treat the instrument non-linearities more accurately. The first figure shows the difference (from the original calibration) the new calibration makes in the global-averaged brightness temperature observations in MSU channel 2. The differences consist of offsets and time-dependent (e.g., NOAA-11 and NOAA-9) components, both of which could contribute to errors in decadal trends of tropospheric temperatures compiled from MSU observations. All of the MSU brightness-temperature observations, with the exception of those from the NOAA-6 satellite (1979–1983), have now been produced in ORA with the recently improved calibration algorithm.

Scientists in ORA are now applying the data from the newly-recalibrated MSUs to derive trends of tropospheric temperatures. One of the most important activities is developing and applying intercalibration techniques to remove biases among instruments on different satellites. The second figure illustrates the importance of intercalibration. Without intercalibration, the MSU channel 2 decadal trend is a very significant 0.35 degrees C. With intercalibration, a more realistic value of 0.05 C is derived. Future work will be focused on adjustments to account for orbital drift in altitude and equator crossing time.



Two-time series of brightness-temperature anomalies (departures from the mean of the time series) of global, monthly-averaged brightness temperatures observed in MSU channel 2, one-time series with and one without intercalibration.

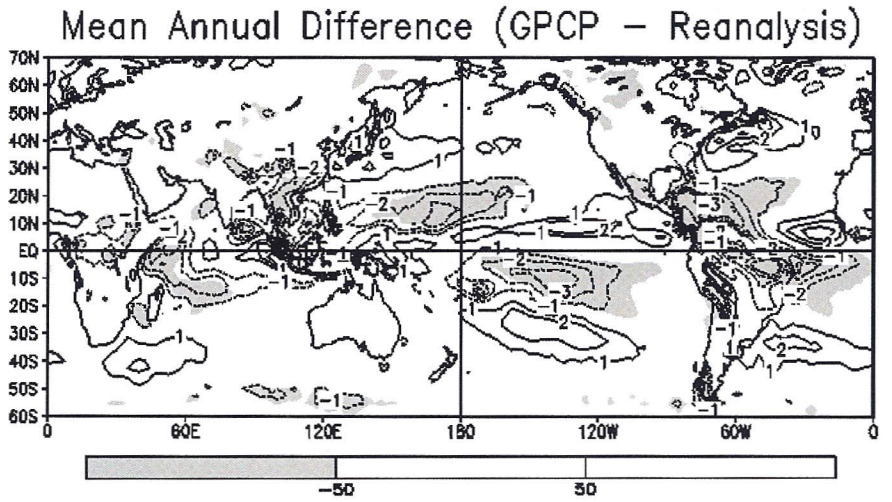
Development of Satellite-Based Global Precipitation Data Set for Model Validation and Monitoring Interannual Variability



Monthly anomaly of sea surface temperature (left) and precipitation (right) for 5N-5S, July 1987 through 1998.

Understanding the global water and energy cycle has been hampered by the lack of reliable global precipitation estimates. The Global Precipitation Climatology Project, which is part of the Global Energy and Water Cycle Experiment of the World Climate Research Program, WMO, has addressed this problem through a combination of satellite and gauge estimates of precipitation. Precipitation is retrieved from geostationary satellites using infrared window observations from 40N-40S, and microwave emission over the oceans and scattering over the land areas from the Defense Meteorological Satellite Program, Special Sensor Microwave Imager (SSM/I). The geostationary satellite data are from GOES (USA), Meteosat (European community) and GMS (Japan). Over land, the satellite estimates are combined with gauges and over the oceans, the satellites provide the only estimates of precipitation. The data set was developed by an international team of scientists which, in addition to the satellite operators, includes U.S. scientists from NESDIS, NWS and NASA, who are mainly responsible for the development of retrieval algorithms and preparing the gridded precipitation analyses. The current suite of GPCP products consists of pentad and monthly mean precipitation on a 2.5 x 2.5 degree latitude/longitude grid from 1979 to the present and a 1 x 1 degree latitude/longitude data set from 1997 to the present.

The monthly mean precipitation data has been used by Janowiak et al., 1998, to evaluate models such as the re-analysis produced by the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR). Since the model precipitation is a predicted quantity, comparison with observed precipitation provide an independent measure of model performance. The figure above



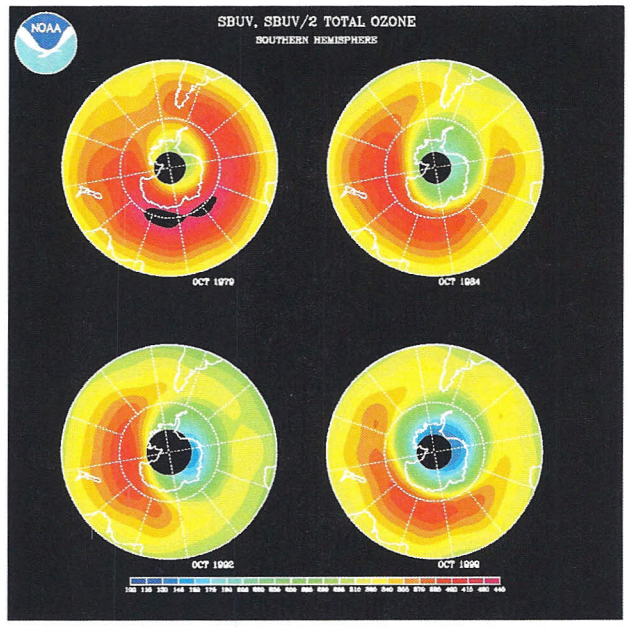
Mean annual difference 1988–1995, GPCP-NCEP precipitation. Shaded areas are in percent difference, contours are absolute difference in mm/day.

shows a comparison of the annual mean GPCP and NCEP/NCAR re-analysis for the period of 1988 to 1995. The percent differences are shown in shading and the absolute differences are contoured. In the tropics the re-analysis tends to overestimate precipitation over the convective land areas of South America, Africa and Indonesian. Over the tropical oceans, the re-analysis underestimates precipitation in the rainy areas ITCZ of the Atlantic and Pacific (positive differences just north of the equator) and the South pacific Convergence Zone and overestimates precipitation in the dry zones surrounding the ITCZ.

The use of the GPCP data to monitor seasonal and interannual variability and study relationships between precipitation and other variables such as sea surface temperature is shown below. This 2nd figure above shows the time longitude variation of anomalies of sea surface temperature and precipitation for the latitude zone 5N-5S for the period July 1987 through 1998. Notice the agreement between the sea surface temperatures and precipitation especially for the warm El Nino episodes of 1991/92 and 1997/98. While the apparent agreement in the two figures suggests a relationship between sea surface temperature and precipitation anomalies, it is worth noting that the position of the heaviest anomalies don't always agree indicating that other factors that may be important.

Evolution of Antarctic Ozone Hole Observed by SBUV/2

The term *Antarctic ozone hole* refers to a decrease in atmospheric total volume ozone (to values below 220 Dobson Units) at high southern latitudes in late winter and early spring. This decrease in total ozone is due to chemical destruction of ozone induced by products of man-made chemicals such as chlorofluorocarbons (CFCs) released into the atmosphere, coupled with favorable meteorological conditions in the Antarctic polar vortex. The long-term monitoring of total ozone amounts will enable scientists to study the progression of the ozone hole and its expected recovery following reductions in CFC emissions. The SBUV/2 total ozone measurements thus far indicate a significant increase in the magnitude of ozone depletion and areal coverage of the ozone hole over the last 20 years. Prior to the 1980s, the ozone hole did not exist. The ozone hole covered a very small area in the early 1980s, less than 5 million square kilometers, with the lowest values at approximately 150 Dobson Units. By the end of 1990s, however, the ozone hole covered an area of 15 million square kilometers, with lowest values below 100 Dobson Units.

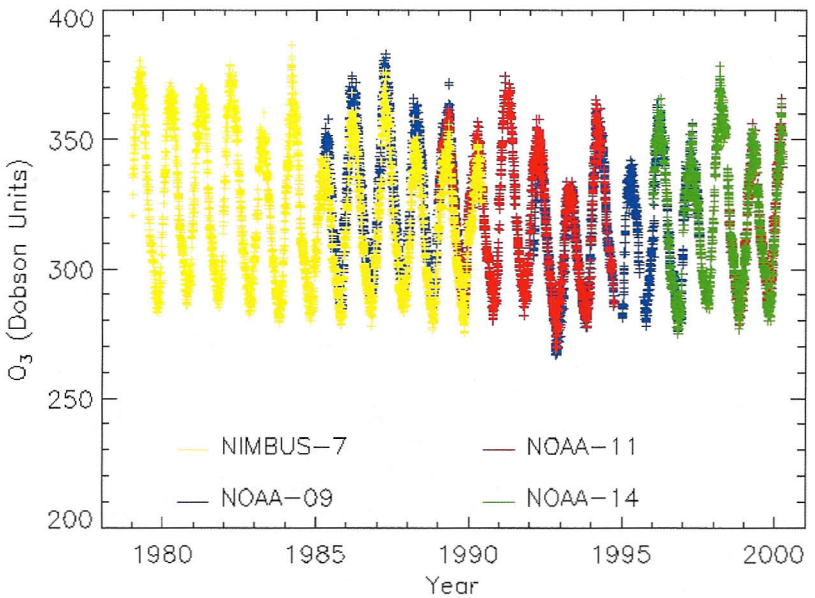


Time evolution of the Antarctic ozone hole over the last 20 years, as observed by the SBUV/2 instruments. The black circular regions at the South Pole are areas of no data. SBUV/2 observations utilize solar radiation, which is not present near the pole in winter.

The SBUV/2 Total Ozone Time Series

One of the objectives of NOAA's Polar Orbiting Environmental Satellites (POES) is to measure total and profile ozone globally over a long time period to infer trends and climate change. To date, 15 years of ozone measurements have been made by the Solar Backscatter Ultraviolet Spectral Radiometer (SBUV/2)

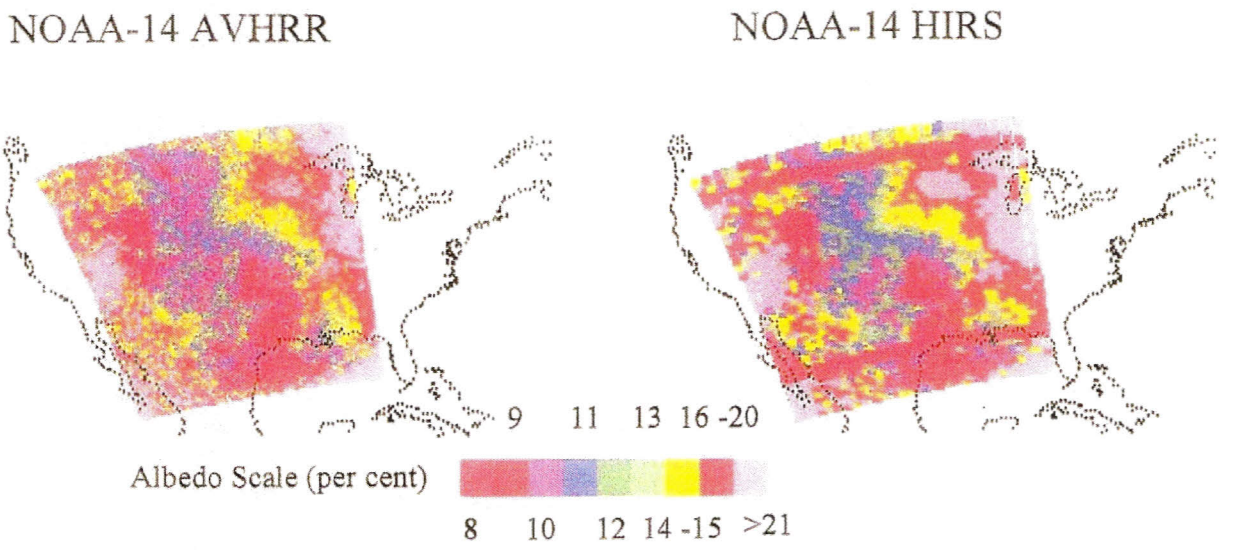
instruments aboard the NOAA-9, NOAA-11, and NOAA-14 satellites. Recently, we reprocessed the entire data record of the NOAA-9 SBUV/2 from early 1985 to 1997 with an improved instrument characterization. We validated the total ozone estimates from NOAA-9 by comparing them with those made by ground-based Dobson instruments and other satellite instruments such as NASA's Total Ozone Mapping Spectrometer (TOMS). The NOAA-11 (1989–1994; 1997–present) and NOAA-14 (1995–present) SBUV/2 total ozone data have also been reprocessed using improved instrument characterization. The reprocessed SBUV/2 total ozone data were combined with the total ozone measurements made by NASA's SBUV instrument, flown on Nimbus-7, to create a twenty-year data record. The NOAA-9 SBUV/2 total ozone data set is a reliable link in the twenty-year SBUV/2 record. Satellite-to-satellite differences of up to 2% in total ozone measurements are observed for NOAA-9, NOAA-11, and NOAA-14 during their overlap. Work is in progress to account for these differences and apply statistical models to the twenty-year total ozone data set to determine trends.



The SBUV/2 Total Ozone Time Series at 30N-50N. The gaps in the time series are due to poor satellite viewing conditions caused by the drifts in satellite orbit.

Intercalibration of Satellite Radiometers in the Visible and Near Infrared

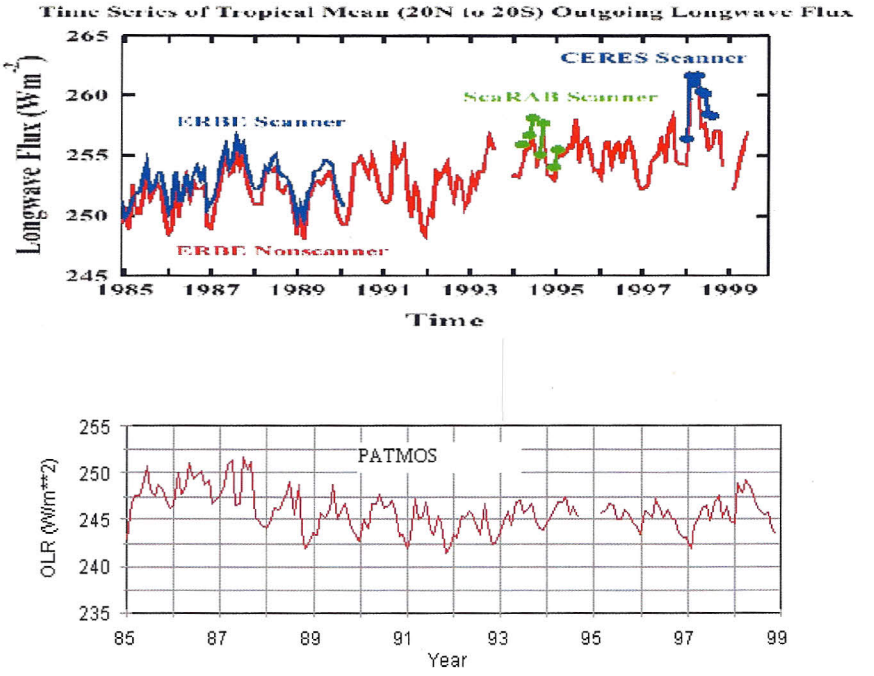
Post-launch calibration of satellite radiometers is necessary to ensure the accuracy of the derived geophysical products; this is crucial in the absence of onboard calibrators and is useful to monitor the performance of onboard calibrators when they are present. A logical extension of this requirement is the intercalibration of satellite radiometers to ensure the viability of blended geophysical products derived from different radiometers. We have developed a simple technique for the intercalibration of satellite radiometers in the visible and near-infrared, using measurements made over stable desert sites and model simulations of the upward radiation measured by the two radiometers. The feasibility of the technique has been established for different combinations of visible channels on the AVHRR, HIRS, GOES imager, and MODIS. The figure illustrates the calibration of the visible channel of the HIRS, using the AVHRR as a calibration reference. The high degree of correspondence between the top-of-the-atmosphere albedos measured by the two instruments is indicative of the efficacy of the technique.



Inter-comparison of the reflected light measured in the visible channels of the Advanced Very High Resolution Radiometer (AVHRR) and the High Resolution Infrared Radiation Sounder (HIRS) over the contiguous United States on October 5, 1999.

AVHRR Pathfinder Data Set

Instruments on operational weather satellites have sufficient continuity to provide long-term climate studies. Multi-year climate data sets have been produced from operational satellites under the NOAA/NASA Pathfinder Project. These data sets are to study climate variability, climate trends, and long-term atmospheric processes. The Office of Research undertook to reprocess some of these data sets.



This figure shows long-term trends in Outgoing Longwave Radiation (OLR) from instruments making direct observations (upper curves) and as estimated from the AVHRR Pathfinder (lower curves). Note that trends are different, a subject currently under investigation.

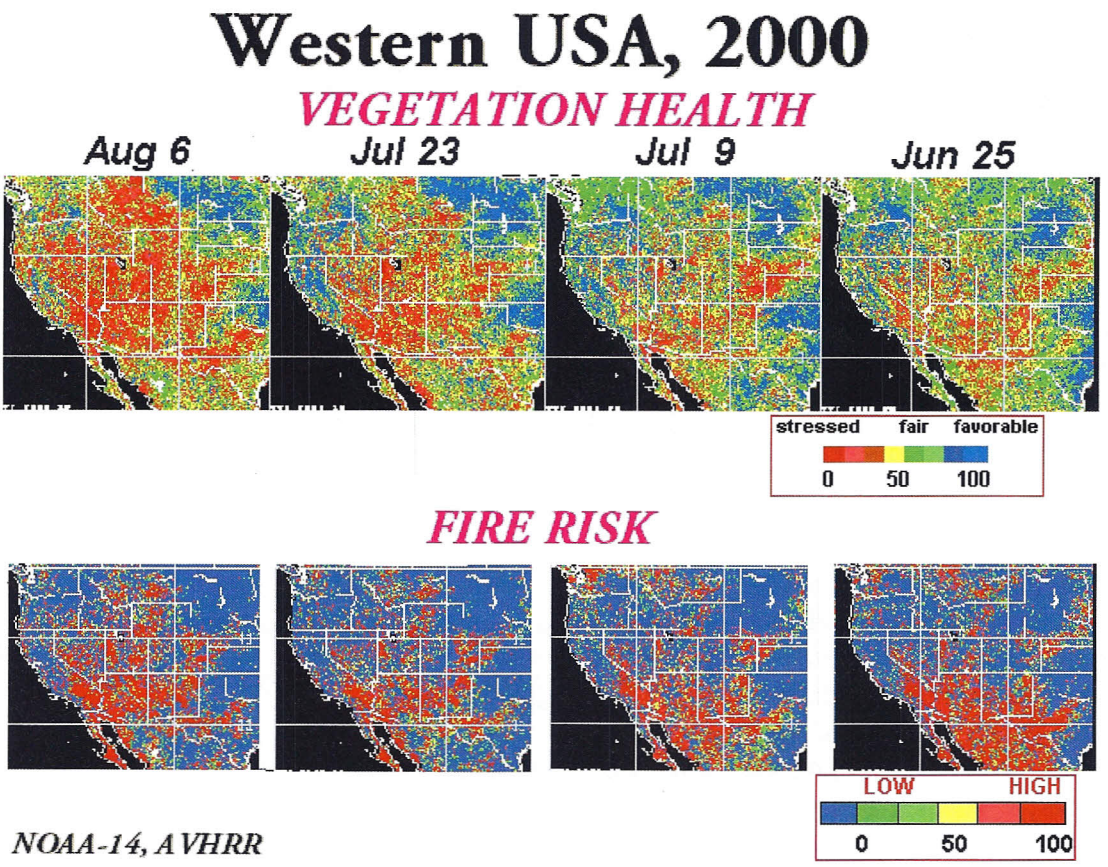
The 20-year AVHRR data set has been processed at NESDIS into a set of climate-quality time series of atmospheric variables. Products from the reprocessing include clear and cloudy radiances, cloud fraction, aerosol optical depth and components of the Earth radiation budget. These geophysical quantities are processed for an equal area grid with a spatial resolution of 1° lat/long. The quantities are produced as daily, pentad, and monthly time series. These series are being analyzed for trends and for fluctuations that

may be related to other atmospheric processes. The figure shows direct measurements of Outgoing Longwave Radiation (OLR) from several experimental instruments (top) and the Pathfinder OLR (bottom). Trends from the direct measurements and the Pathfinder result are different with the Pathfinder OLR showing no trend and the direct measurements showing an upward trend. Such differences are currently under investigation.

Drought Monitoring and Fire Danger Index

Drought is one of the most destructive natural phenomena and because of this, drought detection and monitoring is of wide interest. The Office of Research and Applications produces an experimental drought product (drought indices) derived from the Global Vegetation Index product. This product is used for agricultural crop assessments by USDA and by users in several foreign countries. The drought indices have been compared with conventional measures of drought such as Crop Moisture Index, Palmer Drought Index, precipitation anomalies, and crop yields. The drought indices have proven to be good indicators of agricultural drought.

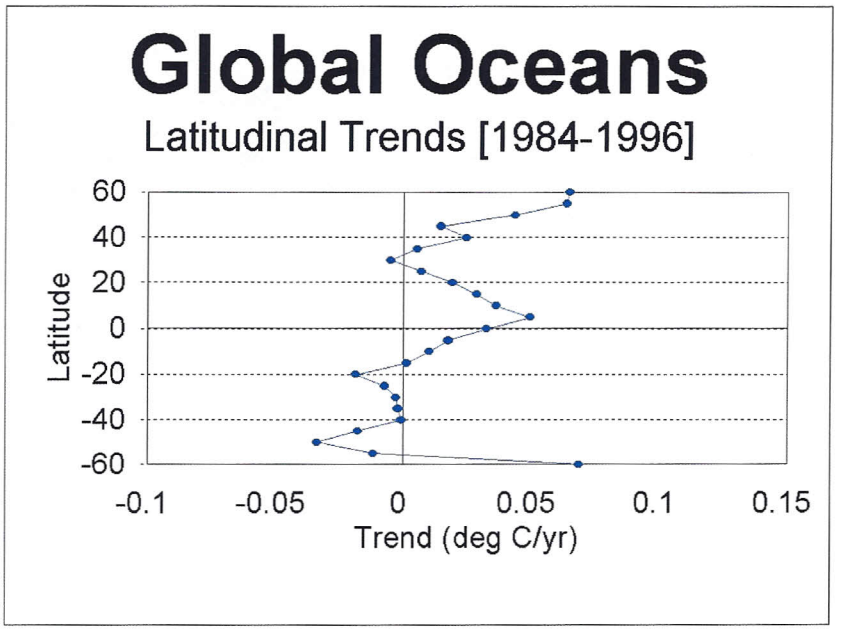
As of August 6, 2000, the NOAA/NESDIS experimental drought product shows a large area of extreme vegetation stress in the western United States (see image below). This stress is the result of intensive drought developed since early summer. As depicted by the red color on the image, large areas of Montana, Nevada, California, Arizona, Utah, New Mexico and Colorado are affected. Vegetation stress accumulated over time is a measure of fire risk and is shown in the lower panel of images. It started to develop in early summer 2000, particularly in the Southwest and by the beginning of August, the vegetation was in very bad condition, creating a high fire risk.



The upper panel shows the progression of vegetation stress through the summer of 2000. Red color represents high vegetaton stress. In the lower panel red shows areas of high fire risk.

Thirteen Years of Satellite SSTs Pinpoint Oceanic Regions of Warming and Cooling

NOAA satellite-derived SSTs, during the period of 1984 to 1996, have been analyzed for tendencies ocean-wide. The Northern Hemisphere's oceans shows some of the most notable increases—+0.05 deg C/yr seen for the composite ocean of the Northern Hemisphere. Ocean basins tend to depict cooling in the centers of each basin and warming around the margins. A most intriguing aspect was the finding that, other than a few regions representing areas that include the Gulf Stream and the Kuroshio, the Northern Hemisphere tropical waters (centered about 5 deg N) have been heating at an enhanced rate since 1984—nearly 0.5 deg/ decade (ten times the global rate). This rapid warming has presented a rather hostile environment for many of the coral reefs ecosystems and is believed to account for much of the reason for increased episodes of bleaching over the past decade. The accompanying figure illustrates these latitudinal warming trends by the zonally averaged satellite SST anomalies over all oceans.



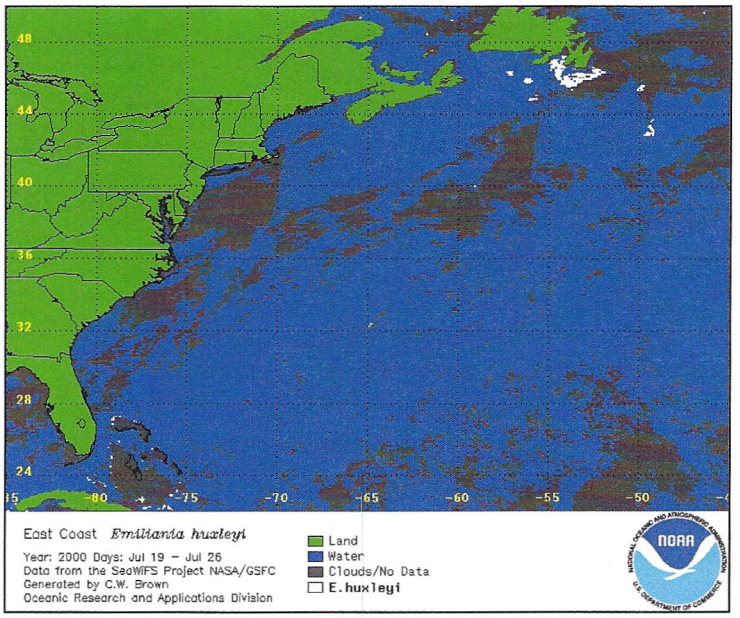
Analysis of the 1984–1996 global satellite sea surface temperatures indicates a significant warming in surface temperatures.

Oceans

Automated Detection of Harmful Algal Blooms

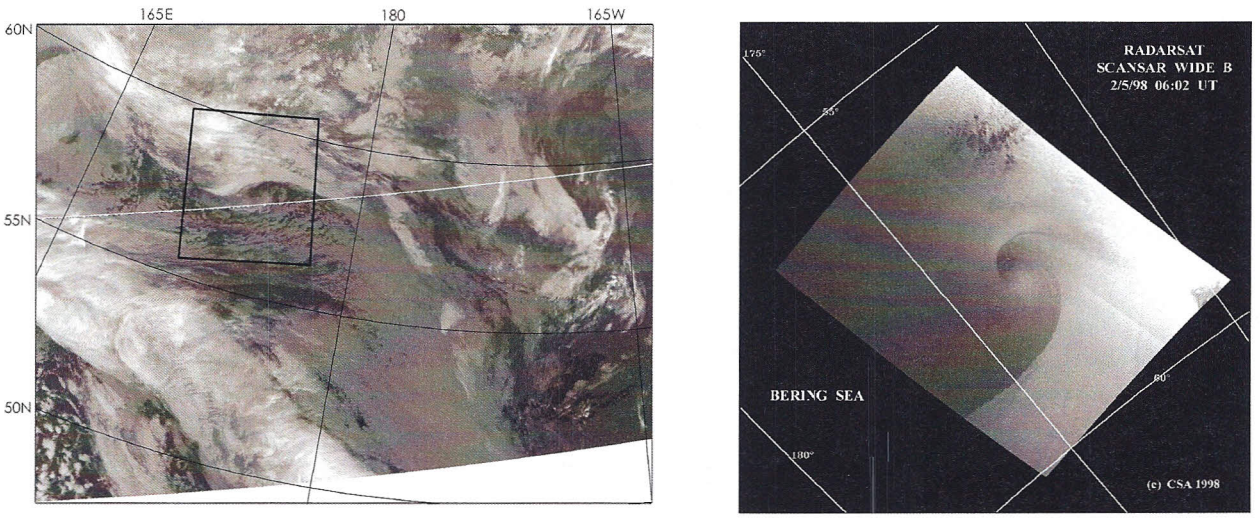
Multiple interacting physical, chemical, and biotic factors lead to the development and persistence of biotic events. Information on many of these factors is accessible in near-real-time from geographic databases, numerical circulation models, operational satellites, and in-situ deployed instrument systems. The capability to assess pertinent environmental factors in near-real-time offers the potential to operationally detect and predict the presence of biotic events if the identifying characteristics of the species, such as their spectral signature, or the environmental conditions associated with their occurrence is known. A major effort of the NOAA/NESDIS Ocean Color Biology Program of the Oceanic Research and Applications Division (ORAD) is to develop and implement methods that employ data derived from disparate sources—numerical circulation models, operational satellites, and moored sensor systems—to generate nowcasts and forecasts of the distribution pattern of marine biota.

We routinely generate weekly maps of the location of three types of algal blooms using satellite ocean color data (figure at right). The ability to remotely characterize the taxonomic composition of phytoplankton from space has application in several fields of study critical to NOAA's environmental stewardship missions, such as the assessment of climate change on oceanic ecosystem structure and the detection and monitoring of harmful algal blooms.



Example of a weekly algal bloom product. This image indicates the location of classified blooms of the coccolithophorid *Emiliania huxleyi* off the U.S. East Coast in July 2000.

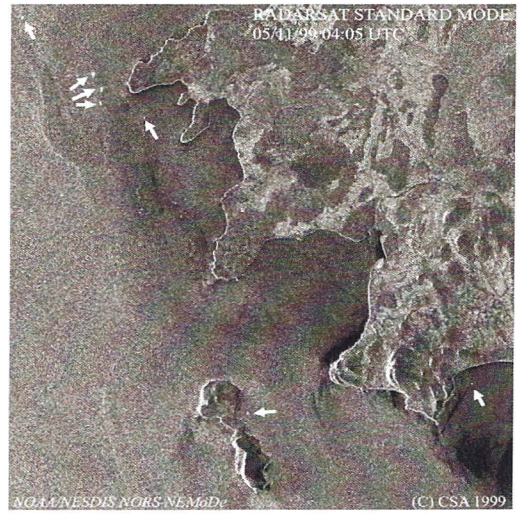
Alaska Synthetic Aperture Radar Demonstration



GOES infrared imagery for February 2, 1998. The "boxed" area in upper, center left of first image shows little evidence of developing low pressure shown in synthetic aperture radar image provided in figure to right. The capability of SAR to image the atmospheric wind footprint may be an important forecasting aid.

The Alaska region is plagued by persistent cloudiness, rendering many of the passive radiometric remote-sensing techniques marginally useful. In an attempt to improve the availability of environmental information, especially that could be used in forecast operations, ORA has established a major research effort to determine how SAR may be useful in an operational mode in the region. The Alaska Synthetic Aperture Radar (SAR) Demonstration commenced in the fall of FY 1999 and has an anticipated duration of 2 years. The demonstration goals are to: 1) Validate and test new experimental SAR-based imagery and data products that respond to critical environmental forecasting needs in the Alaska region not now satisfied by present observational (both satellite and in-situ) data in the Alaska region; 2) Evaluate our capabilities to provide SAR data and information products in near-real-time via the Internet for trial use

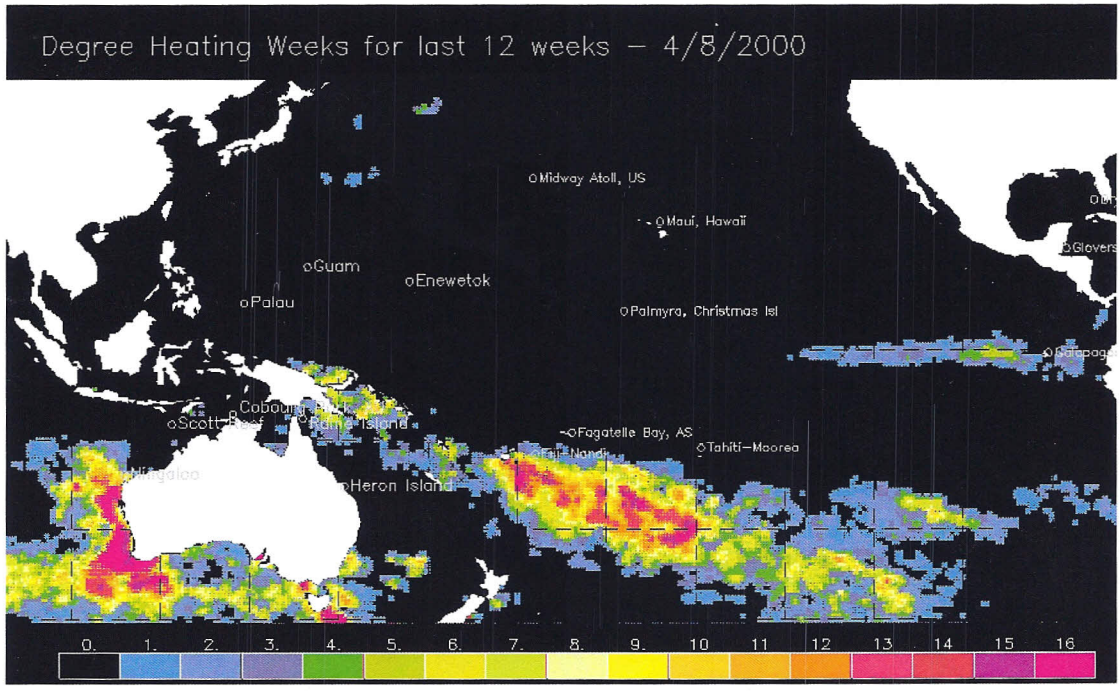
by Federal and state operational user agencies in the region; and, 3) Familiarize operational agencies in the Alaska region with SAR imagery, data, and products that might be produced on and operational basis by NESDIS. Experimental products include all weather, high-resolution ocean wind-induced roughness imagery (please see first figure above to the left showing storm in Bering sea) that provides improved information on developing storms not fully visible in conventional infrared imagery (see second figure above to the right). ORA is also producing SAR-based wind vectors, high-seas ship location detection (see third figure that shows the detection of a number of large commercial fishing vessels in the Togiak, Alaska region), and all-weather high-resolution ocean surface and sea ice. Major demonstration participants include NESDIS, the National Weather Service, the U.S. Coast Guard, the National Marine Fisheries Service, the Alaska Department of Fish and Game, The Johns Hopkins University Applied Physics Laboratory, ERIM International, and the Alaska SAR Facility.



SAR image of Togiak Bay, AK, showing ability to detect large (>30m) fishing vessels (indicated by arrows).

Global Coral Reef Bleaching

Providing automated alert notification to coral reef management activities to the occurrence of anomalously warm sea surface temperature conditions that might give rise to coral reef bleaching is

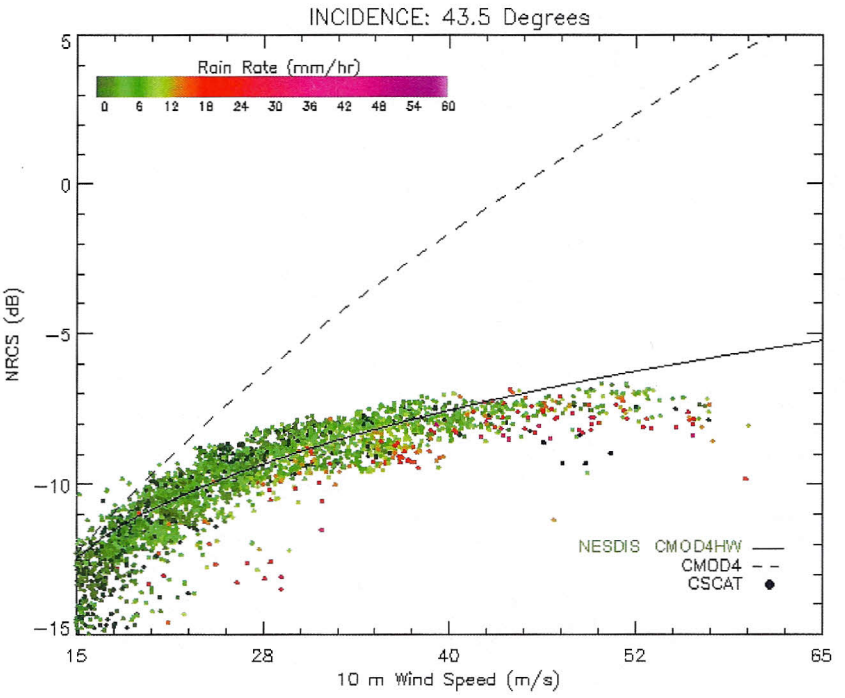


Degree heating weeks analysis for period ending April 8, 2000. Areas of anomalously warm sea surface temperatures are indicated by brightly-colored regions (see attached scale, in units of degree-heating weeks).

important. Human activities within the reef areas could be restricted, thus limiting the severity of any ensuing damage. ORA and NESDIS Office of Satellite Data Processing and Distribution is now providing such alerts through NESDIS' Coral Reef Bleaching web site, which became operational and accessible to the general public in early FY 2000. Bleaching indices (provided for critical Atlantic, Pacific and Indian Ocean reef areas) present a measure of sustained ocean surface water heating at the selected coral reef sites that may be of such a magnitude as to cause concern about coral reef bleaching. Using NOAA polar orbiting satellites, observed sea surface temperatures and the 10-year SST climatological maximum mean temperatures are used to calculate the degree heating weeks (DHW) for each reef site in the monitoring program. A one-degree heating week is equivalent to one week of sea surface temperature that is one degree C above the expected summertime maximum for the particular location. The accompanying figure shows the heating degree weeks for the Pacific and eastern Indian Oceans for the period ending April 8, 2000. Areas of anomalously warm water conditions are highlighted in color. A representative sample of the reef locations for which tailored bleaching products are produced are also shown. When the observed SST exceeds the monthly mean maximum, then coral reef bleaching is increasing likely, and an alert is indicated. The severity of potential bleaching is related to the magnitude of the accumulated degree heating weeks over the preceding 12 weeks. The NESDIS Coral Reef Bleaching Indices was featured at the NOAA-hosted meeting of the Coral Reef Task Force in Washington, DC, on March 2–4, 2000. For additional information, please see http://orbit-net.nesdis.noaa.gov/orad/coral_bleaching_index.html.

Improving High Wind Speed Regime Retrievals From Active Satellite Sensors

Ocean surface wind vector retrievals from satellite remote-sensing instruments such as NASA's SeaWinds scatterometer on QuikSCAT have the potential to revolutionize weather marine forecasting. NESDIS, which has U.S. responsibility for the near-real-time processing and subsequent distribution of QuikSCAT/ SeaWinds data to the operational weather centers, is currently evaluating the operational utility of these data in a collaborative research project with other NOAA line offices. The focus of this evaluation is in the validation of retrieved data and the continuing development of wind retrieval algorithms.



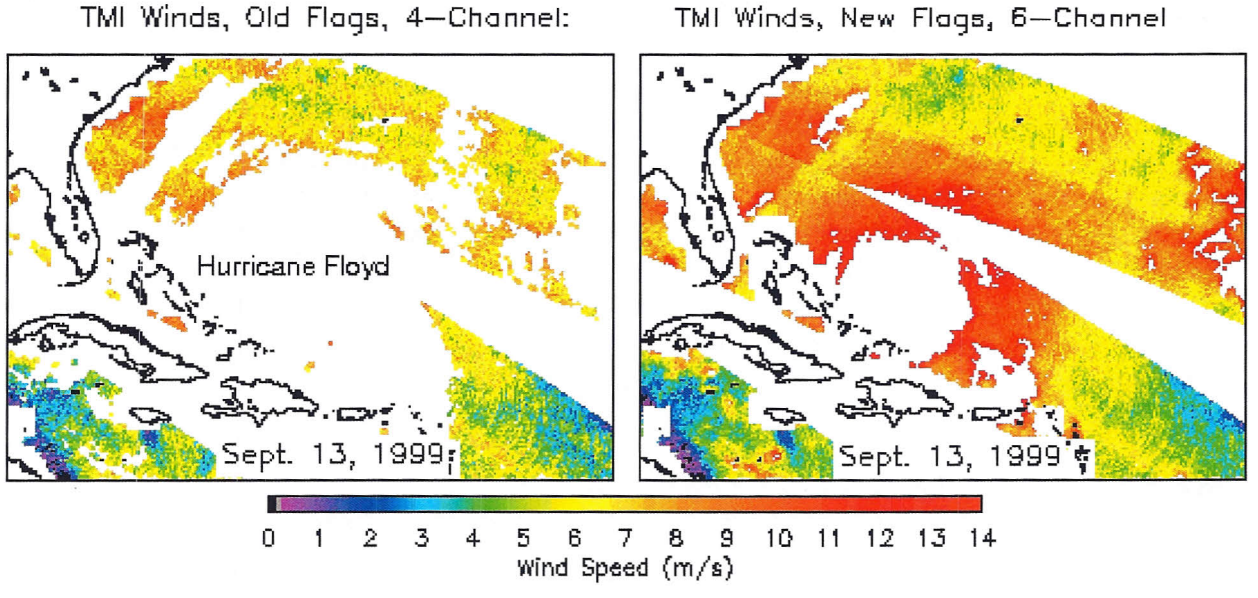
Measurements during high wind speed events indicate current algorithms over estimate wind speed in high wind conditions. The modified NESDIS algorithm (CMOD4H4) is more accurate.

The accuracy of high wind speed retrievals is important for determining storm intensity, as well as defining warning areas which are set according to predefined wind speed thresholds. These wind speed thresholds are: 15.65 m/s (30.41 knots or 35 mph) for the

issuance of gale warning, 22.35 m/s (43.45 knots or 50 mph) for storm warnings, and 32.19 m/s (62.57 knots or 72 mph) for hurricane warnings. The current Ku-band model function (termed NSCAT-2) appears to accurately predict the Normalized Radar Cross-Section (NRCS) up to around 30 m/s. The current C-band model function (CMOD4) appears to accurately predict the NRCS for wind speeds up to around 19 m/s. Additional high winds speed data are needed. ORA and the University of Massachusetts have conducted field experiments in the Gulf of Alaska, Northern Atlantic, the Caribbean and the Gulf of Mexico. These experiments on the NOAA P-3 aircraft have resulted in scatterometer measurements of the ocean surface in wind speeds up to 60 m/s in various environmental conditions. The accompanying figure plots the current CMOD4 and the improved high wind speed CMOD4 (which we designate as CMOD4HW). The data points are color coded according to the rain rate. These new data show unlike Ku-band, C-band (e.g., the QuikSCAT) scatterometer-employed frequency is relatively insensitive to rain. Also shown are wind retrievals in the remnants of Hurricane Irene from the scatterometer aboard ERS-2 using CMOD4 and CMOD4HW. New Ku-band and C-band model functions have been derived from the results of these experiments. Our work suggests that the new CMOD4HW-based wind speeds are much closer to the actual winds than those from the older CMOD4, and, therefore, will have greater operational validity.

Improved Wind Retrieval Algorithm Developed for TMI on TRMM

A new ocean surface wind speed retrieval algorithm has been developed using data from the Microwave Imager aboard the Tropical Rainfall Measuring Mission (TRMM) satellite. Developed using multi-variable regression techniques, the algorithm closely resembles that used to retrieve ocean winds from SSM/I data. TRMM's additional low frequency channels provide the new TRMM Microwave Imager (TMI) algorithm with enhanced capabilities in retrieving ocean winds through adverse precipitation conditions. Such conditions are an acute problem for the SSM/I wind speed algorithm. The included figure shows the resulting coverage enhancement of wind speed observations surrounding hurricane Floyd as it approached Florida's eastern shore on September 13, 1999. The left panel shows wind speed

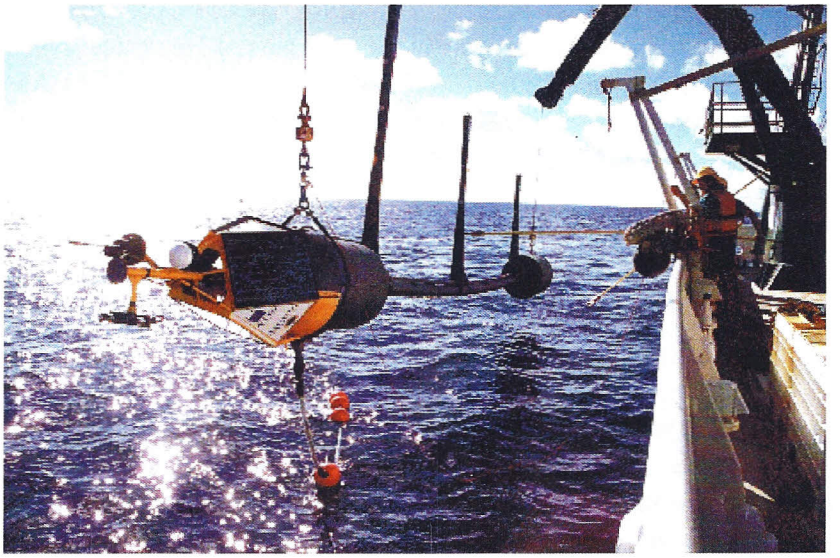


Use of the lower frequency microwave bands allows improved wind speed estimation within rain-affected regions.

retrievals over hurricane Floyd using the old SSM/I rain flag criteria. Many areas, especially those associated with the intense rainfall bands of the hurricane, are inaccessible to the current algorithm. The right panel shows TMI retrievals using the "relaxed" rain flag criteria, revealing an 85% coverage increase with the new algorithm. The TMI algorithm has already proven useful in an operational capacity. The Marine Meteorology Division at the Naval Research Laboratory in Monterey has been using the TMI wind retrievals extensively in the examination of tropical cyclones.

Moderate Resolution Imaging Spectrometer (MODIS) Initialization

The Office of Research and Applications Marine Optical Characterization Experiment (MOCE) Team, sponsored by NASA, completed the first initialization experiment in support of the Moderate Resolution Imaging Spectrometer's (MODIS) ocean color mission. The MOCE team, along with colleagues from the Universities of Miami, San Jose State, and San Diego State, completed a highly successful at-sea experiment in Hawaiian waters during the period of April 9–16. During this 8-day at-sea experiment, complete bio-optical, atmospheric, and physical oceanographic observations were conducted during both MODIS and SeaWiFS overpasses. A total of five coincident stations were acquired for each of the sensor systems. A series of cross calibrations was conducted by the Optical Technology Division of the National Institute of Standards and Technology (NIST) to maintain an absolute calibration scale between MOBY and the MODIS ocean spectral bands. New MOBY meteorological observational capabilities were incorporated into the buoy (see accompanying figure showing the buoy's instrumentation spar being deployed) . For the first time meteorological data will be routinely obtained that will be critical to the development of diffuse sun glint correction algorithms for the nadir-viewing Moderate-resolution Imaging Spectrometer (MODIS). Several overflights by NASA's ER-2 aircraft instrumented with the MODIS Airborne Simulator (MAS) were completed with simultaneous in-situ measurements from the ship and the Marine Optical Buoy. The MOBY buoy is illustrated as it was being deployed in the accompanying figure.

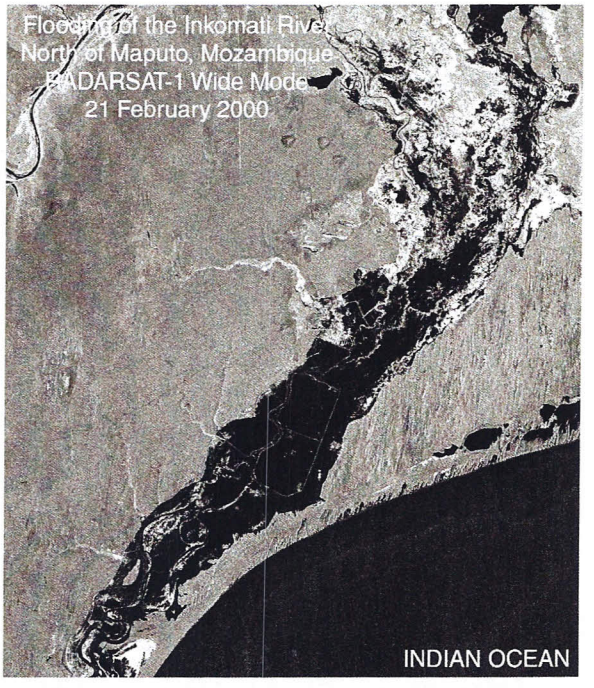


Deployment of high spectral resolution Marine Optical Buoy (MOBY) instrumentation spar off Hawaii.

ORA Provides Synthetic Aperture Radar Imagery Processing and Provides Emergency Support to Mozambique Flooding Response

As a result of a request which originated by the Vice President's Office, the ORA SAR team assisted in the ingestion, processing, and interpretation of RADARSAT-1 Synthetic Aperture Radar (SAR) imagery of the flood-stricken country of Mozambique in Southeastern Africa. Data for February 21, 23, and 25,

2000 were acquired, processed and provided to the U.S. State Department (USAID/Office of Foreign Disaster Assistance) on an urgent basis. The data show major flooding occurring over large areas of southern Mozambique (identified in the accompanying figure as the broad, dark bands in the SAR image representing overflowing waters from the Inkomati River), particularly along the Inkomati, Maputo, and Limpopo rivers. In northern Mozambique, the data indicates flooding conditions along the Zambezi river delta region but no clear indications of major flooding further north. The capabilities that allowed this emergency response were developed under the auspices of the Alaska SAR Demonstration that started in October 1999.

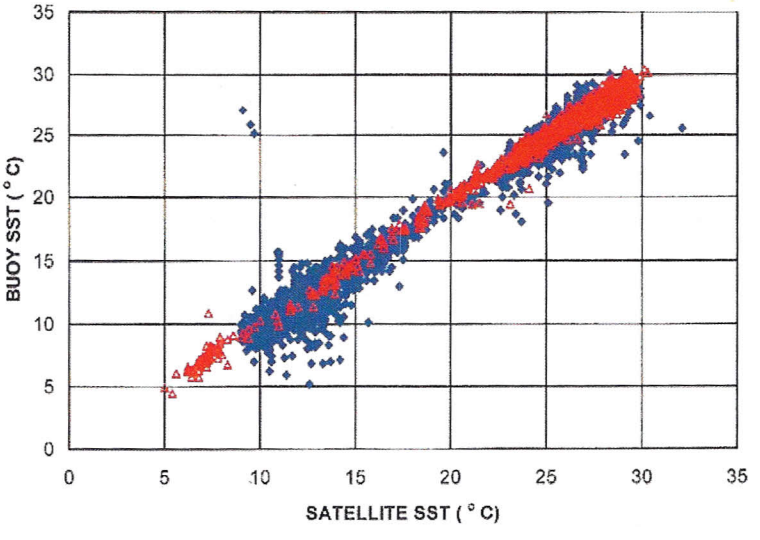


Synthetic aperture radar imagery processed on an emergency basis by ORA helped identify extent of flooding in Mozambique (flooding shown in image as broad dark band) and marshalling of subsequent relief efforts.

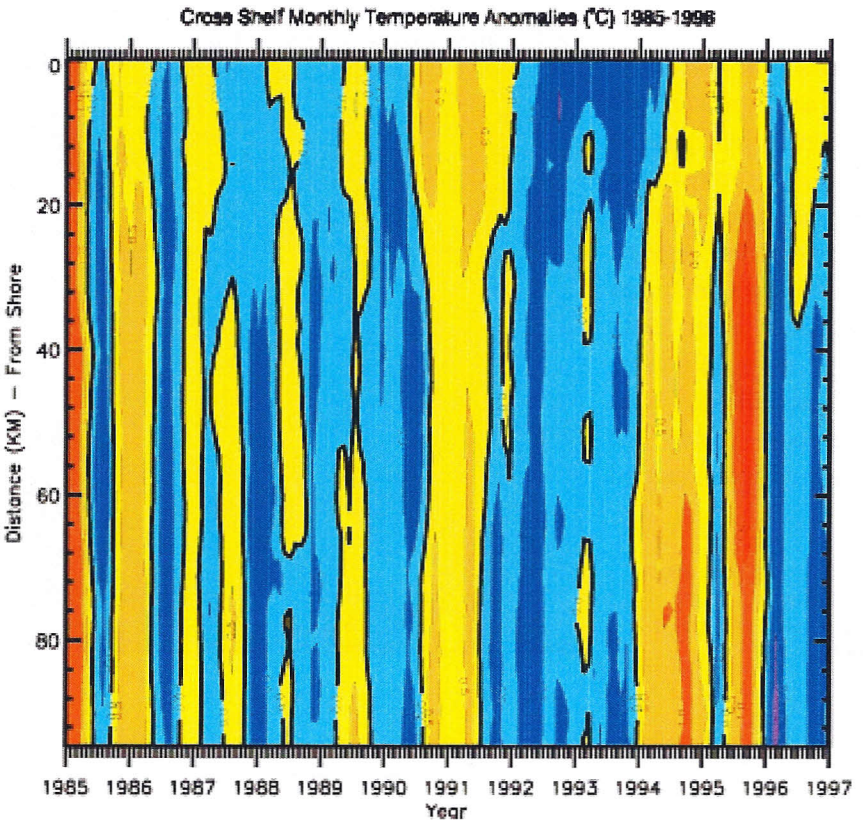
Near Real-Time Calibration for GOES Sea Surface Temperatures

GOES SSTs are now being monitored on a near-real basis, and matched on a global basis with marine buoy observations. The accompanying figure shows the buoy-satellite SST match-ups for the polar-orbiting NOAA-14 (which has demonstrated a calibration accuracy of ~0.5 K) and the geostationary GOES-10 satellites for May of this year. Both day and night values are included. It is believed that some of the scatter may be as a result of errors in the reported buoy observations. The calibration comparisons have been encouraging and are generating increased interest by tropical SST data users where the increased temporal resolution of the geostationary observations provide significantly improved cloud-clearing opportunities than for the polar-orbiting satellites.

Satellite SST vs Buoy SST For May 2000
(Blue- GOES-10 SST and Red - NOAA-14 SST)



Example of ongoing calibration comparisons between GOES and NOAA polar-orbiting satellites. Significant progress has been made in establishing GOES as a reliable source for calibrated SSTs.



Systematic cooling (blue) and warming (red) events along Maine's coast are being indicated in NESDIS-sponsored research as possible contributing factors to fluctuations seen in lobster recruitment success, with warm epochs resulting in greater success.

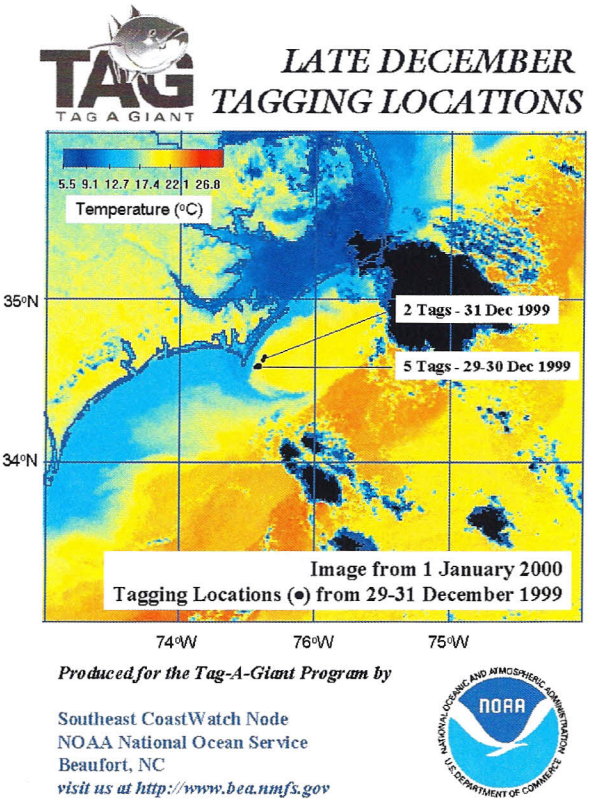
El Nino Plays Possible Role in Lobster Settlement Success in Maine

Results were first presented at the Maine Fishermen's Forum in Camden, ME, in early March 2000, of a possible link between satellite-observed sea surface temperature anomalies along the Maine coast and the observed annual success in lobster larvae settlement to the bottom. This research, supported by the NESDIS Ocean Remote Sensing Program, may have important implications to forecasting future lobster population levels. Using NOAA satellite sea surface temperatures, scientists at the University of Maine noted that fisheries data indicated that lobster larvae were more successful in surviving settlement to the bottom (and having the potential to mature—typically 6–7 years hence) in years where the offshore waters were anomalously warmer than in normal (or typically colder) years. The accompanying figure illustrates these warmer years, which are shown as the yellow-red bands (especially years 1985, 1991, and 1995) represented those periods in which the satellite SST data indicated that the southeastern Maine cross-shelf waters were uniformly warmer than normal. These fluctuations appeared to be correlated with those periods of El Niño episodes in the Pacific. If these preliminary results are sustained by further research, it may be possible to ingest satellite sea surface temperatures into coupled coastal circulation and biological models to provide new observational tools for helping to predict potential future lobster stock levels—a major question in the Gulf of Maine fisheries.

CoastWatch and Giant Blue Fin Tuna

The Southeast CoastWatch Program (SECW) has been working with the "Tag-a-Giant" Program to provide near-real-time temperature and SeaWiFS ocean color support in support of field operations. The tagging operations take advantage of the giant blue fin tuna winter residency off the coast of North Carolina. These tagging efforts provide vital information on blue fin tuna habitat and range characteristics. The image shown illustrates the use of NOAA CoastWatch SST imagery this winter to

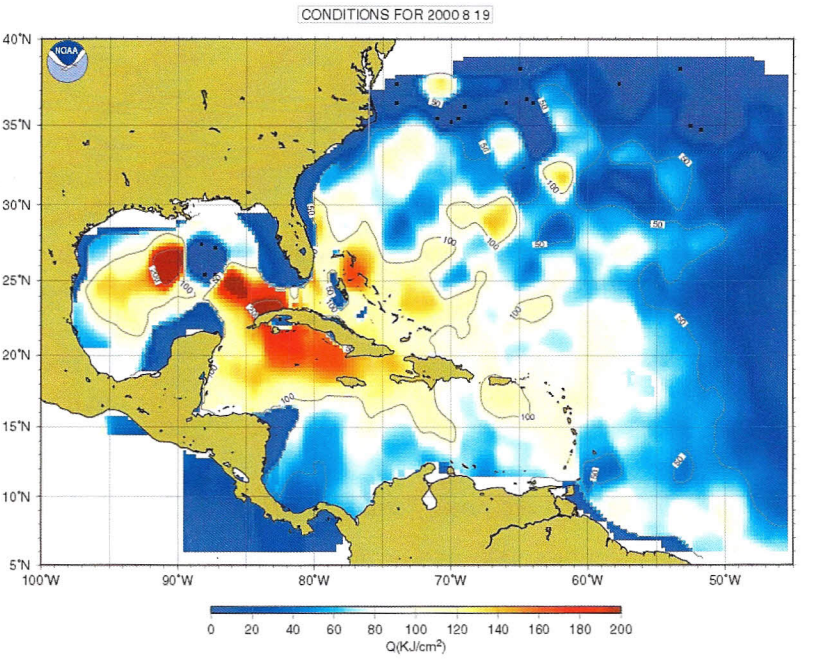
guide the tagging operations during the recently completed winter-spring operations. By exploiting the temperature preferences of these large tuna, tagging operations are able to tag larger numbers of the fish in the time available by using satellite SSTs as a guide each day. The NOAA Southeast CoastWatch regional office is also providing preliminary maps describing tagging locations, while Tag-a-Giant members are producing maps of pop off tag releases and recoveries. For more information, visit http://www.bea.nmfs.gov/giant.html.



Giant blue fin tuna, which can exceed 1,000 pounds, congregate off the North Carolina coast during the winter, affording a significant opportunity for tagging operations. CoastWatch provides satellite imagery (as shown here) to assist tagging operations in targeting prime habitat areas.

Altimetry for Hurricane Forecasting

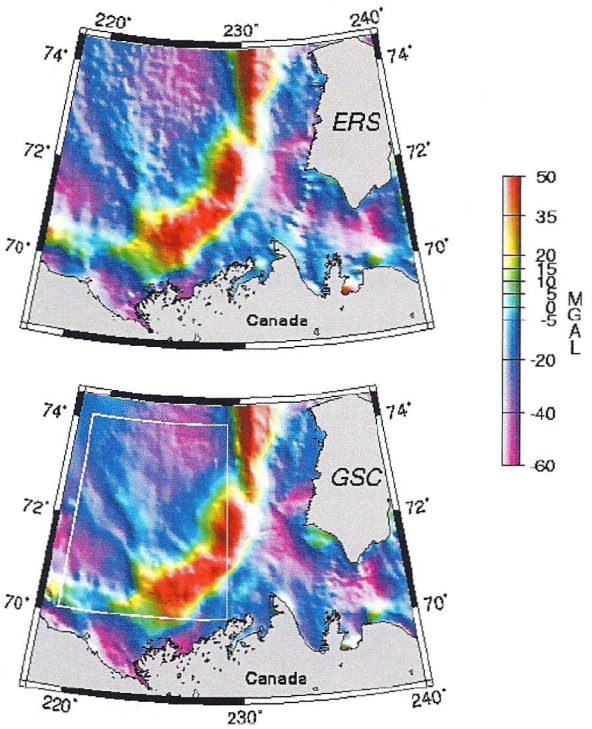
Useful warning systems for hurricanes require prediction of both the storm track and intensity. Whereas forecasting of hurricane tracks has improved during recent years, the same cannot be said of hurricane intensity, partly because the physics is poorly understood. However, transfer of heat from the ocean to the atmospheric boundary layer is thought to be one factor controlling intensification. Accordingly, satellite altimeter data provided by the NOAA Laboratory for Satellite Altimetry (LSA) are being used at the National Hurricane Center and the Atlantic Oceanographic and Meteorological Laboratory to compute a parameter called "hurricane heat potential." This parameter is computed in the context of a two-



Upper ocean heat content, as evidenced by sea height elevation in altimetric measurements, may help identify regions where rapid tropical storm intensification may occur

layer ocean model by combining satellite measurements of sea surface temperature and altimetric sea level anomaly. The map below shows the distribution of hurricane heat potential for August 19, 2000. Areas colored red indicate values of greater than 150 KJ/cm**2 where sudden hurricane intensification might be expected. This new analysis is currently being evaluated using TOPEX/POSEIDON altimeter data provided by LSA in near-real time.

Arctic Gravity Project



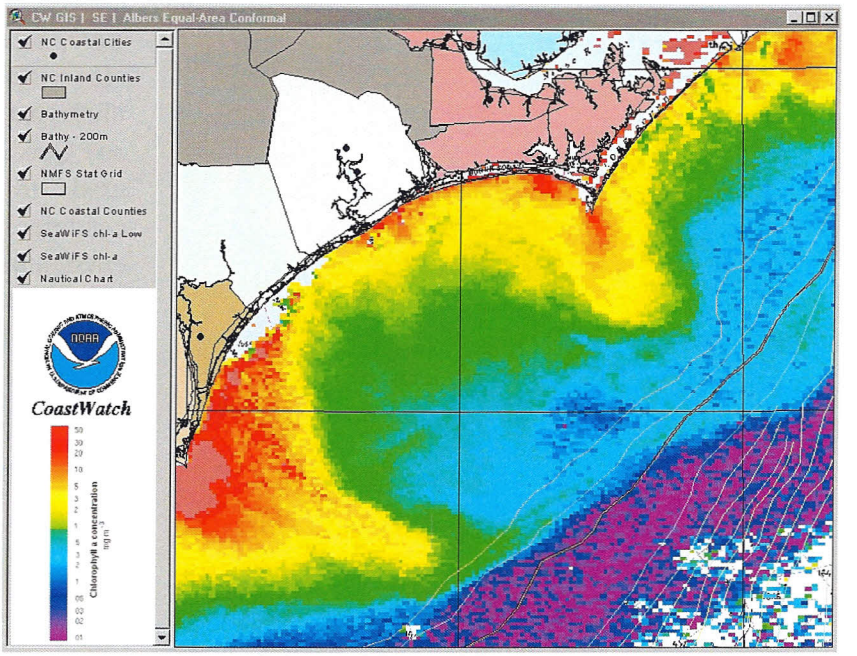
Satellite altimetry (ERS) shows good agreement in inferred gravity field when compared to ground measurements (GSC).

An updated Arctic marine gravity field derived from ERS-1 and ERS-2 satellite altimetry has been computed by scientists at the Laboratory for Satellite Altimetry in collaboration with the University College, London. The new analysis was submitted to the National Imagery and Mapping Agency (NIMA) as input to the international Arctic Gravity Project (ArcGP). This gravity field (top figure below) covers the entire Arctic Ocean south of 82 degrees N. Much of the Arctic Ocean is inaccessible and poorly surveyed with surface gravity techniques. One exception is the southeastern Beaufort Sea where the Geological Survey of Canada (GSC), (bottom figure) has conducted an accurate, detailed gravity survey on the sea ice. Excellent agreement (<~2 mGal rms difference) between surface (GSC) and satellite (ERS) gravity is obtained here. ArcGP is combining satellite, airborne, surface and submarine gravity data into a 5-minute publicly available gravity grid for general release in 2001, for use by geophysicists, satellite geodesists and oceanographers. This international initiative includes representatives from the U.S., Canada, Russia, Denmark, Germany, the United Kingdom and all other circum-Arctic countries.

Improving User Access to Coastal and Ocean Remote Sensing Satellite Data

Until recently being able to use digital remote-sensing data from Earth satellites required substantial investments in computing infrastructure. So it was no surprise that when NASA completed a survey of coastal state environmental managers, it was discovered that satellite imagery was one of the least used of available environmental data sources. States typically are severely limited in their available resources to invest in high-end computing and data processing infrastructure. Low-cost high-performance desktop computers, high-bandwidth network communications using the Internet, together with modern geographic information systems (GIS) software have changed the landscape altogether. Satellite data can now be

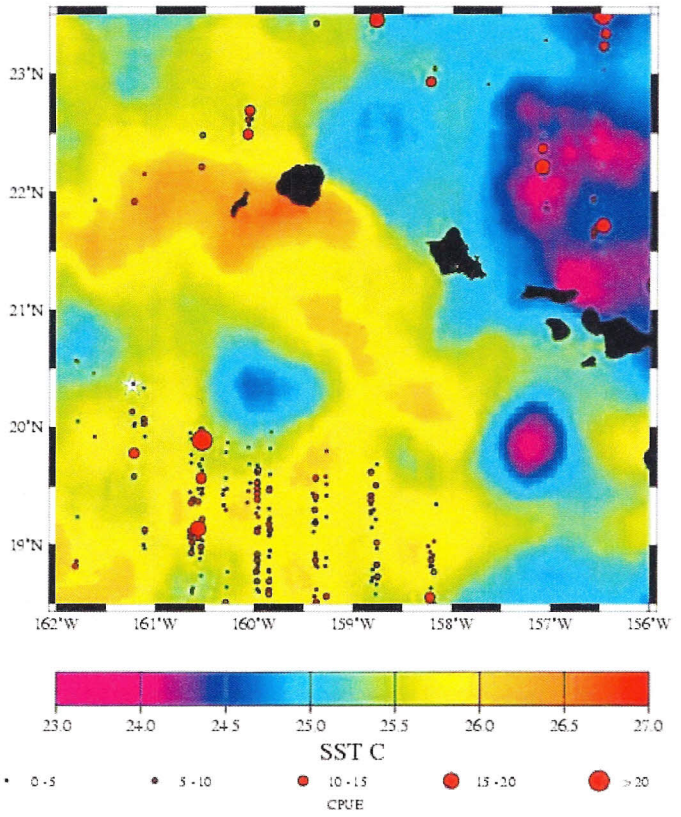
brought from source to the user's desktop where it can be directly inserted into an existing computing and land spatial database analysis software and used like any other spatial data set. In 2000, ORA completed the development and testing of new formats to deliver to users environmental satellite imagery data that take advantage of the Internet, desktop computers, and GIS. The accompanying figure illustrates the presentation of SeaWiFS ocean chlorophyll imagery data in an ArcView GIS spatial analysis software environment. Each ~1 km pixel in the image is associated with a latitude, longitude and chlorophyll value. This presentation is much simpler than the image data formats historically used by scientists, and makes the data much easier to manipulate in quantitative GIS analyses. Second, coastal ocean imagery analyses can be included in coastal applications where land data already exists. GIS is used by more than 0% of coastal states. Providing our data in a GIS format that is directly compatible with this installed used infrastructure greatly increases the accessibility of our satellite data. Through cooperation with NESDIS' Office of Satellite Data Processing and Distribution, we anticipate operational implementation of this new user-friendly data-delivery approach to occur before the end of CY 2000.



ORA emphasis in providing satellite data (such as this ocean chlorophyll image) in GIS-compatible formats will allow easier user access to the data for use in coastal studies.

Ocean Remote Sensing in Hawaiian Fisheries

"Catch per Unit Effort" (CPUE) is an important statistic used by the National Marine Fisheries Service (NMFS) in commercial fisheries management and fish stock assessment. The health of the targeted fisheries stock is gauged by whether the amount of fish caught ("Catch") is increasing or decreasing in comparison to the normalized level of effort ("Unit Effort") expended by the commercial fishing. The NMFS Laboratory in Honolulu, HI, is now showing that CPUE also depends on oceanographic factors such as oceanic winds, currents, and temperatures in the targeted area. Targeted fish can be aggregated (or disaggregated) by the local ocean's temperature patterns with consequent increases or decreases in the CPUE statistics that have little bearing on stock levels. The effectiveness of the long line rigs used by many fishermen can be increased or decreased by whether wind and current conditions gives rise to surface divergence or convergence, respectively. NOAA CoastWatch is now providing satellite data from which these oceanographic factors can now be incorporated into the NMFS stock analyses. In the accompanying figure, the CPUE statistics for Big Eye tuna in the Hawaiian area for November 21–23,



1999, superimposed onto concurrent GOES sea surface temperature image data, is illustrated. TOPEX/POSEIDON altimetry and QuikSCAT scatterometry data are being used to estimate wind and current conditions. By having contemporaneous environmental satellite data, confidence in CPUE statistics estimation can be increased, resulting in improved fishery management decisions.

CoastWatch-supplied satellite data, such as the GOES SST data shown here, is now allowing fisheries management activities now to begin to account for regional habitat and fishing conditions factors in their work.

7. OUTREACH AND DIVERSITY

Diversity

Our Vision

The Office of Research and Applications is committed to a workplace in which all people are respected as individuals and are valued for their contributions to accomplishing NOAA's mission. We foster an inclusive, supportive, open, challenging and innovative work environment to enable employees to be positive, creative and reach their full potential. We encourage our employees to reach out into the community as ambassadors of NOAA and the Department of Commerce.

Summer Students/Interns

D.C. Metropolitan Consortium (METCON). ORA's METCON students successfully completed their summer program with a well received presentation at the METCON Banquet held on August 9. Michael Thomas and Isaiah Pickens were selected to present their newly developed METCON/NOAA home page at: http://welcome.to/METCON. Several of the attendees at the banquet were highly complimentary of this achievement with overall endorsements of the site as a starting point for a permanent site demonstrating the accomplishments of the METCON program in NOAA.



2000 METCON participants.

Howard University's Center for the Study of Terrestrial, Earth and Atmosphere (CSTEA)—Internships Completed. ORA hosted two summer students through the CSTEA Historically Black Colleges and Universities Academic and Research Consortium. Akia Stone, a sophomore from Savannah State University, and Michelle Farver, a junior from Jackson State University, presented their research at the CSTEA HBCU Academic and Research Consortium Y2K Summer Research Program Colloquium held at Howard University. Akia spoke on the "Changes Observed in the Atmosphere and Weather of the Central U.S. region as a Result of Smoke Plumes from the 1998 Mexico Wildfires." Michelle discussed "Testing Stability of Normalized Difference Vegetation Index."

Maryland Educator's Summer Research Program. Yovanda Ingram, an 8th grade science teacher, and Tiesha Taylor, a senior in education at the University of Maryland, spent the summer working with ORA

scientists to develop classroom materials dealing with earth and space science for grades 7–9. They were also invited to participate in the NESDIS Ocean Remote Sensing Program grant review at the Science House, North Carolina State University in Raleigh, NC. The purpose of the review was to evaluate progress by the Science House in developing recommendations on how NESDIS ocean remote sensing satellite data and information can be more widely used in the K–12 classroom to support science education learning objectives.

International/National/Regional/Local

University of Puerto Rico. Scientists from the University visited ORA to discuss areas of mutual interest (coral reefs and synthetic aperture radar), and explore future plans to increase the access by Puerto Rico to NESDIS satellite data.

Central America. A translation into Spanish of a March 6, 2000, NOAA Vacancy News Release for a visiting scientist was provided by Pablo Clemente-Colón to the NESDIS Public Affairs Office for dissemination in at least 20 newspapers in Central America. The work to be conducted by this position is in support of the U.S. Agency for International Development's Hurricane Mitch reconstruction and development work in Central America. The responsibility of this position will be to test and implement real-time geostationary satellite-based Quantitative Precipitation Estimation (QPE) algorithms for Central America with application to flash floods, heavy precipitation, and hydrological and numerical weather prediction models.

Swedish Broadcasting Company. Al Strong and Larry Flynn were interviewed by the Swedish Educational Broadcasting Company regarding satellite-observed evidence relating to climate change.

Briefing to EMTs. John Weaver gave a presentation to a group of Emergency Medical Technician (EMT) regulars and reservists at Poudre Valley Hospital in Fort Collins. The talk was entitled "Emergency Response during Natural Disasters." It focused on how quickly the response infrastructure can be overwhelmed during a natural disaster and showed how developing a robust relationship with local NWS forecasters can help mitigate some of those effects through short term forecast product usage.

Demonstration at the Discovery World Museum. Robert Aune demonstrated weather analysis and forecasting techniques using the Visualization of Five-Dimensional data (Vis5D) software at the Discovery World Museum in Milwaukee, Wisconsin as part of their annual weather day program. Volunteers conducted hands-on experiments that explained properties of our atmosphere. A Vis5D workstation is the central exhibit for the event. It was used to emphasize the forecasting process including information collection, processing, and visualization.

Discovery Magazine. Al Strong of the Office of Research and Applications was interviewed by the Discovery Channel, May 1, 2000, on a provocative paper appearing this same week in Nature Magazine concerning high mortality of corals off Belize following the 1998 massive bleaching episode. Dr. Strong noted that NOAA satellite data showed thermal stress accumulations were highest over the southernmost Belizian reefs.

American Meteorological Society Teacher Enrichment Program. Al Strong and Rod Scofield provided several hours of training to 35 participants in the American Meteorological Society's new "Water in the Earth System" (WES) course held at the U.S. Naval Academy/St. Johns College campus in Annapolis, MD. An innovative Internet-based distance-learning course directed towards middle-school teachers, but open to all K–12 teachers, is being developed and implemented nationwide.

NESDIS Penobscot Bay Research. Research supported by NESDIS's Ocean Remote Sensing Program was highlighted in a Government Computer News article in November 1999. The article dealt with some of the data processing and distribution issues associated with the highly successful project in Maine.

Pioneers in Atmospheric Science Conference. Carmella Watkins served as one of the conference convenors for "Celebrating 20th Century Pioneers in Atmospheric Sciences: Examining 21st Century Challenges and Opportunities." Over 70 atmospheric science students from across the country were in attendance. Ms. Watkins participated on the panel entitled, Matters within Government and Research Laboratories. She also recruited at the Career Fair, presided at the banquet and presented awards to June Bacon-Bercey and John Jones, Jr. The NOAA financial support for the conference was appreciated.

Outreach

Graduate/Undergraduate Level

Course Instructors. Paul Chang and Chris Brown served as instructors in a team-taught course on "Satellite Remote Sensing in Biological Oceanography" hosted by the Shoals Marine Laboratory of Cornell University. The course offers advanced undergraduate and beginning graduate students an opportunity to gain hands-on experience with satellite remote sensing techniques that are applicable to research in biological oceanography.

Recruitment for Graduate Scientist Positions. Carmella Watkins recruited at the 69th North Atlantic Regional Conference, Alpha Kappa Alpha Sorority, Inc. for the NOAA Graduate Scientist positions. Excellent contacts were made in the fields of engineering and science. This was an opportunity to publicize the vacancies to an organization with a college student constituency.

Maryland State Teachers. Lee Dantzler was a speaker in the first offering of a continuing education course on remote sensing given by the Johns Hopkins University. The course is one of several now available to help satisfy teacher continuing education certification in Maryland and is the first on remote sensing.

University of Maryland Eastern Shore. ORA held discussions with staff of the University of Maryland Eastern Shore, Princess Anne, MD. They have an environmental science program for undergraduate students which is almost 20 years old. They also have the only graduate program at a HBCU. They are interested in developing cooperative relationships with the Federal sector.

Senior Job Fair 2000. Carmella Watkins participated in the Senior Job Fair 2000 for seniors, juniors, graduate students and alumni of Bowie State University. All participants were pointed to the NOAA web site for actual vacancies. However, the announcement of the Office of Research and Applications (ORA) system administrator was distributed to some of the computer science majors after the career fair. The school will host an education fair in the fall and ORA will be invited to that as well.

Hurricanes and Severe Weather. John Knaff and John Weaver prepared and delivered presentations discussing Hurricanes and Severe Weather, respectively, for Colorado State University's Kids in College program.

Grades Pre-K through High School

ORAD Concludes First Year in Science-Mentoring Program for High School Girls. The Oceanic Research and Applications Division has concluded its first year in a science-mentoring program for high school girls in conjunction with the American Association of University Women (AAUW). Starting in September 1999, three students from West Potomac High School in Alexandria, Virginia, participated in this year's activities.

Job Shadow Day 2000. The Climate Research and Applications Division hosted 17 students from Maurice McDonough High School in Pomfret, MD, for the Job Shadow Day 2000. This is a national program sponsored by America's Promise, School to Work Opportunities, Junior Achievement and the American Society of Association Executives. The students toured the NOAA Science Center and worked one on one with scientists, support staff and administrators. This was a rewarding experience for both the employees and the students.

Job Shadow Visitor. Nathan Hale, a junior at University High School in Greeley, Colorado, spent a day "job shadowing" Don Hillger of the Regional and Mesoscale Meteorology Team. During the visit Nathan observed the production of several satellite products (such as the fire and volcano products) that are currently being generated at CIRA and made available on the Web. Nathan was also able to view the work of other team members and participate in the daily weather discussion during a snowstorm event in Fort Collins.

Prince George's Science Fair. Celso Barrientos participated as a judge in the Prince George's County High Schools Science Fair held at the Prince George's County Community College. There were over 400 projects in this the Second Round of competitions. Dr. Barrientos served as judge in the Senior Division in Environmental Science Group.

Science Fair Tour. John Weaver served as a site guide for Science Fair participants touring the Colorado State University Campus at the CIRA/Atmospheric Science location. For each small group, he gave a short presentation and answered questions concerning weather satellites, severe weather and careers in meteorology.

Career Fair. Carmella Watkins attended the Career Fair at Benning Elementary School in Southeast Washington, DC. She represented the field of meteorology to over 300 students. The students were interested, kept a lively discussion and inquired about the meteorological instruments displayed.

Career Day at Mattaponi Elementary School. Carmella Watkins participated in the Career Day at Mattaponi Elementary School, Upper Marlboro, MD. She visited with 6 classes of 2nd and 3rd graders. They were interested in the skills that they were learning in the classroom that transfer to real jobs.

Student Creativity Competition Volunteers Honored. Larry Flynn was recognized for his contributions to the Destination Imagination Program of creativity competition at Glenarden Woods Elementary School (GWES) on May 15th. Six of the seven GWES teams advanced to the Maryland state competition, where they competed to attain two second, one third, one fifth, one eighth, and one eleventh place finishes.

Science Fair. Bruce Ramsay participated as a judge in the Piney Branch Elementary School Science Fair, Takoma Park, Maryland. The science fair projects by students in the 3rd, 4th, and 5th grades were excellent, and the students demonstrated that they were highly interested in their respective fields of endeavor.

Community Outreach. Ralph Ferraro spoke with approximately 60 kindergarten students at Ilchester Elementary School (Ellicott City, MD) about how weather satellites work, what they can see, and what we can learn from them.

School Visitation and Presentation. Rod Scofield visited Good Shepherd Pre-School and Kindergarten and gave a talk on "Snowstorms, Lightning, and Tornadoes". Puppets and slides were used to tell the children stories about how different types of clouds produce snow, lightning and tornadoes. In the process of story telling, safety rules were given on avoiding injury from lightning, floods, and tornadoes. The presentation also stressed the importance of dialing 911 for emergencies and asking for the appropriate support group (fire department, rescue squad, police).

Pre-School Visit. Eleven pre-school children from the University Avenue Day Care visited the Advanced Satellite Product Team to learn more about how NOAA uses the U.S. environmental satellites to monitor the Earth-atmosphere system. The tour included overviews of loops of real-time multi-spectral GOES-11 satellite images and a view of the satellite dishes on the roof of the Space Science and Engineering Center (ORA Wisconsin). It was suggested that the kids go home and explain all that they learned about infrared radiation.

APPENDIX 1. LIST OF AWARDS AND RECOGNITION

Department/Agency Awards

Department of Commerce **Gold Medal**—The Department's highest honorary award given annually in recognition of employees and units that have made extraordinary achievements that support the Department's mission and have a significant benefit to the nation or the world.

2000—**Dennis Clark:** For scientific and engineering achievements in the field of ocean color remote sensing.

1999—**Roderick Scofield:** For research and leadership in the use of satellite data to obtain estimates of heavy precipitation that are used in NOAA's critical flash flood forecasting program.

1998—**Michael Weinreb:** For engineering performance in the recovery of the GOES-10 spacecraft to full capability following its solar array failure.

1997—**Robert Cheney, John Kuhn, John Lillibridge, Laurence Miller, Chang Tai:** For improving long-range El Niño forecasts by creating and implementing the NOAA satellite altimeter operational assimilation system.

Department of Commerce **Silver Medal**—The Department's second highest award, recognizes extraordinary achievements in support of the Department's mission.

2000—**Timothy Schmit, Jaime Daniels:** For leadership contributions in research and development of geostationary satellite sounder and winds products and their operational implementation and utilization.

1999—**Mike Chalfant, Ralph Ferraro, Mitchell Goldberg, Norman Grody, Thomas Kleespies, Larry McMillin, Tsan Mo, Anthony Reale, David Wark:** For accelerating the use of new Advanced Microwave Sounding Unit (AMSU) satellite observations in weather prediction.

1999—**Alan Strong:** For contributions in the field of ocean remote sensing and improved understanding of the world's oceans and their fragile ecosystem.

Department of Commerce **Bronze Medal**—The Highest award given by NOAA to recognize significant contributions to the DOC or NOAA missions.

2000—**Eric Stengel, Philip Hovey, Edwin Fisher, Edward King, Kathleen LeFevre, Marilyn Yuen**: Development and deployment of the Marine Optical Buoy System.

2000—**J. Dan Tarpley**: For improving forecasts of maximum and minimum temperatures through innovative use of weather satellite observations.

1999—**David McAdoo, Karen Marks:** For advancements in geophysics and tectonics of the Southern Oceans and Antarctic region using satellite altimeter data.

1999—**Felix Kogan, Elaine Prins, Debra Molenar:** For extraordinary development of unique and specialized remote sensing products that were used to protect the Amazonian rainforest from wildfires.

1999—**Robert Aune, Jaime Daniels, Gary Ellrod, Donald Hillger, W. Paul Menzel, Debra Molenar, Roger Phillips, Timothy Schmit, Roderick Scofield, Gary Wade, John Weaver, Raymond Zehr:** For the development and implementation of Distance Learning Technology to enhance the expertise of NWS forecasters.

1999—**Paul Chang:** For outstanding and innovative contributions in experimental satellite ocean surface wind products development.

1999—**Paul Pellegrino:** For outstanding and extraordinary contributions to quality assurance of meteorological satellite data and products.

1999—**John Weaver:** For outstanding public service in the application of forecast products to emergency preparedness and response.

1999—**William Pichel, Pablo Clemente-Colon:** For superior contributions in the field of ocean remote sensing and pathfinding applications of spaceborne synthetic aperture radar systems.

1999—**Alan Strong:** For leadership, scientific, and administrative/technical support towards the implementation of Department and Administration priorities and objectives related to the U.S. Coral Reef Initiative, the U.S. Coral Reef Task Force, and the President's Executive Order for Production of Coral Reefs.

1998—**Larry Stowe, Nagaraja Rao, Herbert Jacobowitz, Paul Pellegrino, Mitchell Goldberg, David Crosby**: For generation of unique atmospheric data from 17 years of archived satellite observations that will increase understanding of global climate changes.

1998—**Thomas Kleespies, Larry McMillin, Lawrence Crone**: For pioneering development of optimal assimilation of satellite data into global forecast models and of fast, accurate radiative transfer.

1998—**Anne Ball:** For significant contributions toward the development of the NOAAServer System.

1997—**Felix Kogan:** For development, validation, and demonstration of a method to monitor large-scale drought from operational weather satellite data.

1997—**William Pichel:** For RADARSAT negotiations, development, and implementation of an operational system to acquire, process, and distribute Synthetic Aperture Radar data.

1997—**Felix Kogan:** For development, validation, and demonstration of a method to monitor large-scale drought from operational weather satellite data.

1997—**William Pichel:** For RADARSAT negotiations, development, and implementation of an operational system to acquire, process, and distribute Synthetic Aperture Radar data.

1996—**Garik Gutman:** For developing an original technique using satellite data for reliable analyses on the Earth's vegetation cover and its long term variations.

1996—**James Purdom, Debra Molenar:** For developing and supporting the RAMM Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS).

1995—**Norman Grody, Ralph Ferraro, David Forsyth:** For development and production of the first global precipitation climatology from satellite microwave radiometer data.

1995—**C.R. Nagaraja Rao, Tsan Mo, Jerry Sullivan, Charles Walton:** For improving the calibration of NOAA's satellite instruments leading to greater data accuracy.

NOAA Administrator's Award: Honors individuals and groups that have made significant contributions to NOAA's mission.

1998—**Bruce Ramsay**: For significant contributions to the creation and implementation of the Operational Significant Events Imagery service.

1998—**Elaine Prins**: For development of the first automated technique for detection of fires using geostationary satellite data which has proven to be a valuable tool in the detection and monitoring of fire outbreaks in the Western Hemisphere.

1998—**Robert Carey:** For significant contribution to the National Year of the Ocean Conference.

NESDIS Trainer of the Year: For outstanding effort and commitment to the ORA Training Program.

1999—**Mike Hodges**

1997—**Paul Menzel**

Other Awards/Recognition

2000—**Fuzhong Weng:** First David Johnson Award from the National Space Club of U.S.

2000—**Rod Scofield:** University of Louisville Alumni Fellow for the College of Arts and Sciences

1999—**Rod Scofield:** Francis W. Reichelderfer Award of the AMS

1998—**Dennis Clark:** Honorary Professorship—Institute of Ocean Technology, State Oceanographic Administration, People's Republic of China

1997—**James Purdom** and **Paul Menzel:** Special Award—American Meteorological Society Award for extraordinary leadership efforts in introducing information from the new GOES series to weather forecasters throughout the Western Hemisphere.

1996—**James Purdom:** Special Award—National Weather Association

1996—**Debra Molenar:** Special Award—NWS Special Service Award in recognition for contributions made to the Olympic Weather Support Project.

APPENDIX 2. POSTDOCTORAL FELLOWSHIPS AND VISITING SCIENTISTS

Formal Post-Docs and Visiting Scientists—Year 2000

ORA Participates in postdoctoral/visiting scientist fellowship programs administered by the Cooperative Institute for Research in the Atmosphere (CIRA), the University Corporation of Atmospheric Research (UCAR), and the National Research Council (NRC).

Jimmy Adegoke, CIRA

Laurence Connor, UCAR

Ivan Csiszar, CIRA

Alexander Ignatov, CIRA

Kenneth Knapp, CIRA

Nicholas Nalli, CIRA

Youri Plokhenko, UCAR

M.K. Rama Varma Raja, CIRA

Peter Romanov, CIRA

Marguerite Toscano, NRC

Tom Zhao, CIRA

Other Visiting Scientists—Year 2000

Rosario Alfaro, Costa Rica, 2000

James Carswell, University of Massachusetts (summer sabbaticals, 1997–2000)

Amy Doherty, University of Greenwich, United Kingdom, 2000–2001

Byong Jun Hwang, Korean Meteorological Association, Korea, 2000

Seiichiro Kigawa, Japanese Meteorological Agency, 2000

Jeff McCollum, CICS, 1997–Present

Jill Meyer, Sea Grant Fellow, 2000

Keniche Uneo, Japan Meteorological Agency, 2000

Guillame Ramillien, French Space Agency, 1999–2000

Ani Tikku, Scripps Institution of Oceanography, 1998–2000

Zhongdong Yang, State Meteorological Administration, People's Republic of China, 2000–2001

Ming Zhang, University of Western Sydney, Australia, 1999–2000

Xiaoxiang Zhu, State Meteorological Administration, People's Republic of China, 1999–2000

Former Post-Docs and Visiting Scientists—1995–1999

Ken Holmlund, EUMETSAT, 1999

Peter Wang, Central Weather Bureau, Taiwan, 1999

Saskia Esselborn, University of Hamburg, Germany, 1998–1999

Judit Kerenyi, Hungarian Meteorological Service, 1998 and 1999

Guiseppina Melchiorre, University of Greenwich, United Kingdom, 1998

Connie Spinoso, Monash University, Australia, 1998–1999

Dongjaio Wei, NRC Post-Doc, 1998–1999

Zhang Wenjian, National Satellite Meteorology Center, People's Republic of China, 1998–1999

Jun Yang, People's Republic of China, 1998

Licheng Zhao, People's Republic of China, 1998–1999

Chandra Kondragunta, Post-Doc, 1997–1999

Olavi Karner, Tartu Observatory, Estonia, 1997

Guo Wei, State Meteorological Administration, People's Republic of China, 1997–1998

Melanie Wetzel, UCAR Visiting Scientist, 1997

William Liu, Universidade Catolica Dom Bosco, Brazil, 1996

Robert Seilers, University of Rio Cuarto-Cba, Argentina, 1996–1999 (4 months)

Femke Vossepoel, Delft University, Netherlands, 1996–1997

Weihe Wang, State Meteorological Administration, People's Republic of China, 1996–1997

Feng Xian Zhou, Institute for Atmospheric Physics, Beijing, China, 1996

Pu Bu Ciren, State Meteorological Administration, People's Republic of China, 1995

Simon Rosenfeld, UCAR Visiting Scientist, 1995–1997

Gilberto Vicente, UCAR Visiting Scientist, 1995–1999

Fuhzong Weng, UCAR Visiting Scientist, 1995–1999

APPENDIX 3. SHORT TERM VISITORS—FISCAL YEAR 2000

Peter Schluessal, EUMETSAT—January 31, 2000

Kumon Tokumaru, NISSHO Aerospace Corporation—October 26, 1999

Hiroki Sakurai, Nagoya Aerospace System, Mitsubishi Heavy Industries, Ltd.—October 26, 1999

Yoshiro Miki, Research and Development Bureau, Science and Technology Agency—October 28, 1999

Alberto Marzorati, Marketing and Business Development, CESI—July 17–18, 2000

Sherry Ross, Maryland Educator's Summer Research Program Coordinator—July 26, 2000

Robert Hudson, Department of Meteorology, University of Maryland—May 10, 2000

Seymour Laxon, University College, London—March 29, 2000

V. Leis and E. Rodriquez, Argentine Meteorological Service—March 13–14, 2000

Visitors from the Institute of Remote Sensing in Beijing—May 4, 2000

Da-lin Zhang, Department of Meteorology, Univ. of Maryland—May 23, 2000

Bill Rose, Michigan Technological University—April 13, 2000

Jose Pereira, Instituto Brasileiro Meio Ambiente Reursos Naturais Renovaveis—February 7, 2000

Vilma Catro, RMTC, Costa Rica—November 8–12, 1999

Chad Johnson, UW Space Science and Engineering Center—November 8–10, 1999

Jeff Hawkins, Naval Research Laboratory—October 29, 1999

Eric Barrett, University of Bristol, England—August 18, 2000

Beth Ebert, BMRC, Melbourne, Australia—August 18, 2000

Elen Cutrim, Western Michigan University—May 18, 2000

James Doyle, Naval Research Laboratory—July 13, 2000

Franco Einaudi, NASA GSFC—December 17, 1999

John Le Marshall, Australia Bureau of Meteorology—April 13, 2000

Jan Lewis, Aviation Weather Center—August 2000

Ash Mahesh, Cooperative Institute for Research in Environmental Sciences, Univ. of Colorado—July 13–14, 2000

Kevin Maschhoff, Lockheed Martin IR Imaging Systems—February 8, 2000

Leonard McMaster, NASA-Langley Research Center—December 17, 1999

Alberto Setzer, Instituto Nacional de Pesquisas Espaciais, Brazil—October 11–13, 1999

J. David Roessner, Georgia Institute of Technology, SRI International—June 29, 2000

ORA Distinguished Scientist Lecture Series

Dr. Richard Goody, Professor Emeritus, Harvard University, "Observing the Climate: Data to Test Climate,"—May 24, 2000

Professor Thomas Vonder Haar, Director, Cooperative Institute for Research in the Atmosphere, Colorado State University, "Water Vapor in the Climate System,"—April 15, 1999

Professor Graeme Stephens, Colorado State University, "Toward a Space Based Climate Observing System,"—December 14, 1998

Dr. Donald Johnson, Professor Emeritus, University of Wisconsin-Madison, "Challenges in Remote Sensing and Modeling of Hydrologic Processes in Weather Prediction and Climate,"—August 13, 1998

APPENDIX 4. ORA SEMINARS

Water-cycle Process Studies over the Tibetan Plateau—Dr. Ken'ichi Ueno, School of Environmental Science, The University of Shiga Prefecture, Japan, November 29, 1999.

Estimating Precipitation from Satellite Imagery Using Neural Network Methods—Dr. Hoshin V. Gupta, University of Arizona, December 2, 1999.

The Tropical Rainfall Measuring Mission (TRMM)—what have we learned and what does the future hold?—Dr. Christian Kummerow, Goddard Space Flight Center, National Aeronautics and Space Administration, December 16, 1999.

Development of Microwave Land Emissivity Data Sets and Models for Satellite Data Assimilation—Dr. Fuzhong Weng, Atmospheric Research and Applications Division, Office of Research and Applications, NESDIS, January 6, 2000.

Using GOME Data to Estimate Ozone Content with the SBUV/2 Retrieval Algorithm—Y. Pachepsky, L. Flynn & J. Gleason, Climate Research and Applications Division, Office of Research and Applications, NESDIS, January 20, 2000.

IASI and Its Use for Temperature and Moisture Soundings—Dr. Peter Schluessel, IASI/ATOVS Mission Scientist at EUMETSAT, February 2, 2000.

Sensor Spatial and Radiometric Tradeoffs—Dr. Carl F. Schueler, Director, Advanced Concepts, Raytheon Santa Barbara Remote Sensing, Goleta, California, February 25, 2000.

SSM/I-Derived Global Rainfall Statistics—Qihang Li, Caelum Research Corporation, March 2, 2000.

The Use of High Resolution Satellite Data in Weather Analysis and Forecasting—Dr. John F. Le Marshall, Principal Research Scientist, Bureau of Meteorology Melbourne, Australia, April 6, 2000.

Derivation of Long-Wave Net Radiation Flux Over Oceans from Special Sensor Microwave/Imagery—Dr. Quanhua Liu, Raytheon Corporation, Lanham, Maryland, April 20, 2000.

A Multi-sensor Microwave Land Precipitation Algorithm—Dr. Jeff McCollum, Cooperative Institute for Climate Studies (CICS), University of Maryland, College Park, Maryland, May 4, 2000.

GIFTS I—***[Geostationary Imaging Fourier Transform Spectrometer (GIFTS)]*: A System for Temperature, Moisture, Wind, and Trace Gas Profiling from Geostationary Satellites**—Dr. William Smith, NASA Langley, Langley, Virginia, May 5, 2000.

Satellite Products for the Polar Regions: Current Capabilities and Future Potential—Dr. Jeffrey R. Key, Atmospheric Research and Applications Division, Office of Research and Applications, NESDIS, Madison, Wisconsin, May 18, 2000.

Climate Change in the 21st Century: An Alternate Scenario—Dr. James Hansen, Director, Goddard Institute for Space Studies, NASA, New York, New York, May 26, 2000.

Observed Carbon Dioxide Variations in the Lower Atmosphere—Dr. Pieter Tans, Climate Monitoring and Diagnostic Laboratory, Office of Oceanic and Atmospheric Research, NOAA, Boulder, CO, June 2, 2000.

GIFTS II—A System for Temperature, Moisture, Wind, And Trace Gas Profiling from Geostationary Satellites—Dr. Gail Bingham, University of Utah, Salt Lake City, Utah , June 5, 2000.

A New Technique for Remote Sensing Vegetation Fraction—Dr. Anatoly Gitelson, Professor, School of Natural Sciences, University of Nebraska, Lincoln, Nebraska, June 7, 2000.

Touring Australia by Satellite and The 1998 Coral Bleaching Story on the Great Barrier Reef—Dr. William Skirving , Australian Institute of Marine Science, June 7, 2000.

A Multi-sensor Approach to the Retrieval and Model Validation of Global Cloudiness—Dr. Steven D. Miller, Colorado State University, Fort Collins, Colorado, June 8, 2000.

Artificial Neural Network Techniques For Estimating Heavy Rainfall From Satellite Data—Ming Zhang and Roderick A. Scofield, Atmospheric Research and Applications Division, Office of Research and Applications, NESDIS, June 28, 2000.

Satellite Passive Microwave Precipitation Estimation: Relations Evaluated from TRMM Multi-Sensor Precipitation Profile Retrievals—Dr. Emmanouil N. Anagnostou, Civil and Environmental Engineering, University of Connecticut, Storrs, Connecticut, August 3, 2000.

APPENDIX 5. 2000 ORGANIZATION OF SCIENTIFIC MEETINGS

Ralph Ferraro

Chair of the AMS Tenth Conference on Satellite Meteorology and Oceanography, Long Beach, California

George Ohring (Convener)

International Symposium on Forty Years of Weather Satellites: Where are we and Where are we Going?, A Joint COSPAR/International Radiation Commission Event at COSPAR 2000, Warsaw, and International Radiation Symposium 2000, St. Petersburg, Russia

Paul Menzel

Annual CIMSS Workshop on Atmospheric, Earth, and Space Science, Madison, Wisconsin

NWS and NESDIS Moisture Workshop, Madison, Wisconsin

Workshop on Conceptual Models for Cirrus Clouds, Madison, Wisconsin

Nagaraja Rao

Convener of session on Meteorological Satellite Sensor Calibration, Spring Meeting of the American Geophysical Union, Washington, DC

Deputy Organizer, Symposium on Satellite Sensor Calibration, 33rd COSPAR Scientific Assembly, Warsaw, Poland

Member of organizing committee, 2000 Conference on Characterization and Radiometer Calibration for Remote Sensing, Utah State University, Logan, Utah

Alan Strong

International Workshop on the Use of Remote Sensing in Monitoring Coral Reef Bleaching, Honolulu, Hawaii

James Yoe

GPS Radio Occultation Workshop, Camp Springs, Maryland

APPENDIX 6. 2000 PARTICIPATION IN SCIENTIFIC MEETINGS

ORA scientists are frequently requested to provide keynote presentations at major scientific meetings in order to frame the agenda.

Invited Papers

National Weather Association, Biloxi, Mississippi, Oct. 1999

AMS Satellite Conference, Long Beach, California, Jan. 2000

National Aeronautics and Space Administration's Weather Accident Prevention Project Review, Hampton, Virginia, May 23–25, 2000

Conference on Oceans and Sea Ice, Lannion, France, Dec. 1999

AMS Aviation Conference, Orlando, Florida, Sept. 2000

GOES R+ Workshop, Boulder, Colorado, Sept. 2000

Aviation Weather Forum, July 2000

Pacific Jet Experiment (PACJET) planning meeting

International TOVS Study Conference, Budapest, Hungary, Sept. 2000

Fifth International Winds Workshop Lorne, Australia, Status and Development of Operational GOES Wind Products

10th Conference on Satellite Meteorology and Oceanography, Long Beach, California, Recent Advances to the Operational GOES Wind Processing System at NOAA/NESDIS

24th Annual Meeting of the National Weather Association, Biloxi, Mississippi, Recent Advances to the Operational GOES Wind Processing System at NOAA/NESDIS

COSPAR 2000, Warsaw, Poland

Others

International ATOVS Study Conference—8 presentations

Ocean Observations '99, St. Raphael, France—3 presentations

Quadrennial Ozone Symposium—1 presentation

SPIE 45th Annual Symposium on Optical Science and Technology—4 presentations

33rd COSPAR Scientific Assembly—5 presentations

International Radiation Symposium—5 presentations

ECMWF Workshop entitled "The Use of ATOVS Data for NWP Assimilation"—1 presentation

AMS Tenth Conference on Satellite Meteorology —8 presentations

Conference on Characterization and Radiometric Calibration for Remote Sensing—2 presentations

IGARSS 2000—3 presentations

10th Conference on Satellite Meteorology and Oceanography—17 presentations

Fall American Geophysical Union Meeting—1 presentation

American Geophysical Union Spring Meeting—27 presentations

24th Meeting of the National Weather Association—3 presentations

NASA's Weather Accident—1 presentation

5th European Conference on Underwater Acoustics—1 presentation

Prevention Project Review—1 presentation

AMS Aviation Conference—1 presentation

GOEs R+ Workshop—1 presentation

Aviation Weather Forum—presentation

Pacific Jet Experiment Planning Meeting—1 presentation

Fifth International Winds Workshop—1 presentation

PICASSO-CERN Science Team Meeting—1 presentation

International Glaciological Society Meeting—1 presentation

Workshop on Conceptual Models for Cirrus Clouds—1 presentation

NWS and NESDIS Workshop on Improving Observation and Analysis of Atmospheric Moisture for Operational Weather Forecasting—4 presentations

USFS/IBAMA Fire and Environmental Change Working Group Meeting—1 presentation

Program to Address ASEAN Regional Transboundary Smoke (PARTS) Coordination Meeting—1 presentation

NWS GOES Assessment Meeting—1 presentation

North American Observing System Council Meeting—1 presentation

National Symposium on the Great Plains Tornado Outbreak of May 3, 1999—1 presentation

20th Conference on Severe Local Storms—3 presentations

APPENDIX 7. REFEREED PUBLICATIONS

Office of Research and Applications Journal Articles—2000

Baum, .B., P.F. Soulen, K.I. Strabala, M.D. King, S.A. Ackerman, W.P. Menzel, and P. Yang, Remote sensing of cloud properties using MODIS airborne simulator imagery during SUCCESS. *Journal of Geophysical Research*, 105 (D9), 11781–11792.

Bayler, G.M. R.M. Aune, and W.H. Raymond, NWP cloud initialization using GOES sounder data and improved modeling of non-precipitating clouds. Accepted, *Monthly Weather Review.*

Chung, S., S. Ackerman, P.F. van Delst, and W. P. Menzel, Model calculations and interferometer measurements of ice cloud characteristics. *Journal of Applied Meteorology*, 39, 634–644.

Clemente-Colon, P., and X.-H. Yan, Low backscatter features in SAR imagery. *Johns Hopkins University/APL Technical Digest*, 21 (1), 116–121.

Connor, L.N., and P.S. Chang, Ocean surface wind retrievals usingthe TRIMM microwave imager. *IEEE Transactions on Geoscience and Remote Sensing*, 38 (4), July 2000.

Cunnold, D.M., M.J. Newchurch, L.E. Flynn, H.J. Wang, J.M. Russell, R. McPeters, J.M. Zawodny, and L. Froidevaux, Uncertainties in upper-stratospheric ozone trends. *Journal of Geophysical Research*, 105 (D4), 4427–4444.

Dostalek, J.F., and T.J. Schmit, GOES sounder derived product imagery: Comparisons to radiosondes and use in forecasting severe convection. Accepted, *Weather and Forecasting.*

Ellrod, G.P., Satellite images provide valuable information supplement to the aviation meteorologist. *International Civil Aviation Organization Journal*, 55 (2), 6–10.

Ellrod, G.P., J.P. Nelson III, M.R. Witiw, L. Bottos, and W.P. Roeder, Experimental GOES Sounder products for the assessment of downburst potential. Accepted, *Weather and Forecasting.*

Ferraro, R.R., M. Colton, G. Deblonde, G. Jedlovec, and T. Lee, Meeting report on the 10th Conference on Satellite Meteorology and Oceanography. Accepted *Bulletin of the American Meteorological Society.*

Ferraro, R.R., F. Weng, N.C. Grody, and L. Zhao, Precipitation characteristics over land from the NOAA-15 AMSU sensor. Accepted *Geophysical Research Letters.*

Goreau, T., T. McClanahan, R. Hayes and A. Strong, Conservation of Coral Reefs after the 1998 global bleaching event. *Issues in International Conservation*, 14 (1), 5–15.

Goreau, T., T. McClanahan, R. Hayes and A. Strong, Conservation of Coral Reefs after the 1998 global bleaching event. *Issues in International Conservation*, 14 (1), 5–15.

Goreau, T., R.L. Hayes, A.E. Strong, M. Goreau, M. Hayes, E. Williams, G. Smith, and J. Cervino, Global coral reef bleaching and sea surface temperature trends from satellite-derived hotspot analysis. *Conservation Biology*, 14 (1), 5–15.

Grody, N., F. Weng and R. Ferraro, Application of AMSU for obtaining hydrological parameters. *Microwave Radiometry Remote Sensing of the Earth's Surface and Atmosphere*, 339–351.

Gruber, A., X. Su, M. Kanimitsu, J. Schemm, The comparison of two merged raingauge-satellite precipitation data sets. In press, *Bulletin of the American Meteorology Society.*

Gutman, G., I. Csciszar, and P. Romanov, Using NOAA/AVHRR products to monitor El Nino impacts: Focus on Indonesia in 1997-98. *Bulletin of the American Meteorological Society*, 81 (6), 1189–1205.

Heidinger, A.K., and G.L. Stephens, Molecular line absorption in a scattering atmosphere. Part II: Application to remote sensing in the O2 A band. *Journal of the Atmospheric Sciences*, 1615–1634.

Ignatov, A., and L.L. Stowe, Physical basis, premises, and self-consistency checks of aerosol retrievals from TRMM/VIRS. Accepted, *Journal Applied Meteorology.*

Key, J. and J. Intieri, Cloud particles phase determination with Advanced High Resolution Radiometer (AVHRR). Accepted, *Journal of Applied Meteorology.*

Kidder, S.Q., M. Golberg, R.M. Zehr, M. DeMaria, J. Purdom S.S. Velden, N. Grody and S. Kusselson, Satellite analysis of tropical cyclones using AMSU. *Bulletin of the American Meteorological Society,* 81, 1241–1259.

Kogan, F.N. and G. Wei, Using AVHRR data for detection of El Nino/La Nina impacts on land ecosystems. *Advances in Space Research*, 26 (7), 1165–1168.

Li, J., W.P. Menzel and A.J. Schreiner, Variationl retrieval of cloud parameters from GOES sounder longwave cloudy radiance measurements. Accepted, *Journal of Applied Meteorology.*

Li, J., C.C. Schmidt, J.P. Nelson III, T.J. Schmit, and W.P. Menzel, Estimation of total atmospheric ozone from GOES sounder radiances with high temporal resolution. Accepted, *Journal of Atmospheric and Oceanic Technology.*

Li, Q., R. Ferraro and N. Grody, Adequacy of using a 1/3-degree special sensor microwave imager dataset to estimate climate-scale rainfall. *Journal of Applied Meteorology*, 39, 680–685.

Li, X., P. Clemente-Colon, W. Pichel, P. Vachon. Atmospheric vortex streets on a RADARSAT SAR image. *Geophysical Research Letters*, 27 (11), 1655–1658.

Li, X., P. Clemente-Colon, Estimating mixed layer depth from SAR internal wave evolution. *Johns Hopkins University/APL Technical Digest*, 21 (1), 130–135.

Li, X., W. Pichel, P. Clemente-Colon, V. Krasnopolsky, and J. Sapper, Validation of coastal sea and lake surface temperature measurements derived from NOAA/AVHRR data. In press, *International Journal of Remote Sensing.*

Maslanik, J., J. Key, C. Fowler, T. Nugyen and X. Wang, Spatial and temporal variability of surface and cloud products from satellite data during FIE-ACE (First Internatinoal Satellite Cloud Climatology Project) (ISCCP Regional Experiment—Arctic Cloud Experiment (ACE)). Accepted, *Journal Geophysical Research.*

McCollum, J.R., A. Gruber and M.B. Ba, Discrepancy between gauges and satellite estimates of rainfall in Equatorial Africa. *Journal of Applied Meteorology*, 39, 666–679.

Molenar, D.A., K.J. Schrab and J.F.W. Purdom, RAMSDIS contributions to NOAA satellite data utilization. *Bulletin of the American Meteorological Society*, 81 (5), 1019–1030.

Newchurch, M.J., L. Bishop, D. Cunnold, L.E. Flynn, S. Godin, S. Frith, L. Hood, AJ. Miller, S. Oltmans, W. Randel, G. Reinsel, R. Stolarski, R. Wang, E. Yang, and J.M. Zawodny, Upper-stratospheric ozone trends 1979–1998. *Journal of Geophysical Research*, 105 (D11), 14,625–14,636.

Norman, J.M., W.P. Kustas, J.H. Prueger and G.R Diak, Surface flux estimation using radiometric temperature: A double-difference method to minimize measurement errors. In press, *Water Resources Research.*

Partain, P.T., A.K. Heidinger, and G.L. Stephens, High spectral resolution atmospheric radiative transfer: Application of the equivalence theorem. *Journal of Geophysical Research*, 105 (D2), 2163–2177.

Pichel, W., P. Clement-Colon, NOAA CoastWatch SAR applications and demonstration: Status and plans. *Johns Hopkins University/APL Technical Digest*, 21 (1), 49–57.

Plokhenko, Y., and W.P. Menzel, The effects of surface reflection on estimating the vertical temperature-humidity distribution from spectral infrared measurements. *Journal of Applied Meteorology*, 39, 3–14.

Plokhenko, Y., and W.P. Menzel, Mathematical aspects for meteorological processing of infrared spectral measurements from the GOES sounder: Constructing the measurements estimate using spatial smoothing. Accepted, *Journal Applied Meteorology.*

Rosenfeld, S., and N. Grody, Anomalous microwave spectra of snow cover observed from special sensor microwave/imager measurements. *Journal of Geophysical Research*, 105 (D11), 14,913–14,925.

Schmit T.J., W.F. Feltz, W.P. Menzel, J. Jung, J.P. Nelson III, G.S. Wade, Validation and use of GOES sounder moisture information. Accepted, *Bulletin of the American Meteorological Society.*

Schreiner, A.J., T.J. Schmit, and W.P. Menzel, Observations and tends of clouds based on GOES sounder data. Accepted, *Journal Geophysical Letters.*

Sikora, T., K.S. Friedman, W.G. Pichel, and P. Clemente-Colon, Synthetic aperture radar a a tool for investigating polar mesoscale cyclones. In press, *Weather and Forecasting.*

Smith, W., Gravity and the hydrosphere: New frontier. In press, *Hydrological Science Journal.*

Soden, B., S. Tjemkes, J. Schmetz, R. Saunders, J. Bates, B. Weng, F., and N.C. Grody, Retrieval of ice parameters using a microwave imaging radiometer. *Journal of the Atmospheric Sciences,* 57 (8), 1069–1081.

Stephens, G.L. and A. Heidinger, Molecular line absorption in a scattering atmosphere. Part1: Theory. *Journal of the Atmospheric Sciences*, 1599–1614.

Stephens, G.L. and A. Heidinger, Molecular line absorption in a scattering atmosphere. Part1: Theory. *Journal of the Atmospheric Sciences*, 1599–1614.

Stroeve, J., J. Box, C. Fowler, T. Haran, J. Maslanik, and J. Key, Intercomparison between in-situ and Advanced Very High Resolution (AVHRR) Polar Pathfinder derived surface albedo over Greenland. Accepted, *Remote Sensing of the Environment.*

Strong, A.E., E.J. Kearns, K.K. Gjovig, Sea surface temperature signals from satellites—An update. *Geophysical Research Letters*, 27 (11), 1667–1670.

Turner, D.D. W. F. Feltz and R.R. Ferraro, Continuous water vapor profiles from operation ground-based active and passive remote sensors. *Bulletin American Meteorological Society*, 81, 1301–1317.

Vemury, S., L.L. Stowe, V.R. Anne, AVHRR pixel level clear-sky classification using dynamic thresholds (CLAVR-3). Accepted, *Journal Atmosphere and Oceanic Technology.*

Vicente, G., C. Davenport and R. Scofield, The role of orographic and parallax correction on satellite rainfall estimation. Accepted, *International Journal of Remote Sensing.*

Weaver, J., E. Gruntfest, and G.M. Levy, The floods in Fort Collins, Co. Accepted, *Bulletin of the American Meteorological Society.*

Wellington, G.M., A.E. Strong and G. Merien, Sea surface temperature variation in the Galapagos Archipelago: A comparison between AVHRR nighttime satellite data and in-situ instrumentation (1982–1988). In press, *Bulletin of Marine Research.*

Weng, F., and N.C. Grody, Retrieval of ice cloud parameters using a microwave imaging radiometer. *Journal of the Atmospheric Sciences*, 1069–1081.

Zapotocny, T.H., S.J. Nieman, W.P. Menzel, J.P. Nelson III, J.A. Jung, E. Rogers, D. F. Parrish, G.J. DiMego, M. Baldwin, and T.J. Schmit, A case study of sensitivity of the Eta Data Assimilation System. Accepted, *Weather and Forecasting*.

Office of Research and Applications Journal Articles—1999

Achutuni, R., and P. Menzel, Space systems considerations in the design of advanced geostationary operational environmental satellites. *Advances in Space Research*, 23 (8), 1377–1384.

Arrigo, K.R., D.H. Robinson, D.L. Worthen, R.B. Dunbar, G.R. Ditullio, M.L. Van Woert, and M.P. Lizotte, Influence of phytoplankton community structure on the draw down, of nutrients and CO2 in the Southern Ocean. *Science*, 283, 365–367.

Beal, R. and W. Pichel, High resolution coastal winds with SAR: the case for international cooperation. *Backscatter,* 10 (4), 25–28.

Bromwich, D.H., R,I. Cullather, and M.L. Van Woert, Antarctic precipitation and its contribution to the global sea level budget. *Annals of Glaciology*, 27.

Brown, C.W., and W.E. Esaias, NOAA and NASA propose new mission. *Backscatter*, Observing the Marine Environment, February 1999, 25.

Chang, P., W.J. Donnelly, J.R. Carswell, R.E. McIntosh, J. Wilkerson, F. Marks, and P.G. Black, Revised ocean backscatter models at C and Ku band under high-wind conditions, *Journal of Geophysical Research*, 104 (C5), 11485–11497.

Chang, P., R. Legeckis, T. Zhu, and S. Chen, Satellite animations reveal ocean dynamics for shortest timescales ever. *EOS Transactions*, American Geophysical Union, 80 (20), 229, 232–233.

Clemente-Colon, P., and X.-H. Yan, Observations of east coast upwelling conditions in synthetic aperture radar imagery, *IEEE Transactions on Geoscience and Remote Sensing*, 37 (5), 2239–2248.

Csiszar, I., and G. Gutman, Mapping global land surface albedo from NOAA AVHRR. *Journal of Geophysical Research*, 104 (D6), 6215–6228.

DeMaria, M., and J. Kaplan, An updated statistical hurricane intensity prediction scheme (SHIPS) for the Atlantic and Eastern North Pacific basins. *Weather and Forecasting*, 14, 326–337.

Donnelly, W.J., J.R. Carswell, R.E. McIntosh, P.S. Chang, J. Wilkerson, F. Marks, and P.G. Black, Revised ocean backscatter models at C. and Ku band under high-wind conditions. *Journal of Geophysical Research*, 104 (C5), 11,485–11,497.

Ellrod, G.P., The use of GOES sounder imagery for the detection of hazardous volcanic ash plumes. *National Weather Digest*, 22 (4), 3–9.

Ferraro, R., G. Vicente, M. Ba, A. Gruber, R. Scofield, Q. Li, and R. Weldon, Satellite techniques yield insight to devastating rainfall associated with Hurricane Mitch, *EOS, Transaction of the American Geophysical Union,* 80 (43), 505–514.

Ferraro, R.R., S.J. Kusselson, and M. Colton, An introduction to passive microwave remote sensing and its applications to meteorological applications to meteorological analysis and forecasting. *National Weather Digest*, 22 (3), 11–23.

Frey, R.A., B.A. Baum, W.P. Menzel, S.A. Ackerman, C.C. Moeller, and J.D. Spinhirne, A comparison of cloud top heights computed from airborne lidar and MAS radiance data using CO2 slicing. *Journal of Geophysical Research*, 104 (D20), 24547–24555.

Friedman, K.S., P. Clemente-Colon, W.G. Pichel, and X. Li, Routine monitoring of changes in the Columbia Glacier, Alaska, with synthetic aperture radar. *Remote Sensing of the Environment*, 70, 257–264.

Gallo, K.P., and T.W. Owen, Assessment of urban heat islands: A multi-sensor perspective for the Dallas-Ft. Worth, USA region. *Geocarto International,* 13 (4), 35–41.

Gallo, K.P., and T.W. Owen, Satellite-based adjustments for the urban heat island temperature bias. *Journal of Applied Meteorology*, 38, 806–813.

Gallo, K.P., T.W. Owen, D. Easterling, and P.F. Jamason, Temperature trends of the U.S. historical climatology network based on satellite-designated land use/land cover. *Journal of Climate*, 12, 1344–1348.

Goldberg, M.D., and L.M. McMillin, Methodology for deriving deep-layer mean temperatures from combined satellite infrared and microwave observations. *Journal of Climate*, 12, 5–20.

Gutman, G., On the use of long-term global data of land reflectances and vegetation indices derived from the advanced very high resolution radiometer. *Journal of Geophysical Research*, 104 (D6), 6241–6255.

Gutman, G., On the monitoring of land surface temperatures with the NOAA/AVHRR: removing the effect of satellite orbit drift. *International Journal of Remote Sensing*, 20 (17), 3407–3413.

Ignatov, A., and G. Gutman, Monthly mean diurnal cycles in surface temperatures over land for global climate studies. *Journal of Climate*, 12, 1900–1910.

Jacobowitz, H., AVHRR Pathfinder atmosphere (PATMOS) data sets available online from NOAA. *Bulletin of the American Meteorological Society Announcements*, 80 (5), 967–968.

Jacobowitz, H., L. Stowe and C. Crandall, Analysis of cloud radiative forcing derived from the AVHRR Pathfinder atmosphere (PATMOS) 16-year data set. *Advances in Space Research*, November 1999.
Jones, R.W., and M. DeMaria, Further studies of the optimization of a hurricane track prediction model using the adjoint equations. *Monthly Weather Review*, 127, 1586–1598.

Kaufman, Y.J., P.V. Hobbs, V.W.J.H. Kirchhoff, P. Artaxo, L. Remer, B.N. Holben, M.D. King, D.E. Ward, E.M. Prins, K.M. Logo, L.F. Mattos, C.A. Nobre, J.D. Spinhirne, Q. Ji, A.M. Thompson, J.F. Gleason S.A. Christopher, and S.C. Tsay. Smoke, clouds, and radiation—Brazil (SCAR-B) experiment. *Journal of Geophysical Research*, 103 (D24), 31,783–31,808.

Kaufman, Y.J., C.O. Justice, L.P. Flynn, J.D. Kendall, E.M. Prins, L. Giglio, D.E. Ward, W.P. Menzel, and A. Setzer, Potential global fire monitoring from EOS-MODIS. *Journal of Geophysical Research*, 103 (D24), 32,215–32,238.

Keiner, L.E., and C.W. Brown, Estimating oceanic chlorophyll concentrations with netural networks. *Journal of Remote Sensing*, 20 (1), 189–194.

Kiligowski, R.J., and A.P. Barros, High-resolution short-term quantitative precipitation forecasting in mountainous regions using a nested model. *Journal of Geophysical Research*, 194, 31,553–31,564.

Legeckis, R., P. Chang, T. Zhu and S. Chen, Satellite animations reveal ocean surface dynamics for shortest time scales ever. *EOS, Transactions*, American Geophysical Union, 80 (20), 229, 232–233.

Li, X., P. Clemente-Colon, W. Pichel, and P. Vachon, Atmospheric vortex streets on a RADARSAT SAR image. *Geophysical Research Letters*, 27(11), 1655– 1658.

Lillibridge, J., Real-Time ERS Altimetry at NOAA. *Earth System Monitor*, 9 (2).

Ma, X.L., T.J. Schmit and W.L. Smith, A nonlinear physical retrieval algorithm—Its application to the GOES-8/9 sounder. *Journal of Applied Meteorology*, 38 (5), 501–513.

Marks, K., Evolution of the Australian-Antarctic discordance since Miocene time, *Journal Geophysical Research,* 104, 4967–4981.

McPeters, R.D., d.J. Hofmann, M. Clark, L. Flynn, L. Froidevaux, M. Gross, B. Johsnon, G. Koenig, X. Liu, S. McDermid, T. McGee, F. Murcray, J.J. Tsou, T. Walsh, and J.M. Zawodny, Results from the 1995 stratospheric ozone profile intercomparison at Mauna Loa. *Journal of Geophysical Research*, 104 (D23), 30,505–30,514.

Miller, L., Use of sea level observations to estimate salinity variability in the equatorial Pacific. *Journal Atmosphere and Oceanic Technology*, 16, 1401–1415.

Mo, T., AMSU-A antenna pattern corrections. *IEEE Transactions on Geoscience and Remote Sensing*, 37 (1), 103–112.

Petersen, W.A., L.D. Carey, S.A. Rutledge, J.C. Knievel, N.J. Doesken, R.H. Johnson, T.. McKee, T. Vonder. Haar, and J.F. Weaver, Mesoscale and radar observation of the Fort Collins flash flood of 28 July 1997. *Bulletin of the American Meteorological Society*, 80 (2), 191–216.

Peterson, T.C., K.P. Gallo, J. Lawrimore, T.W. Owne, A. Huang and D.A. McKittrick, Global rural temperature trends. *Geophysical Research Letters*, 26, 329–332.

Prins, E.M., J.M. Feltz, W.P. Menzel, and D.E. Ward, An overview of GOES-8 diurnal fire and smoke results for SCAR-B an the 1995 fire season in South America. *Journal of Geophysical Research*, 103 (D24), 31,821–31,836.

Rao, C.R.N., and J. Chen, Revised post-launch calibration of the visible and near-infrared channels of the Advanced Very High Resolution Radiometer on the NOAA-14 spacecraft. International *Journal of Remote Sensing*, 20, 3485–3491.

Rao, C.R.N., J. Chen, J.T. Sullivan, and N. Zhang, Post-launch calibration of meteorological satellite sensors. *Advances in Space Research*, 23 (8), 1357–1365.

Reinsel, G.C., G.C. Tiao, A.J. Miller, R.M. Nagatani, D.J. Wuebbles, E.C. Weatherhead, W.-K. Cheang, L. Zhang, L.E. Flynn, and J.B. Kerr, Update of Umkehr ozone profile data trend analysis through 1997. *Journal of Geophysical Research*, 104 (D19), 23,8810–23,898.

Romanov P., Urban influence on cloud cover estimated from satellite data. *Atmospheric Environment*, 33, 4163–4172.

Romanov P., N.T. O'Neill, A. Royer, and B. McArthur, Simultaneous retrieval of aerosol refractive index and particle size distribution from ground-based measurements of direct and scattered solar radiation. *Applied Optics*, 38 (36).

Russell, P.B., P.V. Hobbs and L.L. Stowe, Aerosol properties and radiative effects in the United States East Coast haze plume: An overview of the tropospheric aerosol radiative Forcing Observation Experiment (TARFOX). *Journal of Geophysical Research*, 104 (D2), 2213–2222.

Schmetz, J., D. Hinsman and W.P. Menzel, Summary of the Fourth International Winds Workshop. *Bulletin of the American Meteorological Society*, 80 (5), 893899.

Schweiger, A.J., R. Lindsay, J. Key, and J. Francis, Arctic clouds in multiyear satellite data sets, *Geophysical Research Letters,* 24 (5), 443–451.

Scofield, R.A., and C. Margottini, Earth observation satellites for flood management and flash flood analysis and prediction. *Space Forum*, 4, 199–222.

Shultz, F.M., K. Stamnes and F. Weng, VDISORT: An improved and generalized discrete ordinate method for polarized radiative (vector) radiative transfer. *JQSRT*, 61, 105–122.

Slonaker, R.L., and M.L. Van Woert, Atmospheric moisture transport across the Southern Ocean via satellite observations. *Journal of Geophysical Research*, 104 (D8), 9229–9249.

Smith, W.L., W.F. Feltz, R.O. Knuteson, H.E. Revercomb, H.M. Woolf, and H.B. Howell, The retrieval of planetary boundary layer structure using ground-based infrared spectral radiance measurements. *Journal Atmosphere and. Oceanic Technology*, 16, 323–333.

Stowe, L.L., P.A. Davis and E.P. McClain, Scientific basis and initial evaluation of the CLAVR-1 global clear/cloud classification algorithm for the advanced very high resolution radiometer. *Journal of Atmospheric and Oceanic Technology*, 16, 656–681.

Strong, A.E., T.J. Goreau and R. Hayes, Ocean hotspots and coral reef bleaching: January–July 1998. *Reef Encounters*, 24, 20–22.

Sullivan, J., New radiance-based method for AVHRR thermal channel nonlinearity corrections. *International Journal of Remote Sensing*, 20 (18), 3493–3501.

Toscano, M.A., A.E. Strong and I.C. Guch, New analysis for ocean hotspots and coral reef bleaching. *Reef Encounters*, 26, 26–31.

Van Woert, M., Wintertime dynamics of the Terra Nova Bay polynya. *Journal of Geophysical Research*, 104 (C4), 7753–7769.

Weinreb, M.P., R.X. Johnson, J.G. Baucom, and J.C. Bremer, GOES-8/10 calibration experience. *Advances in Space Research*, 23 (8), 1367–1375.

Wetzel, M.A., and L.L. Stowe, Satellite-observed patterns in stratus microphysics, aerosol optical thickness, and shortwave radiative forcing. *Journal of Geophysical Research*, 104 (D24, 31,287–31,299.

Wilkinson, C., O. Linden, H. Cesar, G. Hodgson, J. Rubens and A.E. Strong, Ecological and socioeconomic impacts of 1998 coral mortality in the Indian Ocean: An ENSO impact and a warning of future change? *AMBIO*, 29 (2), 188–196.

Wu, X., W.P. Menzel and G.S. Wade, Estimation of sea surface temperatures using GOES-8/9 radiance measurements. *Bulletin of the American Meteorological Society*, 80 (6), 1127–1138.

Wylie, D.P., and W.P. Menzel, Eight years of global high cloud statistics using HIRS. *Journal of Climate*, 12, 170–184.

APPENDIX 8. 2000 NOAA TECHNICAL REPORTS AND OTHER PUBLICATIONS

Ahern, F., A. Belward, C. Elvidge, J. Goldammer, J.-M. Gregoire, C. Justice, J. Pereira, E. Prins, and B. Stocks, The fire component of global observation of forest cover: A plan of action. *Global and Regional Wildfire Monitoring: Current Status and Future Plans, SPB Academic Publishing, The Hague, Netherlands.*

Aune, R.M., W.P. Menzel, J. Thom, G.M. Bayler, A. Huang, and P. Antonelli, Preliminary findings from the geostationary interferometer observing system simulation experiments (OSSE). *NOAA Technical Report NESDIS 95, U.S. Department of Commerce, Washington, DC.*

Berman, M., H. Berquist, E. Dobson, C. Hershner, G. Silverhorn, D. Schatt, J. Glober and J.E. Meyer. The development of a new land cover classification data set in support of Virginia's coastal and tributary management: *Final Report. Comprehensive Coastal Inventory Program, Virginia Institute of Marine Science, College of William and Mary, Gloucester Pt., VA.*

Brown, C.W. Spatial and temporal variability of Emiliania huxleyi blooms in SeaWiFS imagery. *Proceedings of the AGU Ocean Sciences Meeting, January 24–28, 2000, San Antonio, TX.*

Cheney, R., The future of sea surface height observations. *Proceedings of Oceanobs99, St. Raphael, France, October 1999.*

Clemente-Colon, P., The use of spaceborne synthetic aperture radar in the monitoring and management of Bering sea fisheries. Scientific and Operational Applications of Remote Sensing for Coastal and Marine Fisheries, J. Morales and D. Blackburn (Eds.) CSI Series, UNESCO, Paris.

Daniels, J., W. Bresky, C. Velden, and A. Irving, Recent advances to the operational GOES wind processing system at NOAA/NESDIS. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA,* American Meteorological Society, Boston, MA, 24–27.

DeMaria, M., J.A. Knaff, S.Q. Kidder and M.D. Goldberg, Tropical cyclone wind retrievals using AMSU-A data from NOAA-15. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA,* American Meteorological Society, Boston, MA, 149–152.

DeMaria, M., R.M. Zehr, C.S. Velden, and F.M. Horsfall, Further improvements to the statistical hurricane intensity prediction scheme using GOES imagery. *Proceedings of the 24th Conference on Hurricans and Tropical Meteorology and 10th Conference on Interaction of the Sea and Atmosphere, May 29–June 2, 2000, Ft. Lauderdale, FL,* American Meteorological Society, Boston, MA, 240–241.

DeMaria, M., Evolution of hurricane forecasting. *Proceedings of the 54th Interdepartmental Hurricane Conference, February 16, 2000, Houston, TX.*

Doesken, N.J., Use of the advanced microwave sounding unit for the upcoming Pacific Landfalling Jets Experiment. *Pacific Northwest Weather Workshop, February 3–4, 2000, Seattle, WA.*

Doesken, N.J., and J.F. Weaver, Microscale rainfall variations as measured by a local volunteer network. *Proceedings of the 12th Applied Climatology*, American Meteorological Society, Boston, MA, 308–311.

Ellrod, G.P., Proposed improvements to the nighttime GOES fog product to provide ceiling and visibility information. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA,* American Meteorological Society, Boston, MA, 454–456.

Esaias, W.E., and C.W. Brown, The need for geostationary ocean color. Proceedings of the AGU Ocean Science Meeting, January 24–28, 2000, San Antonio, TX.

Ferguson, M.P., and A.L. Reale, Cloud detection techniques in NESDIS advanced—TOVS sounding product systems. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 252–254.

Flynn, L.E., S. Kondragunta, K. Horvath and E. Beach, Internal validation of SBUV/2 ozone vertical profile data sets. *Proceedings of the Quadrennial Ozone Symposium, Sapporo 2000, Hokkaido University, Sapporo, Japan, July 3–8, 2000.*

Friedman, K.S., P. Clemente-Colon, W.G. Pichel, T.D. Sikora, and G. Hufford, Synthetic aperture radar forecast experiment. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA.

Hillger, D.W., and G.P. Ellrod, Detection unusual atmospheric and surface features by employing principal component image transformation of GOES imagery. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 461–464.

Iglesias-Rodrizez, D., C.W. Brown, S. Doney, J. Kleypas, D. Kolber, Z. Kolver, R. Najjar, P. Hayes, L. Medlin, and P. Falkowski, Statistical distribution of functional phytoplankton groups in the oceans: Representing coccolithophores in carbon cycle models. *Proceedings of the AGU Ocean Sciences Meeting, January 24–28, 2000, San Antonio, TX.*

Kogan, F.N. Global drought detection and impact assessment from space. Drought: A global assessment, (Ed. D.A. Wilhite) 1 (14), 196–209.

Legeckis, R., Geostationary satellites reveal ocean surface dynamics. Ocean and Sea Ice Workshop, Perros-Guirec, France, November 30–December 2, Satellite Applications Facility Workshop Report, ISSN 1011–3932, EUMETSAT, EUM-P27, 72–77.

Legeckis, R., and P. Chang, Geostationary satellite animations at the Charleston Bump. *American Fisheries Society, Book Chapter on the Charleston Bump Colloquium, October 28–29, 1999.*

Legeckis, R., Geostationary satellites reveal ocean surface dynamics. *Ocean and Sea Ice SAF Workshop, Perros-Guirec, France, November 30–December 1999.* Satellite Applications Facility Workshop Report, ISSN 1011-3932, EUMETSAT, EUM-P-27, 72–77.

Li, Q., and R. Ferraro, SSM/I derived global rainfall statistics and their application. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 365–368.

Li, X., W.G. Pichel, F. Monaldo, C. Wackerman, R. Beal, P. Clemente-Colon, and K.S. Friedman, Retrieval and validation of sea surface winds from calibrated RADARSAT ScanSAR images. *Proceedings of the CEOS SAR Working Group Meeting, Toulouse, October 26–28, 1999*, 6 pp.

Maturi, E., X. Li, and X. Wu, GOES sea surface temperature products in NOAA/NESDIS. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA,* American Meteorological Society, Boston, MA, 141–143.

Mavor, T.P., and R. Legeckis, Spatial and temporal variability of the experimental GOES SST product. *GOES SST Workshop, Beaufort, N.C. November 1–2, 1999,* American Meteorological Society, Boston, MA.

McCollum, J.R., and R.R. Ferraro, Development of PM-1 AMSSR and TMI land preceipitation algorithms. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 304–307.

McMillin, L.M., and S. Zhou, A procedure to use satellite measurements to determine differences between radiosonde types. *Proceedings of the 4th Symposium on Integrated Observing Systems, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 55–57.

Menzel, P., Advances in geosynchronous observations of the atmosphere. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA,* American Meteorological Society, Boston, MA, 40–43.

Miller, A.J., L.E. Flynn, R.M. Nagatani, J. Wild, R. Lin, E. Beach, S. Kondragunta, R. McPeters, R. Stolarski, G. Labow, and W.G. Planet, Observation and analysis of SBUV(/2) total ozone and veritical ozone profiles. *Proceedings of the Quadrennial Ozone Symposium, Sapporo 2000, Hokkaido University, Sapporo, Japan, July 3–8, 2000.*

Mo, T., T.J. Kleespies and J.P. Green, MSU Antenna Pattern Data. *NOAA Technical Report NESDIS 94,* U.S. Department of Commerce, Washington, DC, 13 pp and CD-ROM.

Mo, T., NOAA-L and NOAA-M AMSU-A Antenna Pattern Corrections. *NOAA Technical Report NESDIS 98*, U.S. Department of Commerce, Washington, DC, 27 pp.

Moore, D., L. Zhao, J. Zhao, R. Ferraro, N. Grody, and F. Weng, The new NOAA AMSU hydrological products suite, Part 1: Tour of web site. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach*, CA, American Meteorological Society, Boston, MA, 189–191.

Nagatani, R.M., A.J. Miller, L. Zhang, G.C. Tiao, S. Zhou, G.C. Reinsel, D.J. Wuebbles, L.E. Flynn and J.B. Kerr, Observed solar effects on ozone and temperature. *Proceedings of the Quadrennial Ozone Symposium, Sapporo 2000, Hokkaido University, Sapporo, Japan, July 3–8, 2000.*

Newchurch, M.J., L. ishop, D. Cunnold, L.E. Flynn, S. Godin, S. Frith, L. Hood, AJ. Miller, S. Oltmans, W. Randel, G. Reinsel, R. Stolarski, R. Wang, E. Yang, and J.M. Zawodny, Upper-stratospheric ozone trends 1979–1998. *Journal of Geophysical Research*, 105 (D11), 14,625–14,636.

Planet, W.G., L.E. Flynn, E.Hilsenrath, J. Hornstein, E. Kang, J. Larsen, F. Sanner, C. Seftor, C. Wellemeyer, and G. Jaross, OMPS (Ozone Mapping and Profiling Suite) The next generation of United States operational ozone-monitoring instruments. *Proceedings of the Quadrennial Ozone Symposium, Sapporo 2000, Hokkaido University, Sapporo, Japan, July 3–8, 2000.*

Prins, E., J. Schmetz, L. Flynn, D. Hillger, J. Feltz, Overview of current and future diurnal active fire monitoring using a suite of international geostationary satellites. *Global and Regional Wildfire Monitoring: Current Status and Future Plans,* SPB Academic Publishing, The Hague, Netherlands.

Reale, A.L., M. Chalfant and L.M. Wilson, NESDIS advanced TOVS sounding products. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 259-262.

Scofield, R.A., G. Vicente, C. Davenport and S. Qiu, Mapping the course of satellite precipitation estimates for flash floods into the 21st Century. *Proceedings of the 15th Conference on Hydrology, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 239–242.

Scofield, R.A., and R. Weldon, Exciting uses of satellite data for daily weather discussions, classroom weather education, and science projects. *Proceedings of the 9th Symposium on Education, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 115–118.

Smith, W., Bathymetric estimation. *Satellite altimetry and Earth Sciences, L.-L Fu and A. Cazenave (Eds) Academic Press.*

Stolarski, R.S., R.D. McPeters, G. J. Labow, S.H. Frith, and L. Flynn, On the long-term calibration of the TOMS total ozone record. *Proceedings of the Quadrennial Ozone Symposium, Sapporo 2000, Hokkaido University, Sapporo, Japan, July 3–8, 2000.*

Sun, X., B.H., Corliss, and C.W. Brown, The effect of seasonality of primary productivity on the distribution of deep-sea bethic foraminifera in the North Atlantic. *Proceedings of the May 30– June 3, 2000 Meeting, Washington, D.C.*

Vaillancourt, R., C.W. Brown, and R.R.L. Guillard, A taxonomic survey of the optical properties of marine phytoplankton with special emphasis on the backscattering coefficient. *Proceedings of the AGU Ocean Sciences Meetings, January 24–28, 2000, San Antonio, TX.*

Weaver, J.F., Windstorms associated with extratropical cyclones. Chapter 23 (1), Storms, Pielke, R.A., Jr. and Pielke, R.A. Sr., (Eds), Routledge Press, London and New York, 449–460.

Weng, F., R.R. Ferraro and N.C. Grody, Effects of AMSU-A cross track asymmetry of brightness temperatures on retrieval of atmospheric and surface parameters. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 202–205.

Weng, Z., T. Zhu, and D. Zhang, Applications of advanced microwave sounding unit to improving the analysis of atmospheric wind field in tropical cyclones. *Proceedings of the 4th Symposium on Integrated Observing Systems, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 209–214.

Wilkerson, J.C., and J.R. Proni, Monitoring tropical and subtropical rainfall over the ocean using underwater sound. *Proceedings of the 5th European Conference on Underwater Acoustics, ESCEP Lyon/Lasso, France, July 10–13, 2000.*

Yuen, M.A., Particulate absorption and CDOM measurements coordinated with SeaWiFS and MODIS imagery. *Proceedings of Ocean Optics XV. October 16–20, 2000, Monaco.*

Zehr, R.M. Tropical cyclone research using large infrared image data sets. *Proceedings of the 24th Conference on Hurricanes and Tropical Meteorology and 10th Conference on Interaction of the Sea and Atmosphere, May 29–June 2, 2000, Ft. Lauderdale, FL*, American Meteorological Society, Boston, MA, 486–487.

Zhao, L., R. Ferraro and D. Moore, Validation of NOAA-15 AMSU-A rain rate algorithms. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 192–195.

Zhao, J., N.C. Grody, R.R. Ferraro, C. Zou, and F. Weng, The new NOAA AMSU hydrological product suite: The validation of AMSU TPW and CLW. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 196–198.

Zou, C., and M.L. Van Woert, Satellite-derived poleward moisture transport over the southern oceans. *Proceedings of the 10th Conference on Satellite Meteorology and Oceanography, January 9–14, 2000, Long Beach, CA*, American Meteorological Society, Boston, MA, 406–409.

APPENDIX 9. 2000 EDITORSHIPS (SINCE 1995)

Robert Cheney—Guest Editor, Topex/Poseidon Scientific Results, *Journal of Geophysical Research* 100 (C12), 1995.

Kevin Gallo—International Editorial Board of *Geocarto International,* 1991 to present.

William Pichel—Guest Editor for the January–March 2000 issue of the *Johns Hopkins APL Technical Digest,* special issue devoted to the Wide Swath Synthetic Aperture Radar Symposium.

Nagaraja Rao—Guest Editor, Special Issue of the *International Journal of Remote Sensing,* 1999 CALCON, Utah State University, November 1999

APPENDIX 10. 2000 NATIONAL AND INTERNATIONAL COMMITTEES AND SCIENCE TEAMS

Bob Aune

North American Observing System Council, Technical Evaluation Working Group.

Christopher Brown

NASA SeaWiFS Science Science Team.

NASA SIMBIOS Science Team.

Paul Chang

NASA Ocean Vector Winds Science Team

NASDA/NASA ADEOS II Science Team (Sea Winds).

WindSat Cal/Val Team.

Robert Cheney

NASA Topex/Jason Science Team.

Dennis Clark

NASA SeaWiFS Science Working Group.

International Space Year Expert on Ocean Productivity.

NASA EOS MODIS Team.

NASA SeaWiFS Science Team.

NASA SIMBIOS Ocean Color and Instrument Teams.

Japan's ADEOS-Ocean Color Temperature Sensor Team.

Japan's GLI Sensor Team.

Pablo Clemente-Colon

WMO Committee on Marine Meteorology Oceanographic Satellite and Other Remote Sensing Sub-Group.

CEOS Disaster Management Support Project Oil Spill Team.

CEOS SAR CAL/VAL Users Working Group.

NASA/JPL Synthetic Aperture Radar Information Users Working Group.

NASA Tropical Center for Earth and Space Studies (TCESS) Advisory Committee.

Marie C. Colton

Chair, AMS Committee on Satellite Meteorology and Oceanography.

Chair, NPOESS CMIS Operational Algorithm Team.

AMS ad hoc Committee on restructuring of the Bulletin of the AMS.

Mark DeMaria

USWRP Science Steering Committee.

Weather Research and Forecast Model Science Board.

Gary Ellrod

Committee for Earth Observation Satellites (CEOS) Disaster Management Support Group, Volcano hazards team co-lead.

National Weather Association Council.

Ralph Ferraro

AMS Committee on Satellite Meteorology and Oceanography.

National Weather Association Remote Sensing Committee.

Joint NOAA/DOD/NASA SSM/I Algorithm Research Panel.

NASA/EOS-PM AMSR Science Team.

DOD SSMIS Calibration/Validation Team.

World Climate Research Program/Global Precipitation Climatology Project Working Group on Data Management.

Larry Flynn

EUMETSAT Integrated Functional Chain Team for GOME-2.

Chair of IPO OMPS Operational Algorithm Team.

EOS Aura OMI Science Team.

1998 Stratospheric Processes and their Role in Climate (SPARC) Ozone Profile Assessment.

IGOS Ozone Profile Report Consultant.

NASA Total Ozone Mapping Spectrometer Science Team.

Kevin Gallo

NASA/EOSDIS Land Processes Distributed Active Archive Center's Science Advisory Panel.

International Geosphere-Biosphere Programme's Global Land 1-km AVHRR Data Set Project.

Rapporteur for Urban Climatology on WMO Advisory Working Group related to Commission for Climatology.

American Meteorological Society Board on the Urban Environment.

Mitch Goldberg

EUMETSAT Integrated Functional Chain Team for IASI.

EUMETSAT/CNES Infrared Atmospheric Sounder Interferometer (IASI) Science Team.

IPO SOAT for CrIS.

NASA/AIRS Science Team.

Norman Grody

National Research Council Panel on Reconciling Observations of Global Temperature Change.

Arnold Gruber

Director of the Global Precipitation Climatology Project, GEWEX, World Climate Research Program.

AMS Hydrometeorology Committee.

COSPAR, Sub-Commission A1 on Atmosphere Meteorology and Climate.

Andy Heidinger

PICASSO Science Team.

Advisor to VIIRS OAT.

Don Hillger

Board of Directors of the U.S. Metric Association.

Frances Holt

Councilor of National Weather Association.

Chair, National Weather Association Remote Sensing Committee.

Fellow, Cooperative Institute for Research in the Atmosphere (CIRA).

Jeff Key

AMS Committee on Polar Meteorology and Oceanography.

NASA EOS Cryospheric Working Group.

Advisory Committee for MODIS Snow and Ice Products.

NASA/EOS MODIS Science Team, adjunct member.

Tom Kleespies

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Felix Kogan

COSPAR Committee A3.2, Land Processes.

Richard Legeckis

Advisor, Integrated Program Office NPOESS/VIIRS Team.

John Lillibridge

ESA Envisat Science Advisory Group.

USN Geosat Follow-On Cal/Val Team.

Karen Marks

AGU Tectonophysics Publications Committee.

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Larry McMillin

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NASAEOS AIRS Science Team.

EUMETSAT/CNES Infrared Atmospheric Sounder Interferometer (IASI) Science Team.

Paul Menzel

Meteosat Sounding Mission Team.

Chairman, WMO Expert Team on Observational Data Requirements and Redesign of the Global Observing System.

Co-Chairman, Upper Air Measurements Project (reporting to Strategic Implementation Team of CEOS).

WMO Working Group on Satellites.

Chair, NPOESS CRIS Operational Algorithm Team.

Coordinating Group for Meteorological Satellites.

Co-chairman, GOES Technical Advisory Committee.

NASA/EOS MODIS Science Team.

Co-chair, International TOVS Working Group (a committee in the International Radiation Commission).

Council of the NOAA/NASA Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin.

Tsan Mo

NOAA representative, Subgroup on microwave sensors, CEOS Working Group on Calibration and Validation.

George Ohring

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Member, IAMAS International Commission for Climate.

William Pichel

CEOS SAR CAL/VAL Users Working Group.

SAR Information Users Working Group.

Elaine Prins

EOS MODIS Fire Product Science and Development Team.

CEOS Global Observations of Forest Cover (GOFC).

James Purdom

Chair, WMO's Open Program Area Group on Integrated Observing Systems

Member, American Meteorological Society

Fellow, Cooperative Institute for Research in the Atmosphere

Institute Advisory Boards (Member)

- Cooperative Institute for Research in the Atmosphere
- Cooperative Institute for Meteorological Satellite Studies
- Cooperative Institute for Climate Studies
- Cooperative Institute for Atmosphere Science and Terrestrial Applications

Member, U.S. Weather Research Program Interagency Working Group,

Member, Committee for Cooperative Research, Office of the Federal Coordinator for Meteorology

Nagaraja Rao

NOAA representative, CEOS Working Group on Calibration and Validation.

NOAA representative, Sub-group on IR and visible sensors, CEOS Working Group on Calibration and Validation.

Science Team for Calibration of ENVISAT Sensors.

Tim Schmit

Sounding Algorithms Research Panel (SARP).

Advanced Baseline Imager (ABI)/Advanced Baseline Sounder (ABS) Science Team.

Rod Scofield

President of the National Weather Association.

Co-chair of CEOS activities on Flooding.

Walter Smith

IHO/IOC GEBCO Global Bathymetry (Science Advisor).

ICSU SCOR WG 107 Global Bathymetry.

U.S. NRC Earth Gravity from Space.

AGU Education and Human Resources.

AGU Books Board.

Larry Stowe

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Member of VIIRS OAT

Alan Strong

U.S.-NOAA Coral Reef Task Force.

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James Yoe

EUMETSAT Integrated Functional Chain Team for GRAS.

IPO OAT for GPSOS.

NCEP OSSE Advisory Team.

LIST OF ACRONYMS

ABBA	Automated Biomass Burning Algorithm
ABI	Advanced Baseline Imager
ABS	Advanced Baseline Sounder
ACARS	Aircraft Communications and Reporting System
AE	Auto-Estimator
AIRS	Atmospheric Infrared Sounder
AMSU	Advanced Microwave Sounding Unit
AMSU-A	Advanced Microwave Sounding Unit-A
AOD	Aerosol Optical Depth
ARAD	Atmospheric Research and Applications Division
ArcGP	Arctic Gravity Project
ASADA	Automated Smoke and Aerosol Detection Algorithm
ASOS	Automated Surface Observing System
ATOVS	Advanced TIROS Operational Vertical Sounder
AUTEC	Atlantic Undersea Test and Evaluation Center
AVHRR	Advanced Very High Resolution Radiometer
AWIPS	Advanced Weather Information Display System
CCRS	Canada Center for Remote Sensing
CICS	Cooperative Institute for Climate Studies
CIORS	Cooperative Institute for Ocean Remote Sensing
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIRA	Cooperative Institute for Research in the Atmosphere

CLAVR	Clouds from AVHRR
CMDL	Climate Monitoring and Diagnostics Laboratory
CMIS	Conically Scanning Microwave Image/Sounder
CMOD4	C-Band Model Function
CNES	French Space Agency
COMET	Cooperative Program for Operational Meteorology
CONUS	Continental United States
COSMIC	Constellation Observing Satellites for Meteorology, Ionosphere, and Climate
CPC	Climate Prediction Center
CPUE	Catch Per Unit Effort
CrIS	Cross-track Infrared Sounder
CRAD	Climate Research and Applications Division
DAAC	Distributed Active Archives Center
DoD	Department of Defense
DAO	Data Assimilation Office
DHW	Degree Heating Weeks
DMSP	Defense Meteorological Satellite Program
DWL	Doppler Wind Lidar
EDC	EROS Data Center
EMC	Electromagnetic Compatibility
EOS	Earth Observation System/Satellite
EROS	Earth Resources Observation System
ERS	European Remote Sensing
ETL	Environmental Technology Laboratory
EUMETSAT	European Meteorological Satellite

FTP	File Transfer Protocol
GDAS	Global Data Assimilation System
GDR	Geophysical Data Record
GEWEX	Global Energy and Water Cycle Experiment
GIS	Geographical Information System
GOES	Geostationary Operational Environmental Satellite
GOME-2	Global Ozone Monitoring Experiment
GPCP	Global Precipitation Climatology Project
GPSOS	GPS Occultation Sensor
GRAS	GPS Radio Atmospheric Sounder
GSC	Geological Survey of Canada
GSFC	Goddard Space Flight Center
GVI	Global Vegetation Index
HIRS	High-Resolution Infrared Radiation Sounder
HRS	High-Resolution Infrared Radiation Sounder
IASI	Infrared Atmospheric Sounding Interferometer
IFCT	Instrument Functional Chain Team
IFFA	Interactive Flash Flood Analyzer
IGBP	International Geosphere Biosphere Programme
IGOS	Integrated Global Ocean Observing Strategy
IMI	Irish Marine Institute
IOCCG	International Ocean Color Coordinating Group
IT	Information Technology
JPL	Jet Propulsion Laboratory
LDAS	Land Data Assimilation System

LRC	Lesser Regional Contingency
LSA	Laboratory for Satellite Altimetry
MAS	MODIS Airborne Simulator
METOP	Meteorological Operations Platform
MOBY	Marine Optical Buoy
MODIS	Moderate Resolution Imaging Spectro-Radiometer
MSU	Microwave Sounding Unit
NASA	National Aeronautics and Space Administration
NAVOCEANO	Naval Oceanographic Office
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCEP/NCAR	National Centers for Environmental Prediction/National Center for Atmospheric Research
NDVI	Normalized Difference Vegetation Index
NESDIS	National Environmental Satellite, Data, and Information Service
NIMA	National Imagery and Mapping Agency
NIST	National Institute of Science and Technology
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRCS	Normalized Radar Cross-Section
NSF	National Science Foundation
NWP	National Weather Prediction
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research

OH	Office of Hydrology
OLR	Outgoing Longwave Radiation
OPT	Ozone Processing Team
ORA	Office of Research and Applications
ORAD	Oceanic Research and Applications Division
OSDAD	Office of Satellite Data Processing
OSDPD	Office of Satellite Data Processing and Distribution
OSSE	Observing System (Simulation) Experiment
PATMOS	Pathfinder Atmosphere
POES	Polar-orbiting Operational Environmental Satellites
POP	Product Oversight Panel
QPE	Quantitative Precipitation Amounts
QPF	Quantitative Precipitation Forecasts
RAMMT	Regional and Mesoscale Meteorology Team
RAMSDIS	Regional and Mesoscale Meteorology Team Advanced Meteorological Satellite Demonstration and Interpretation System
RFI	Radio Frequency Interference
SAR	Synthetic Aperture Radar
SBUV/2	Solar Backscatter Ultraviolet Spectral Radiometer, MOD 2
SECW	Southeast CoastWatch Program
SRSO	Super-Rapid Scan Operations
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature
TIROS	Television and Infrared Observation Satellite
TOMS	Total Ozone Mapping Spectrometer

TOPEX	Ocean Topography Experiment (A Sensor)
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
TST	Technical Support Team
UKMO	United Kingdom Meteorological Office
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USWRP	United States Weather Research Program
VCI	Vegetation Condition Index
VIIRS	Visible/Infrared Imager/Radiometer Suite
VIRS	Visible Infrared Scanner
VISIT	Virtual Institute for Satellite Integration Training
WINDEX	Wind Experiment